Scientific Conference of Young Researchers 2016

16th Scientific Conference of Young Researchers

May 17th, 2016
Herľany, Slovakia

Proceedings from Conference

Faculty of Electrical Engineering and Informatics
Technical University of Košice

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Foreword

Dear Colleagues,

SCYR (Scientific Conference of Young Researchers) is a Scientific Event focused on exchange of information among young scientists from Faculty of Electrical Engineering and Informatics at Technical University of Košice - series of annual events that was founded in 2000. Since 2000 the conference has been hosted by FEI TUKE with rising technical level and unique multicultural atmosphere. The Sixteenth Scientific Conference of Young Researchers (SCYR 2016), conference of Graduates and Young researchers, was held on 17th May 2016.The primary aims of the conference, to provide a forum for dissemination of information and scientific results relating to research and development activities at the Faculty of Electrical Engineering and Informatics has been achieved. 105 participants mostly by doctoral categories were active in the conference.

Faculty of Electrical Engineering and Informatics has a long tradition of students participating in skilled labor where they have to apply their theoretical knowledge. SCYR is opportunities for doctoral and graduating students use this event to train their scientific knowledge exchange. Nevertheless, the original goal is still to represent a forum for the exchange of information between young scientists from academic communities on topics related to their experimental and theoretical works in the very wide spread field of a wide spectrum of scientific disciplines like informatics sciences and computer networks, cybernetics and intelligent systems, electrical and electric power engineering and electronics.

16th Scientific Conference of Young Researchers at Faculty of Electrical Engineering and Informatics Technical University of Košice (SCYR 2016) was organized in a beautiful village Herľany. The Conference was opened in the name of dean prof. Ing. Liberios Vokorokos, PhD. by the vicedean of faculty, prof. Ing. Alena Pietriková, CSc. In her introductory address she noted the importance of the Conference as a forum for exchange of information and a medium for broadening the scientific horizons of its participants and stressed the scientific and practical value of investigations being carried out by young researchers.

Traditionally, the program includes two parallel sessions:

- Electrical & Electronics Engineering
- Information Technologies

with 105 technical papers dealing with research results obtained mainly in university environment. This day was filled with a lot of interesting scientific discussions among the junior researchers and graduate students, and the representatives of the Faculty of Electrical Engineering and Informatics. This Scientific Network included various research problems and education, communication between young scientists and students, between students and professors. Conference was also a platform for student exchange and a potential starting point for scientific cooperation. The results presented in papers demonstrated that the investigations being conducted by young scientists are making a valuable contribution to the fulfillment of the tasks set for science and technology at Faculty of Electrical Engineering and Informatics at Technical University of Košice.

We want to thank all participants for contributing to these proceedings with their high quality manuscripts. We hope that conference constitutes a platform for a continual dialogue among young scientists.

It is our pleasure and honor to express our gratitude to our sponsors and to all friends, colleagues and committee members who contributed with their ideas, discussions, and sedulous hard work to the success of this event. We also want to thank our session chairs for their cooperation and dedication throughout the whole conference.

Finally, we want to thank all the attendees of the conference for fruitful discussions and a pleasant stay in our event.

Liberios VOKOROKOS
Dean of FEI TUKE

May 17th 2016, Herľany

Contents

3D imaging and image processing – literature review

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***Abstract*—This review aims to provide an overview of the latest trends in 3D computer vision. Both in imaging and image processing, the research has advanced significantly over the past decade. This paper reviews the fundamentals and advanced techniques of 3D image acquisition and algorithms for storing, processing and understanding this information. This overview is focused on the application domain of autonomous mobile robotics and automated industry. Several most widely used passive and active optical range imaging techniques are reviewed with their strengths and weaknesses. This paper also describes some of the most common range image processing techniques and structures.**

***Keywords*—3D imaging, computer vision, laser scanning, mobile robotics, point cloud, quality control, stereo vision**

I. Introduction

Used in industry, autonomous robotics and other fields, 3D imaging provides very detailed and valuable information about the environment or examined objects. Especially in mobile robotics, 3D vision has become the area of interest of many researchers and numerous imaging and processing algorithms have been developed over the past decade. In modern industry, both 2D and 3D vision systems are the basis of automatic construction, product inspection and quality control.

The fundamental difference between 2D and 3D vision is the inclusion of the third coordinate – depth. This information can be acquired by various means ranging from stereoscopy (use of two specifically aligned cameras) to laser scanning of the environment, while each of these techniques have their own advantages and disadvantages. Downsides can often be eliminated by using multiple 3D imaging methods in conjunction.

In robotics, 3D representation of the environment allows for better navigation, obstacle avoidance and object classification. 3D scans of the surrounding objects enables the robot to interact with them more easily and in more sophisticated manner such as grabbing various objects and opening doors [1]. In industry and manufacturing, 3D vision systems provide unprecedented precision and flexibility in control, measurement and quality inspection. While these areas require different approaches to hardware construction and methods of 3D image acquisition, most of the image processing algorithms are used universally.

II. Methods of 3D image acquisition

The collection of techniques that are used to measure the distance to a set of points in a scene from a specific point is called range imaging. The result is a 2D *range image*, where the pixel values correspond to the distance. As with many other types of measurements, both active and passive sensors are available for this task.

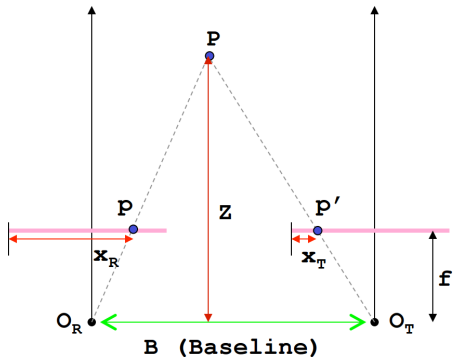

Fig. 1. Depth triangulation – based on the known intrinsic and extrinsic parameters (baseline B, focal length f, ...) and disparity ($x_R - x_T$), the depth Z is calculated [3].

A. Stereo triangulation

Perhaps the most well known range imaging technique is stereo vision. It is a passive method, since it only requires a pair of cameras and no energy is emitted. The depth is calculated by triangulation based on the *disparity* of each pixel – the difference between the x coordinate of two corresponding points, representing the same homologous point in the scene (Fig. 1). Based on intrinsic and extrinsic parameters of the setup (acquired by calibration), the physical coordinates can be calculated from the pixel position and disparity. While having many advantages (passive sensing, low cost and latency [2], small size, color information), stereo vision has its pitfalls. Solving the correspondence problem is difficult in homogeneous regions, repeating patterns or when there are specular reflection or transparent materials in the scene [3].

B. Laser triangulation

Utilization of lasers is very common in 3D scanning. One of the techniques using this device is laser triangulation. In this case, the laser shines on the scanned object, which is simultaneously recorded with a camera. The distance is triangulated using the known separation between the camera and the laser emitter as well as the angles to the illuminated point (Fig. 2).

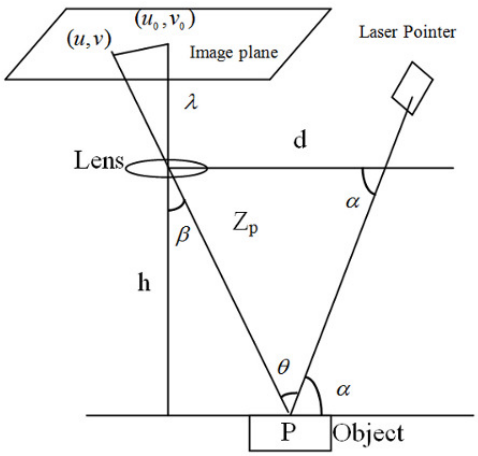

Fig. 2. Laser triangulation – distance to the object P is equal to the height of a triangle with two known angles (α, β) and one known side (d) [5].

Often a line laser is used instead of a single laser dot for faster acquisition process. Since energy is emitted towards the scene, all laser scanners are categorized as active sensors [4]. This technique offers extremely accurate depth measurements, however it struggles to correctly scan transparent and reflective surfaces, since those do not diffuse the laser well enough to be captured by the camera. Result of this technique yields no color or light intensity information.

C. LIDAR, Time-of-Flight

LIDAR (acronym for Light Detection And Ranging) is another laser-utilizing technique for 3D scanning of the environment (Fig. 3). Often used in geodesy, geography, and related fields, LIDAR has found its use in autonomous vehicles and robotics as well. LIDAR may use various techniques to infer the distance to the illuminated point. One of those is time-of-flight, where a precise timing mechanism measures the delay between emitting and receiving the laser pulse. Using this delay and the known speed of light in the environment, distance to the surface is calculated [6]. The whole scene is scanned point-by-point by slewing the laser beam around using a rotating mirror. Both 2D (planar) and 3D LIDARs are available. The main advantages of LIDAR are its hight precision and long range, however these devices are usually rather expensive due to their very precise hardware.

Time-of-Flight technique (Fig. 4) can also be used with fast gated CMOS cameras. In this case the whole scene

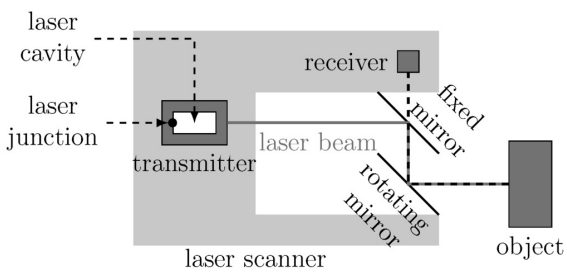

Fig. 3. Time-of-Flight LIDAR. Pulsed laser beam is reflected by a rotating mirror creating a fan-like scanning pattern. The pulse is then reflected from the scanned surface and returns to the receiver. The time of flight between transmission and reception is then used to estimate the distance to the surface [7].

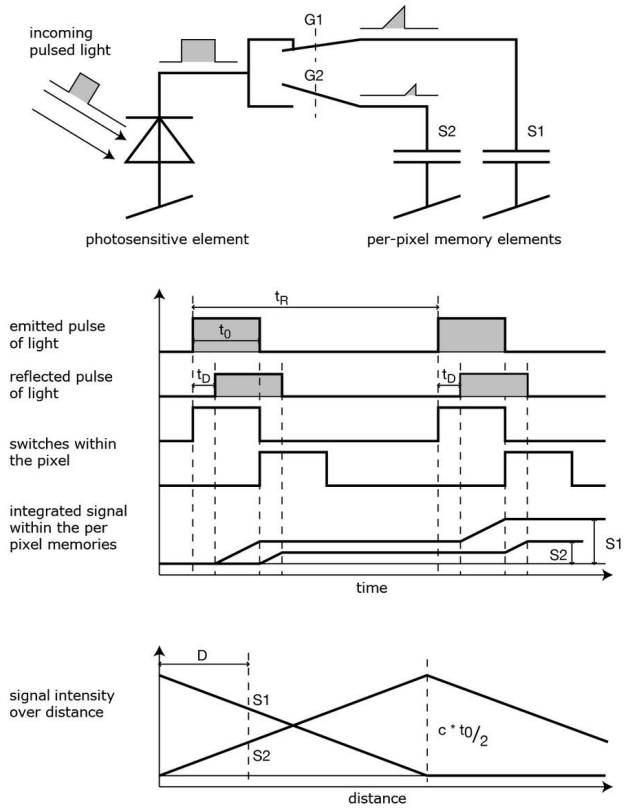

Fig. 4. Diagrams illustrating the principle of a time-of-flight camera with analog timing [8].

is illuminated at once and the delay is measured per-pixel between the emission and reception of a single laser or LED pulse. The main advantage of this technique is its high acquisition speed reaching up to 160 frames per second.

D. Structured Light 3D scanners

Structured-light 3D scanner is an active 3D scanning device which measures the depth by recording projected light patterns with a camera. The most widely used light pattern in this technique are parallel stripes generated by either projection or laser interference. Both the displacement and width of individual stripes, as well as their frequency and phase provide cues to calculate the depth. Several patterns (e.g. stripes of varying width) are usually used per scan (Fig. 5). Advantages of this technique are its low hardware cost and high scanning speed, however it requires a controlled environment and projector calibration.

A very popular example of a structured-light 3D scanner is an entertainment device called Kinect. Named *Light Coding*, this scanner is uses an infrared laser to project a pattern of dots which is then captured by a monochrome CMOS camera.

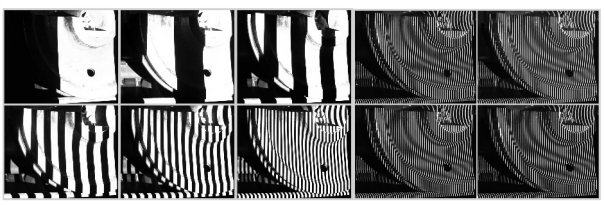

Fig. 5. Set of structured light patterns consisting of parallel stripes of varying width projected on a scanned object [9].

Due to its affordability and relatively good performance, it has found its use in many robotics projects [10].

E. Structure from motion

Structure from motion (SFM) is a range imaging technique which estimates 3D structures from sequences of 2D images captured at different points in the scene. These methods include both camera localization and 3D shape reconstruction. Traditional feature detectors, descriptors and matchers may be used to determine motion trajectories. Depth calculation algorithms similar to those used in stereo triangulation are then used to retrieve the 3D structure of the environment or the scanned object [11]. Some variants of SFM, called direct approaches, estimate geometric information without intermediate abstraction to features or corners [12]. Pitfalls similar to those in stereo triangulation are present here as well – reflective materials, transparency, homogeneous surfaces, etc. Occlusion are partially solved by having multiple points of view available for shape reconstruction.

A very related problem to SFM is SLAM (Simultaneous Localization And Mapping) which is often found in autonomous robotics. This is a problem of constructing and updating a map of environment by a mobile agent (robot) equipped with some kind of a sensing device. A pair of cameras or a LIDAR is often used, while solutions for single-camera (monocular) systems have been found too [12][13].

F. Combination of techniques

As mentioned, each of the techniques has its own advantages and disadvantages. To mitigate their downsides, solutions have been found to use multiple range imaging techniques simultaneously. One such combination is a laser scanner with a stereo camera, providing both precise depth measurements as well as color image [14]. When combining several sensors, thorough calibration has to be performed to align the acquired data. Algorithms exist that solve this problem even when the sensors' fields of view are not overlapping [15].

III. Range processing

Range images are often processed before applying any classification or scene-understanding algorithms. There are various forms of representation of 3D environments or objects, each of them having their use.

A. Point clouds

The most precise 3D scene representation and often the direct output of a depth scanner is a raw point cloud. This consists of a set of points in 3D space which may also bear color information and usually represent the external surface of an object (Fig. 6). Point clouds are often post-processed using some type of filtering algorithm to remove outliers introduced by sensor noise. One of the most commonly used filtering algorithm is RANSAC [17], or one of its later variants [18]. Filtering is also used to remove local noise – smoothing. Several scans – point clouds – of the scene can be aligned to create a complete representation of the environment.

Point clouds can be generated from range image using a simple conversion algorithm by providing the parameters from calibration. Many of the most frequently used algorithms for generating, manipulating and visualizing point clouds are implemented within the popular open-source library called PCL [16]. Raw point clouds can be difficult to process due to large amount of data they contain. To accelerate the manipulation, the sampled points can be organized in octrees [19].

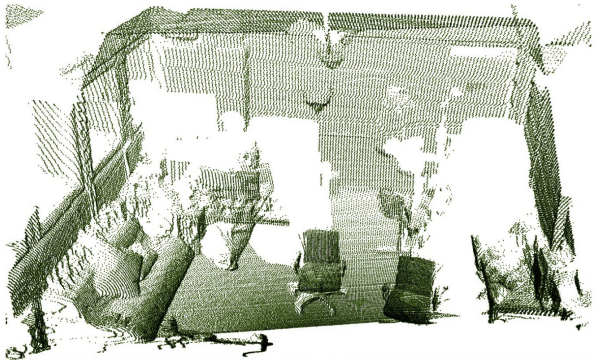

Fig. 6. Example of a point cloud representation of a room visualized using the PCL library [16].

B. Triangulation

Point clouds are not ideal for further modification and real-time visualization. For those purposes, it is often required to use a different geometric representation such as a polygonal model (mesh). Delaunay triangulation method is often used with 2D data (Fig. 7), while 3D input requires a more difficult approach called tetrahedralization or tetrahedrization [20]. This method can be very computationally expensive and modern techniques are able to accelerate this process by exploiting graphics hardware [21]. Surface normal estimation is often a part of the surface reconstruction process.

Geometry represented in this way can then be further optimized and compressed by traditional polygon mesh optimization algorithms to save space and accelerate further processing.

C. Object detection and pose estimation

Both in autonomous robotics and industry, the problem of detecting and classifying objects appears very frequently. In case the geometry of the object is known in advance (e.g. a CAD model is available), the task consists of finding this object in the scene and fitting it to the segmented data (estimating its position and rotation – 6DOF pose) [22]. Once this is achieved, the results can be used for various tasks, for example to navigate a mobile robot or detect and measure surface defects in industrial quality control [23].

Another type of problem is detection and general classification of objects in the environment such as people, cars,

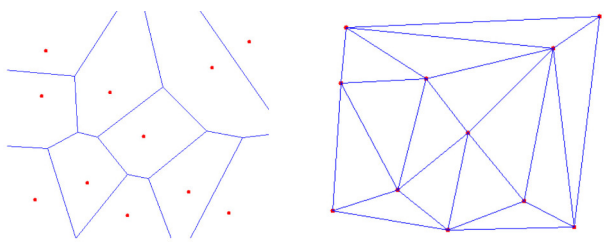

Fig. 7. Delaunay triangulation (right) corresponds to the dual graph of Voronoi diagram (left) [20].

furniture, switches, door handles, etc. This problem occurs mainly in autonomous robotics, where the robot has no prior information about the environment. Some of the tools used for solving this problem are Markov networks [24] and conditional random fields [25].

IV. Conclusion

The field of 3D imaging and processing is very wide and there are still numerous unsolved problems in both imaging (some techniques still struggle with transparent and reflective materials, occlusions, etc.) and range processing (scene understanding, semantic mapping, ...). As autonomous mobile robots are slowly becoming a part of the human society, we believe it is important to focus on the perception capabilities of these machines. Understanding its surroundings is crucial for safe and useful operation of these machines.

In our next work, we would like to focus on developing techniques and algorithms for scene understanding, object detection and classification with its main use in autonomous mobile robotics. We want to work on solving problems and improving existing solutions in the domain of segmentation and semantic labeling of point cloud data for the purpose of robot navigation and interaction with focus on both static and dynamic environments. Combining these methods with existing 3D imaging and SLAM algorithms will aid the development of fully autonomous robots with the ability to perform useful tasks in previously unknown environments. Since robotics has very strong presence in automated manufacturing, we believe our work will find its application in this field as well.

Acknowledgment

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A review of track finding algorithms for the JEM-EUSO experiment

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***Abstract*—The JEM-EUSO experiment plans to detect extensive atmospheric showers caused by ultra high energy cosmic rays by observation of fluorescence and Cherenkov radiation from the Earth's orbit. The paper reviews and classifies track finding algorithms in high energy physics experiments and describes a few examples including algorithms implemented in the ESAF framework. Algorithms not implemented in the JEM-EUSO event reconstruction are considered as possible areas of future research.**

***Keywords*—feature extraction, ESAF, JEM-EUSO, track finding, UHECR**

I. Introduction

The JEM-EUSO [1] is a wide field-of-view telescope planned to be installed on Exposed Facility of the International Space Station. The telescope will serve as florescence and Cherenkov light detector which will observe the Earth's atmosphere to spot an extensive atmospheric shower (EAS) as a bright spot moving along a line at the light speed followed by splash of Cherenkov light, depending on shower zenith angle. The brightness of the shower projection depends on the energy of the cosmic ray. The direction of the line shows one of the arrival direction angles of the cosmic ray. Length of a shower projected on the focal surface of the telescope depends on the shower inclination angle - highly inclined showers are easier to detect. The focal surface has 300,000 photo-sensitive pixels. Individual photons are counted using photomultiplier tubes (PMTs) with resolution 8×8 pixels. Bigger structural units are elementary cells and photo-detector modules. The time is measured in discrete units called gate time units (GTU), in standard configuration 2.5 μ seconds [2]. Online event analysis is done by the two-level triggering system which significantly lowers the data rate of the downlink. An important factor affecting detection capabilities [3] is amount of a background noise mainly caused by atmospheric nightglow.

The ESAF framework [4] was developed for event simulation and offline event reconstruction. The reconstruction is presently implemented as a chain of reconstruction modules, where module is dependent on results from a previous module or multiple previous modules. The main purpose of the reconstruction is determination of an atmospheric shower properties which are used to determine properties of the primary particle. The reconstructed properties include 3D direction reconstruction - azimuth and zenith angle, altitude where EAS reaches maximum of development, corresponding atmospheric slant depth, and energy of the primary particle. All of the mentioned parameters are determined from the projection of the atmospheric shower (or other observed event) on focal surface, so it is a matter of great importance to thoroughly discriminate the background noise from the track of the shower. This becomes a difficult task when signal to noise ratio is low.

II. Track finding methods in High Energy Physics

Although, the JEM-EUSO is a unique and novel way of cosmic ray detection, the underlining tracking algorithms are somewhat similar to algorithms in other experiments focused on ultra high energy cosmic rays (UHECR) detection or in other fields of high energy physics. Especially, track finding algorithms in the field of particle detectors can serve as inspiration for track finding algorithms in the JEM-EUSO.

Track finding algorithms can be organized into two main groups - global and local methods [5].

A. Global methods

Global methods treat all detector hits in similar fashion and does not consider order of hits. If method searches for multiple tracks, all tracks are expected to be handled simultaneously. Examples are template matching, histogramming methods as Hough transform, or neural networks.

1) Threshold-based filtering: It can be assumed that events observed by any kind of pixel detector would have higher intensity (in case of photomultipliers higher counts value) than a background noise. The simplest method of selecting the track is then to simply filter out everything under certain threshold value. This basic technique might be the first step of more complex track finding method or it can be used as a part the complex method.

The Peak and Window Searching Technique (PWISE) [6] [7] searches photon-counts that resemble the expected behaviour of moving spot projected onto focal surface of the JEM-EUSO detector. The method is applied per pixel. First, it finds peaks above threshold in the pixel's photon-counts. Then, around each peak the time window is defined and signal to noise ratio is calculated. Finally, a window with the highest signal to noise ratio is selected.

2) Template matching: As the name of the method says, the template matching methods are based on comparison of analysed track image with a dataset of existing track patterns. This requires number of patters to either be small or geometry of a pattern simple enough. The technique does not scale

well with growing dimensionality or granularity of the pattern. Basic form of the template matching has been utilized in triggering systems of drift chambers in coliders. Here the implementation is done on low level using special purpose components [8]. Implementations with tree-search algorithms deal with the problem of low granularity. The granularity of a pattern is increased with the increasing level of the tree [9].

The approach that may look similar to template matching compares Monte Carlo simulation results or analytical model with a detector data. Such method has been applied in H.E.S.S. experiment to reconstruct γ-ray properties [10]. The parametrized model of pixel illumination by Cherenkov light based on semi-analytical descriptions of distributions is constructed. Additionally, the night sky background noise is modelled. This removes the need for noise discrimination from the measured data. The parameters of the calculated shower that best fits the measured shower image are determined in a minimisation procedure. The procedure yields a selection criteria to discriminate the γ-ray induced shower from the hadronic background. The advantage of the approach is that the model is less sensitive to instrumental or environmental effects in comparison to reconstruction techniques based on parametrizations for shower description.

Template matching reconstruction methods has not been tested in the JEM-EUSO experiment yet and feasibility of such method would have to be investigated more in depth. The ESAF reconstruction is currently based on analytical calculations from the detector data, a method similar to one used in the H.E.S.S. experiments also has not been explored. Challenges in implementation of such methods would be resolution of the JEM-EUSO detector and amount of the background noise.

3) Histogramming: Well-known approach in image feature extraction methods is Hough transform [11], which can be considered as special form of the Radon transform. This technique can detect lines and with changes in calculation circles. In its generalized form with r-table [12] the detection of other shapes is possible. For purpose of this method description line selection form is considered. Line, represented by equation $y = ax + b$ in an image-space, is represented by pair (a, b) in a parameter-space. However, this representation is unbounded and cannot represent vertical lines. The solution is to represent line in a normal parametrization which describes lines by a pair (ϕ, ρ). Angle ϕ is angle of line normal and ρ is an algebraic distance from the origin. Algebraic distance ρ is then calculated by $\rho = xcos\phi + ysin\phi$. Point in the image-space represents sinusoidal line in the parameter-space, and point in the parameter-space represents line in the image-space. The first step of the method is construction of accumulator matrix - the Hough space. For each point a sinusoidal line is constructed in the parameter-space by incrementing point int the space by one. Maxima in the parameter space represent significant lines in the image space.

Hough transform for searching lines has been utilized in many high energy physics experiments. For the ATLAS experiment [13] there was proposed an algorithm which combines Legendre transform and Hough transform [14]. The algorithm is intended to reconstruct particle track segments recorded by drift tube chambers. The Legendre transform $F(p)$ finds point of convex (or concave) function $f(x)$ where the tangent line has slope p. Each point $(p, F(p))$ in Legendre space represents a line, tangent to the curve $f(x)$. A drift tube signal is depicted as a circle, concentric with the tube. The circles represent all the possible track paths that cross the chamber. Each particle track is the common tangent that can be drawn to a collection of circles from several drift tube layers (can be imagined as rows of tubes stacked onto each other). The algorithm transforms each drift tube circle into Legendre space, considering that circle can be represented by combination of convex and concave function. After this transformation the problem is reduced to Hough transform and the task becomes to find the most significant lines representing particle tracks. To deal with neighbouring lines the clustering method is applied to the constructed histogram (Hough space). The performance study in the [14] concludes that method is robust in noisy environments.

For the reconstruction of events from the JEM-EUSO immediately interesting part of the article might be to consider similar clustering and the least squares fitting procedures applied to the Hough space.

Hough transform can be also applied as ring candidate detector [15] utilized to find centres of unknown rings. Ring selection is presently not required for the JEM-EUSO detector, but technically possible and work done in the area might provide useful information in the future.

This algorithm is especially suitable for feature extraction in the JEM-EUSO, because according to simulations [4], the most intensive part of a shower is projected onto the focal surface as a line. Two methods which includes this transform were proposed and implemented in the ESAF [16].

The first method (*Hough 1*) consists of two main phases. The phase one selects shower pattern starting by creating a combined image of an analysed area of the focal surface by the selecting the highest photon-count record (within an analysed event) of each pixel id. Then the pixel-gtu records above predefined threshold are used in the Hough transform which selects pixels around (determined by the distance parameter) the most significant line. In the phase two, the Hough transform is applied on all of the pixel-gtu records which pixel id belongs to group selected in the first phase. The transformation is expanded into three dimensions where the third dimension is the time (in GTU). This can be done because primary particle speed is expected to be constant within the configured parameter values.

The second method (*Hough 2*) selects parametrized number of unique pixels with the highest photon-counts values, also relative distance of pixels is important and cluster with the highest sum of photon-counts is selected. The Hough transform in plane XY is applied on these pixels with the goal of selection true shower maximum, and then the Hough transform in XYT is applied on pixel-gtu records in the area around the predicted maximum. The area around this selected area is expanded to include all input pixel-gtu records for the following analysis. In this analysis, pixels are divided by their photon-counts into groups and starting with the highest photon-counts the Hough transform is applied on each group to select maximum intensity line until threshold is reached. Finally the filtration rules based on observed shower characteristics were defined and are applied on the selected pixel record. Although, the method might seem to be "cluttered" it has shown to produce best results from the angular reconstruction point of view (see Fig. 1).

4) Artificial neural networks: The motivation to utilize artificial neural networks (ANN) in a process of track finding

is their ability to find good approximate solution to difficult optimization problems. Real advantage of the approach comes from techniques that are able to adapt to data which do not conform to the properties of the training sample [17]. Selection of suitable ANN is important. For example, solutions based on multilayer perceptron (feed-forward neural network) do not fit this criteria because they only can only generalize based on the training set. Another motivation for use of neural network is computing speed in comparison with histogramming methods which makes them suitable for trigger system role [18].

These methods are concerned with both track finding and track fitting or rather they are removing the boundaries between them. Two described methods require complicated energy function calculations and there are also other methods that propose different ways of minimizing it [17].

Early attempts to were made on Hopfield neural networks, in this specific version Denby-Peterson networks [19] [18]. The method can be considered adaptive because of the recall procedure in which the energy function is calculated. The energy function describes the amount of mismatch between the values of the neurons and what they should be according the weights. Recall procedure is repeated until the network stabilises - reaches local minima. The track segments S_{ij} are represented by binary neurons such that a neuron is active ($S_{ij} = 1$) if segment $i - j$ is part of the track, and inactive ($S_{ij} = 0$) otherwise. The calculation of the weights on the neuron synapses is defined in a way which increases the value of energy function when there are long segments and large angles in a track. The requirement of no bifurcating tracks is that no segments with one identical index should be activated at the same time, otherwise a positive contribution to the energy function is made. The last rule is that number of active neurons is roughly equal to the number of signals. To help reaching a global minimum rather than a local one, the mean field theory is applied. To improve the performance there is a radius around each signal beyond which no signals connect. The value of this "radius cut" was determined from the characteristics of the data.

Another attempts in a field were based on annealing techniques, namely elastic arms [20] and elastic tracking [21]. The methods start at presumption of a parametric form of an observed event - in studied case it is particle moving in circles. The strategy of the elastic arms approach is to match the observed events to simple parameterized models.

In the elastic arms technique, Hough transforms are used to provide initial parameters for the template arms and to specify the number of templates required. The templates are Gaussian distributions centred around the arm values where the width of the template is given by the temperature (in a sense of simulated annealing). The technique uses concept of attraction which is basically a factor in the energy function calculation. Arms are attracted to tracks and repulsed form each other. As the temperature gets lower the intensity of track attraction to nearby signal (hit) increases. Eventually arms are attracted to points belonging to the tracks or to the noise.

Currently, there has not been any efforts to implement any of the ANN algorithms to shower track reconstruction from data of the JEM-EUSO detector. These approaches were usually designed to reconstruct multiple curved and tangled tracks of particles moving in a magnetic field. Algorithm changes would be required for shower reconstruction of JEM-EUSO events, because the shape of the observed event is different. However, the basic idea of the methods - principle of the ANN algorithms would be similar.

B. Local methods

Local methods do not treat all hit information in equal and unbiased way. Rather they make use of continuous measurements provided by many of detector layouts. This hit proximity indicates probability that they belong to the same track.

These methods require a parametric model describing the track trajectory, a method of track seed generation, and a quality criterion [5]. Seed is a starting point of track construction, it selection should happen under condition where hit density is the lowest (e.g. the last layer of a detector).

1) Naive Track Following: The Naive Track Following is the simplest method mentioned by Mankel [5]. It is expected to be applicable only in situations with low hit density. Also complications might be caused by missing hits of the track, invalid hits in location of presumed trajectory, left-right ambiguities in wire drift chambers.

2) Combinational Track Following: The method extends the previous one by creating a new branch of tracking procedure at every possible continuation hit. Each branch is added into a tree which is evaluated after adding stage is finished. In terms of track finding efficiency the method might provide the best results, but the price is high resource demands. However, it is applicable in cases of limited combinatorics, as it is demonstrated in Track finding method [22] mentioned in the next section.

3) Kalman Filter: This method is the progressive fit implementation [23]. Unlike the least squares parameter estimation which requires global availability of all measurements at fitting time, the Kalman filter proceeds progressively. The decision power increases when more hits are accumulated.

An iterative process starts with an estimation of the next step. Then an error term is calculated based on the actual value produced in the next step, and the estimate is corrected. Both estimate and actual value are used in making of the next prediction. And process continues with next iteration.

An algorithm referred as "Track finding method" [22] that utilizes aforementioned local algorithms was implemented in the ESAF. The algorithm is very similar to standard Combinational Track Following but tracks are evaluated by "deviation from track line" criterion, which limits amount of possible tracks. Also there are criteria that describe pixel relation to track. Finally, the algorithm select only one with the highest sum of counts.

4) Clustering: Cluster analysis is well established in a filed of exploratory data analysis. The analysis organizes data by extracting underlining structure as grouping of individuals or as hierarchy of groups. The problem in cluster identification of data is specification of proximity and its measurement. The proximity matrix is one and only input into clustering method. There are multiple ways of dealing with this task and certain techniques might be more suitable for particular nature of analysed data than others [24].

In ESAF, there has been efforts to use clustering as a method for shower pattern recognition [25]. The algorithm proposed by Maccarone is two-dimensional single-link clustering algorithm which sees the data as random graph forming Minimum Spanning Tree. In this tree, the edges weight is Euclidean distance between the nodes. Cluster track is then identified as those pixels whose inter-distances are less than threshold.

Very similar approach is also utilized in the second Hough transform algorithm *Hough 2*, the Hough transform is applied on pixels that are selected as a cluster with the maximum sum of counts. This is very useful combination of techniques because selecting cluster of possible pixels lowers the amount of data entering transformation (resource demands reduction) and also removes almost certain outliers from the data.

III. Conclusion and future work

There have been at least four different methods for track finding implemented in the ESAF framework, namely clustering, local track finding, histrogramming by Hough transform, and PWISE. However due the interface changes, reconstruction pipeline changes, or simply lack of satisfactory performance statistics, not all of them are used. Presently, the PWISE method is regarded as a standard choice for a shower track finding in the ESAF. The figure 1 presents γ_{68} statistics describing the performance of angular reconstruction of shower tracks provided by track finding methods [7] [16] [22]. Please notice that results highly depend on particular parametrization of simulation and reconstruction.

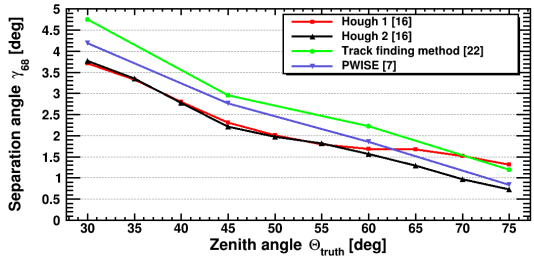

Fig. 1. Separation angle γ_{68} for different methods in ESAF.

Our implementation of shower track finding based on Hough transform displayed promising results, but especially the second more advanced method *Hough 2* needs to be streamlined. The filtration rules should be reviewed to check their correctness from the analytical shower description point of view.

There is a need to make in depth analysis of the available algorithms in different simulation conditions. Also, the algorithms should be tested throughout the range of their configuration parameters which should be correlated with algorithm performance in given conditions. This analysis would also increase a confidence in so far presented results [7] [16] [22].

According current results, the implemented methods satisfy the JEM-EUSO mission requirements [1] for angular reconstruction, and there probably only minor tweaks to be done. However, the JEM-EUSO experiment is planned not only to be the EAS detector, but it is to observe whole range of events happening in the atmosphere. Those events might require more sophisticated methods of feature extraction. This is where the more advanced approaches presented in this paper might be useful. Examples of another observed types of events are meteorites (much larger time-scales, speed cannot be regarded as constant) and gravitational waves caused by seismic events (not particle-like tracking).

This goals are also tied to the software used. There will be need for additional visualization tools to be created. The analysis of the algorithms will require additional parts of simulation-reconstruction-analysis toolset to be implemented. There is also possibility of requirement to reimplement current track finding methods to other reconstruction frameworks.

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Abstract Language of Internal Concepts

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***Abstract*—Internal concepts represent an abstraction of symbolized reality. Such concepts are in a form of a language. Their exchange fuels the communication process. In order to represent them inside of a computer, we may need to use non-redundant form, since by using an arbitrary concept form, a structural explosion may occur, where many similar objects are created. Therefore we present a way to abstract and hence reduce the size of grammars of languages with the use of meta-lambda calculus. It's capable to create nonredundant supercombinator form of that grammar. The reduction of grammar elements enabled by this form is rather high, as we prove with the experiment performed on grammars obtained from book samples.**

***Keywords*—Language abstraction, Language concepts, Meta-lambda calculus, Supercombinator machine mind.**

I. Introduction

Language is a tool that enables communication. According to Shaumyan [1], we communicate by a sign exchange. Signs are all around us, like words for example, but pictures, graphs, gestures, music etc. are also signs. The unifying property of signs is a meaning, with which they form a bond. Signs without any meaning (and a meaning without signs as well) are rather useless if we want to communicate [2].

Signs can be perceived as externally communicated symbols [3]. They are obtained by a process called symbolization. It's bidirectional mapping between a symbol and a real world object. For example, object $\triangle$ is a triangle. The word *triangle* itself is a symbol. However, symbols could be something else . The important fact is, that we know what the symbolization bidirectional mapping is. Therefore mapping $\triangle \leftrightarrow t$ represents the process of symbolization, where the triangle is represented by the symbol t.

Externally communicated symbols are not to be confused with abstract grammar symbols present in generative linguistics. The former represent coarse grained elements of communication where the latter are fine grained abstraction of generative process [3].

Internal concepts are obtained from symbols by performing an abstraction process called conceptualization on them [4]. Such concepts are now in a form of languages, therefore if we consider generative view presented by Chomsky hierarchy [5], we may represent them by grammars. An e-mail address is an example of a concept. Regular expression `words` **`(at sign)`** `words` **`(dot sign)`** `domain name` represents all e-mail addresses, therefore it's a concept of them.

If indeed the communication is achieved by a concept exchange, we need to have some form that we can represent internal concepts with. This form should be nonredundant, i.e. should be in form that does not represent the same subconcept twice. If this condition is achieved, we are then able to prevent the structural explosion. Also less elements means memory efficiency. But because of that, the form should be highly parallel as well (as our brains certainly are [6]).

Contributions of this paper are:

- We briefly show the Meta-lambda calculus as a tool to abstract internal concepts with. The description of it is in Section II.
- We describe the algorithm for concept transformation into meta-lambda supercombinator form. Some steps of this process may be performed in parallel, the algorithm itself is described in Section III.
- We outline our future work in Section IV, where we note the possibility of an extension to the realm of context-free grammars.

II. Meta-lambda Calculus

We have formally defined Meta-lambda calculus in [3]. We won't show this definition here for brevity. But the idea of it is rather simple. What makes meta-lambda calculus meta is the fact, that the result of its β-reduction is a regular expression, not data. Let's have following expression:

$$L \;=\; \lambda x_1.\ \lambda x_2.\ \lambda x_3.\ x_1 + x_2 \mid (x_3)^* \tag{1}$$

This is a ternary expression and a supercombinator, which β-reduction results into a regular expression. We see three types of regular operations. The sum, represented by a $\mid$ sign, sequence represented by a $+$ sign and closure represented by the Kleene star $()^*$. If we apply terminal symbols a, b and c to supercombinator L, we obtain the following regular expression:

$$L\ a\ b\ c\ \rightarrow a + b \mid (c)^* \tag{2}$$

Supercombinators are lambda expressions without free variables. And all lambda abstractions that they contain need to be supercombinators themselves. These formalisms allow us to decompose a regular language to simple, content independent parts. By an abstraction, that is based upon their structure, we obtain redundancy free set of supercombinators. And what is more interesting, we are able to reconstruct the original expression from that set just by applying the arguments in the same fashion as we see in the application (2).

III. Abstract Language Construction Algorithm

We are going to explain, how to obtain a set of supercombinators from any regular expression. We have presented an algorithm for that process in [7] and updated version in [8].

TABLE I
SUPERCOMBINATOR SET FOR REGULAR EXPRESSION $a + b \mid c$.

Supercombinators			Arguments
L^0	=	$\lambda x_1.\ x_1$	$\{\ a,\ b,\ c\ \}$
L^2	=	$\lambda x_1.\ \lambda x_2.\ L^0\ x_1 + L^0\ x_2$	$\{\ a\ b\ \}$
L^4	=	$\lambda x_1.\ \lambda x_2.\ \lambda x_3.\ L^2\ x_1\ x_2 \mid L^0\ x_3$	$\{\ a\ b\ c\ \}$

The starting point is the construction of a tree from the initial expression. Each metaoperation represents a node and every terminal symbol is transformed into a leaf. There is only one possible tree for any regular expression, since regular expression operations abide by the rules of the priority and associativity. The definition of a tree type is shown bellow. We use closure, option, sum and sequence metaoperations. We explain this in more detail in [9]. Note, that to express an n-ary operation, which sum and sequence are, we use a list for their subtrees. The resulting trees are thus n-ary as well.

```
data Tree   = Leaf Char  | Sum [Tree]
 | Opt Tree | Seq [Tree] | Cls Tree
```

Now, we are able to construct the first set of supercombinators. We use supercombinators that only have one metaoperation inside of them. This then allows us to break our tree apart into separate supercombinators, precisely one per node. The leaves are transformed into the id function. Therefore we get supercombinator $\lambda x.\ x$ for each leaf. Other nodes contain subsupercombinators inside of them.

Each supercombintor has also a permissible argument string. It's a string of all arguments that are applicable to that particular supercombinator. We obtain it from all accessible leaf nodes for each node (since each node is represented by a supercombinator). These strings are important, since only arguments inside of them are applicable to supercombinators if we want to reconstruct the original expression.

This obtained supercombinator set is not the final set however. It can contains many supercombinators that are equal. For supercombinators to be equal, they need to have the same underlying function with the same arity and all subsupercombinators are equal as are all argument applications. The merge is formally described in [3]. The argument string is not a part of equality, so all `Leaf` node supercombinators, the id supercombinators, are equal. We need to merge them. This means, that we only get one supercombinator of such a merge with accompanying argument string set. This set contains all strings from merged supercombinators.

We have a complete, redundancy free set of supercombinators at this stage. As an example, the expression $a + b \mid c$ supercombinator set is depicted in Table I.

IV. EXTENSION TO CONTEXT-FREE LANGUAGES

Our paper [9] dealt with the idea, that difference between regular and context-free languages is not that big. Especially, if we represent them in a tree form, similar to the definition shown above. We named that notion Higher order regular expressions. They are expressions that can contain another expressions as their argument.

An example of such expression is:

$$A \ \rightarrow\ a\ A\ b \mid a\ b \tag{3}$$

It's a context-free grammar for language $a^n b^n$ in the BNF form. At the same time, it's an expression, that consists of one sum operation over two sequences. Second sequence is ordinary binary sequence of terminal symbols, but the first one contains nonterminal. It merely represents a jump into another level of execution. This idea translates also to automata. We can see the automaton of (3) in Fig. 1. It's an infinite state automaton.

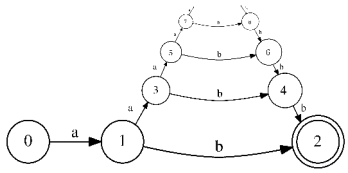

Fig. 1. The infinite state automaton obtained from the higher order expressions $A \rightarrow aAb \mid ab$.

We concentrate on this proposition in our currently unpublished work. We have connected context-free languages with our supercombinator acquisition algorithm with the use of higher order expression principle. There always exist one "top" supercombinator for each grammar rule. And it can then represent higher order jump. We have effectively tested this proposition on book samples.

We have used samples from the King James Bible and War and Peace by Leo Tolstoy. Plain text has been transformed into a context free grammar by sequitur algorithm [10]. This algorithm transform any text into a context-free grammar that generates only the input text. Yet, our abstraction mechanism dramatically reduces the number of elements, where in the case of The Book of Genesis, we have reduced 3660 grammar rules to 282 supercombinators and in the case of the fist 24 chapters of War and Peace the number had dropped from 3086 to 69.

V. CONCLUSION

We have presented the state of our research in this review paper. Our work revolves around abstract language in meta-lambda calculus form. We believe, that such a form opens a possible way to abstract grammatical representation of any conceptualized information obtained by symbolization. Therefore it may have uses in fields of grammarware, language acquisition or even, as we have shown on experimental results, in grammar based text compression.

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Accumulation of electricity research

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***Abstract*—This paper deals with accumulation of electricity research. It is summarization of work during last year of post gradual study. Short introduction, present status, solved research tasks and published articles are presented here. Proposal of future research tasks is also presented. This work involves design and modeling of hybrid generation electric power systems, which utilizes some kind of energy storage for accumulation; testing of various scenarios; sizing optimization of each component; design of system control and comparison with measured values.**

***Keywords*—accumulation of electricity, energy storage, hybrid system, sizing optimization.**

I. Introduction

In recent years, power generation from renewable energy sources records tremendous growth. This happens because conventional power plants combust fossil fuels and this process cause a production of carbon dioxide and other emissions. Fossil fuels are also more and more depleted. The huge penetration of renewable sources into power systems brings some concerns from the viewpoint of maintaining the existing security, quality and reliability of electricity supply [1]. These concerns have a reason arising from the nature of most renewable energy sources types. They have varying, intermittent and hard predictable output power, which varies according to environmental conditions [2].

The residual load as the difference between electricity demand and must-run generation of renewable energy sources will become highly volatile. To avoid a system black out due to an insufficient technical and economical flexibility of conventional power plants, storage technologies are becoming more and more discussed as one of main means to ensure the security of electricity supply in future [3].

Energy storage systems are one of the solutions necessary to integrate renewable energy generation to the existing power networks [4]. By their mutual cooperation mainly with photovoltaic power plants or wind farms within hybrid systems they can achieve powerful features.

This situation and related problems are very current nowadays and they are similar both in Slovak republic and most of European countries. Dynamic development together with unknown impact of these changes on present electric power system was sufficient motivation for conducting a research in this field.

II. Initial status

Nowadays, accumulation of electricity is well known and various energy storage technologies are also well established. But, their cooperation and practical utilization, especially in electric power system of Slovak republic, together with renewable energy sources has not been evaluated yet. There are not enough practical experiences, and supposed positive impact is not verified. For better understanding, testing under various scenarios and evaluation of impacts, some computer models are required.

After studying theoretical background about energy storages and accumulation of electricity as well as options of their utilization in electric power system, dissertation exam was passed and following PhD thesis was defined:

1. Analysis of current status of electricity accumulation and renewable energy sources in Slovak republic and in the world.
2. Analysis of cooperation possibilities between renewable energy sources and accumulation facilities in the island operating systems.
3. Design and modeling of island operating system based on renewable sources in cooperation with electricity accumulation.
4. Analysis of grid services providing options by energy storages.
5. Modeling and benefits verification of selected storage functions in electric power system
6. Results analysis and proposal of solutions which can be used in practice.

III. Tasks solved in previous year

During last year of post gradual study some work in accordance with PhD thesis was performed. It lies in modeling of renewable sources in combination with storage device. All of these tasks were performed using Matlab/Simulink environment. Results were published in international conference papers and scientific journals. Major publications are further described in following sections.

A. The implementation of an ideal photovoltaic module in Matlab/Simulink using Simpowersystems Toolbox

Paper describes first and one of necessary steps, which are needed for modeling of processes related to accumulation of electricity, because sources are required. Electricity storing is gaining importance mainly with increasing share of renewable energy sources in total generation capacity therefore photovoltaic module as a base of photovoltaic power plants

was chosen to model and simulate.

This paper deals with creating a one-diode mathematical model of ideal photovoltaic module. Ideal module in this case means, that series and shunt resistance was neglected. Real photovoltaic module parameters were simulated and impact of changing weather conditions was observed. The performance of the model is demonstrated with module output characteristics, which also show the effect of changes in temperature and solar radiation on the output parameters.

This model can be used for testing various types of photovoltaic modules and their behavior in other than standard test conditions. It can be also duplicated for creating photovoltaic array or whole power plant. Further description can be found in [5].

B. Smoothing the power output of photovoltaic plant using a battery energy storage system control

In this paper, the model of hybrid system which is formed by the battery energy storage system in combination with photovoltaic power plant is proposed. Battery energy storage system is based on Lithium-ion technology and it is connected to DC bus by DC-DC power converter. Hybrid system is connected by DC-AC voltage source converter to the loads.

Paper describes modeling of the system and its configuration to achieve stable and controllable power output. This approach makes possibility to change variable and intermittent power generation, typical for photovoltaic power plants, to generation of constant or actually required power.

In this simulation, constant power output was set by system control and results show power output response of the proposed system during slowly and rapidly changing irradiation [6].

C. Cooperation of photovoltaic power plant with battery energy storage system

This paper deals with a modelling of photovoltaic power plant in combination with battery energy storage system and their cooperation in order to better renewable energy utilization at local level. In this paper, the model of grid on hybrid system is proposed. Hybrid system modelling and simulation of system behavior during the random day of the year was performed. Results show the cooperation of battery energy storage system and photovoltaic power plant using system control in order to satisfy load requirements [7].

D. Design and simulation of hybrid system for public lighting power supply

This paper deals with design and simulation of hybrid system which consists of photovoltaic power plant, battery energy storage and load. It is used for power supply of public lighting based on renewable energy. Parameters of public lighting are inspired by real situation in small Slovak village. Hybrid system was designed and sizing optimization of each element was performed based on public lighting data, typical load curves and weather conditions in a locality. For this purpose, Homer software was used. Subsequently, system was modeled in Matlab/Simulink and its behavior under real conditions during random day in a year was observed to verify design correctness. Results from both simulations were compared and evaluated. Both simulation results are similar and behavior of the system shows that it was sized properly. Power delivered to the AC bus by hybrid system follows power required by load. The proposed hybrid system fully covers daily consumption of modeled public lighting load. There are not power outages. System consists of 100 kW sized photovoltaic power plant, battery bank creates 180 pieces of 200Ah, 12 V batteries Vision 6FM200D. Power conversion is provided by 12 kW converter [8].

IV. Future Research

Future research tasks are similar to previous work. Some modifications and extensions of present models will be performed. Wind power plant implementation into hybrid system models can be useful.

Besides that, work related to unsolved PhD theses will be performed. Analysis, modeling and benefits evaluation of grid services, which can be provided by energy storages, will be a subject of future study.

V. Conclusion

This paper reviews work during last year of post gradual study. PhD thesis and major publications are presented. It can be seen, that first half of theses was at least partially solved, and so future work lies in second half.

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Acknowledgment

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Acoustic Signal Processing Using Microphone Arrays

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***Abstract*— This publication deals with acoustic signal processing using microphone arrays. Microphone arrays can be used to solve many important room acoustic problems such as sound source localization and tracking, noise reduction, speech enhancement, source separation etc. In combination with proper processing of all microphone array sensors outputs, the signal of interest can be extracted while unwanted noise, interference, and late reflections can be suppressed.**

***Keywords*— acoustic beamforming, ASL, DOA, microphone array, source localization, spatial aliasing, TDOA**

I. Introduction

In general, microphone array refers to a sound acquisition system. These systems sample the sound field with spatial diversity using multiple microphones positioned in a way, that the spatial information is well captured. Spatial diversity is represented by the acoustic impulse responses from a signal source to the microphone. This diversity provides rich information that needs to be processed. Then, the primary objective of acoustic signal processing using microphone arrays is the estimation of parameters or extraction of signals of interest using spatio – temporal information available at the output of microphone array. Depending on the applications, the geometry of microphone array is very important. In source localization array geometry must be known in order to be able localize source of acoustic signal. However, in other applications such as noise reduction or source separation, the geometry of the array may have little importance. In particular applications can regular (linear and planar) microphone array geometry even simplify problem of estimation. Nowadays we can see more sophisticated three-dimensional spherical arrays [1].

The problems that have potential to be solved using microphone arrays may look easy, becouse the same or very similar problems have been tackle in narrowband antenna arrays (radar, sonar). But microphone arrays work diferently for the several reasons:

- Speech is wideband nonstationary signal,
- Reverberation,
- Multipath signal propagation,
- Nonstationary enviroments,
- Length of the modeling filter must be very long, because human ear has wide dynamic range, etc.

Many algoritms for wideband signal processing were borowed or generalized from narrowband array procesing. As a result, many derived algorithms do not perform well and performances are limited [2].

Microphone arrays cas be used to solve several problems such as source localization, source separation, dereverberation, noise reduction, etc. This problems are depictet in Fig. 1.

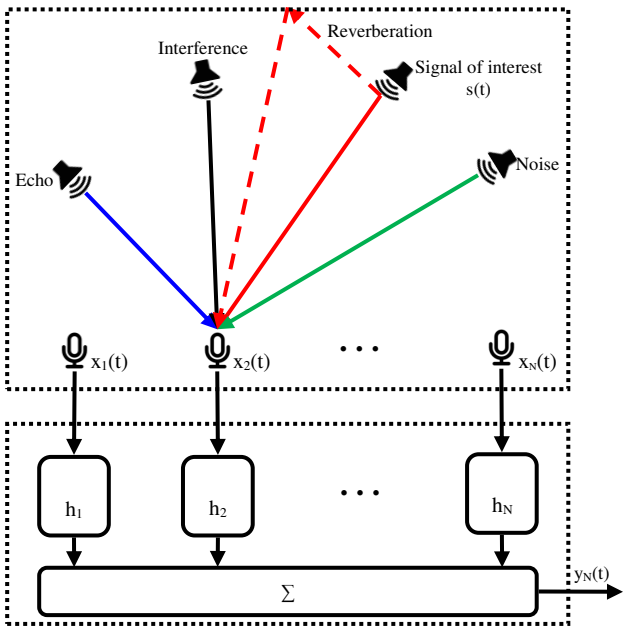

Fig. 1. Block diagram of signal processing using microphone array

The aim of speech enhancement and noise reduction algorithms is to extract signal of interest from corrupted observation. Many single channel algorithms distort the speech signal – speech quality may be improved but the speech intelligibility is degraded. However, with microphone array in combination with proper processing algorithm we should be able to reduce the noise without significant affection of speech signal [5].

II. Spatial Aliasing

The array beamwidth decreses as the spacing between microphones increses. In order to create sharper beam we can simply increse the spacing between microphones which leads to a larger array aperture. This approach can potentially leads to more noise reduction. Therefore, in microphone array

design we would expect the spacing between microphones large as possible. However, spatial sampling theorem, which is analogous to a Nyquist sampling theorem, must be observed:

$$d < \frac{\lambda_{min}}{2} = \frac{c}{2f}\ [m], \qquad (1)$$

where d is spacing between microphones and $\boldsymbol{\lambda}_{min}$ is minimum wavelenght [7].

III. DOA AND TDOA

One of the primary functionalites of microphone array signal processing is the estimation of the location from which signal of interest originates. Based on the distance between source of the signal and microphone array can be problem of location estimation divided into two categories:

- DOA (Direction Of Arrival) estimation
- Source localization

The direction of arrival estimation can be used in scenario, when the source of signal is in the array`s far field. In the far field scenario, the source of signal radiates a plane wave that propagates through the non- dispersive medium – air [10].

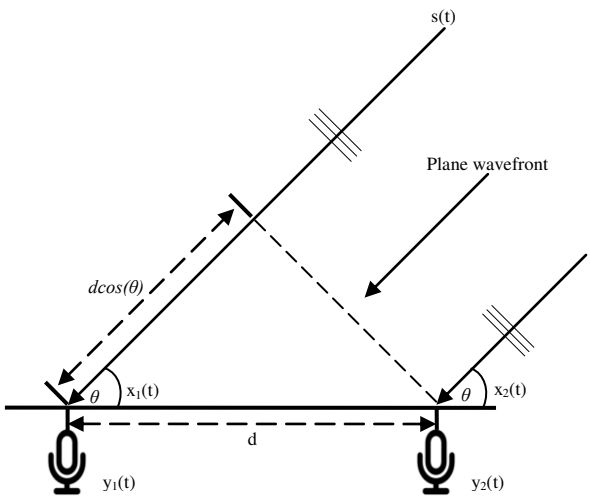

Fig. 2. DOA estimation - far field scenario

In Fig. 2. is depicted the illustration of DOA estimation, where *s(t)* is source of signal, θ is incident angle and d is spacing between microphones. Signal recieved at each sensor is a time delayed version of original version of signal at the reference sensor. The signal at the second microphone is delayed by the time required for the plane wave to propagate through distance *dcos(θ)*. The time delay between two microphones is given by:

$$\tau_{12} = \frac{dcos(\theta)}{v}, \qquad (2)$$

where v is the sound velocity in air. The estimation of incident angle is basically the same as estimation of τ_{12}. It follows that the DOA estimation in far field scenario is essentially identical with TDOA (Time Difference Of Arrival) estimation in near field scenario. In far field case is almost impossible to determine the range between sound source and microphone. However, in near field case is possible to estimate incident angle and also distance between source and each sensor in microphone array [15].

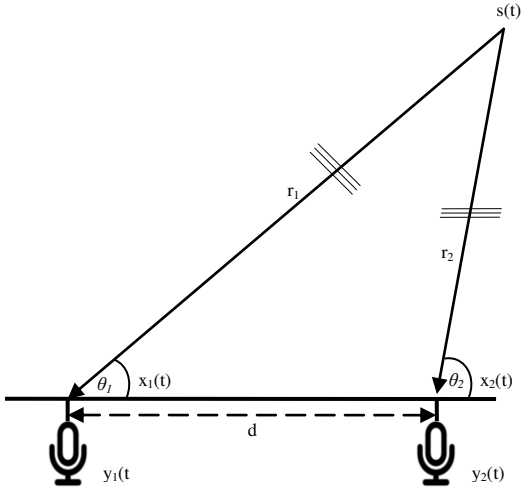

Fig. 3. TDOA estimation – near field scenario

In Fig. 3. is depicted TDOA estimation, where θ_n denotes incident angle and r_n denotes distance between sound source and n-t sensor. Then the TDOA between sensors is given by:

$$\tau_{12} = \frac{r_1 - r_2}{v}. \qquad (3)$$

Using the cosine rule, we obtain:

$$r_2^2 = r_1^2 + d^2 + 2r_1 dcos(\theta_1). \qquad (4)$$

For practical reasons, the spacing between microphones can be measured once the array geometry is fixed. If time delay between microphones is available then we can easily calculate rest of the unknown parameters by solving the equations (3) and (4). If all parameters are known then source position can be determined using the triangulation rule. Triangulation rule forms the basis of the most sound source localization methods. Regardless if the source is located in the far-field or near-field, the most fundamental step in obtaining the source origin information is the one of estimating the TDOA between different microphones [2]. TDOA estimation can be easy task in perfect scenario if the recieved signals are delayed version of each other [13].

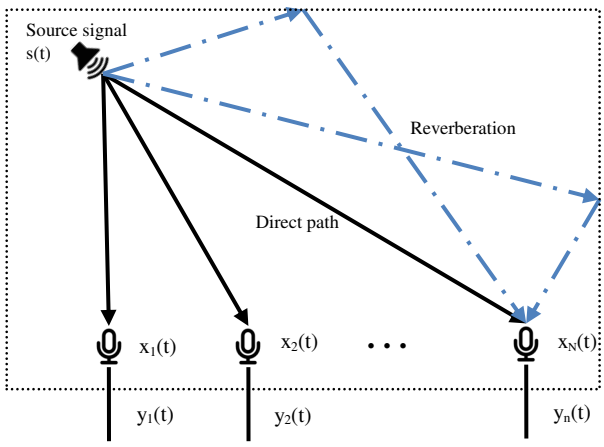

Fig. 4. Reverberant model of single signal source

However, in practical situations is the signal of interest embedded in ambient noise since the existence of noise is necessary in real environment. Each recieved signal then may contain multiple delayed replicas of source signal due to reflections from objects. This effect, termed as multipath propagation, introduces reverberation in the source signal that is ilustrated in Fig. 4. Source signalcan also changing position, resulting in time delay diferences. These complications make TDOA estimation a dificult and challenging problem [20].

IV. Beamforming

Beamforming has been studied in many areas (radar, sonar, seismology, etc.) and can be used for signal detection, DOA estimation and speech enhancement from its measurements corrupted by interferences such as noise, reverberation and competing sources of signal. Beamformers are defined as spatial filters that form a desired beam pattern at the output of microphone array. Beamforming was originally developed for narrowband signals that can be characterized by a single frequency. However, speech has a wide frequency spectrum. To design beamformers for broadband signals are used subband decomposition techniques and narrowband beamformers at each frequency. Beamforming is a two step approach:

- Synchronization
- Weight and sum

In the synchronization step are the signals from each sensor output delayed or advanced by a proper amount of time that the signals coming from a desired direction are sinchronized. The TDOA information is necessary in this step, which can be estimated from the array measurements using TDOA estimation methods. In the second step are signals weighted and summed together. The output from this step is one aligned output. Synchronization process controls the stering direction and weight and som process controls the beamwidth of the mainlobe and sidelobes [15].

A. DELAY AND SUM BEAMFORMER

Delay and sum (DS) beamformer also consist of two processing steps. First step is time shifting of each sensor by a proper value using TDOA estimation between particular sensor and reference one [2].

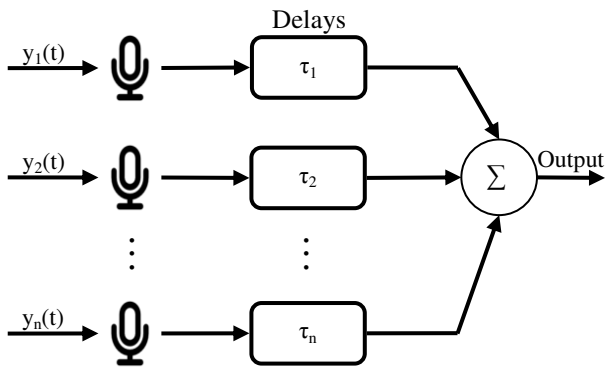

Fig. 5. Block diagram of DAS beamformer

Widely used signal model assumes that each propagation channel introduces some delay and attenuation:

$$\begin{aligned} y_n(t) &= \alpha_n s[t - t_1 - F_n(\tau)] + v_n(t) \\ &= x_n(t) + v_n(t), n \\ &= 1,2,\dots,N, \end{aligned} \tag{5}$$

where α_n is the attenuation factor, $s(k)$ is the source signal, t_1 is the propagation time from source to reference sensor, $v_n(t)$ is the additive noise signal at the n-th sensor, τ is the delay between sensors (TDOA) and $F_n(\tau)$ is the relative delay between reference and n-th sensor. With the signal model given in (5) and after time shifting, we obtain [20]:

$$\begin{aligned} y_{a,n}(t) &= y_n[t + F_n(\tau)] \\ &= \alpha_n s(t - t_1) + v_{a,n}(k) \\ &= x_{a,n}(t) + v_{a,n}(t), n \\ &= 1,2,\dots,N, \end{aligned} \tag{6}$$

where

$$v_{a,n}(t) = v_n[t + F_n(\tau)], \tag{7}$$

and the subscript a implies an aligned copy of sensor signal. The second step consists of adding up the time shifted signals, giving the output of a Delay and Sum beamformer:

$$\begin{aligned} z_{DS}(t) &= \frac{1}{N}\sum_{n=1}^{N} y_{a,n}(t) \\ &= \alpha_s s(t - t_1) + \frac{1}{N} v_s(t), \end{aligned} \tag{8}$$

where

$$\alpha_s = \frac{1}{N}\sum_{n=1}^{N} a_{n,} \tag{9}$$

$$v_s(t) = \sum_{n=1}^{N} v_{a,n}(t) = \sum_{n=1}^{N} v_n[t + F_n(\tau)]. \tag{10}$$

V. Motivation

Microphone array signal processing is a technical domain where speech and array processing meet. The main goal is to enhance and extract information carried by acoustic waves received by a multiple sensors at different positions.

Speech is a random, broadband and nonstationary signal and the presence of room reverberation and noise makes microphone array signal processing very difficult and complicated topic. Processing algorithms need to be specially tailored for the specific problem. As a matter of fact, in this area are produced many journal papers and PhD. thesis.

A key challenge is to create a proper algorithm that can process broadband speech signals no matter whether they propagate from far field or near field sources.

Microphone array signal processing can be also useful in blind source separation area. It has been recognized for some time that a human has the ability of focusing on one particular voice or sound amid a mixture of distracting conversations and background noise. This phenomen is refered as the cocktail party problem or attentional selectivity. To solving these problems is necessary to solve two key problems:

- How do the human auditory system and brain solve this problems

- How to replicate this ability of human brain for man made inteligent systems

However, all necessary know-hows in order to provide a solutions for this problems still not exist.

VI. Conclusion

This article describes methods for microphone array signal processing. In future, we want to focus on creating algorithms for the processing of acoustic signals recorded by a spherical microphone array (EIGENMIKE). Designed algorithms should be used to localization of the position of static as well as moving sound sources and source separation. Efficiency of proposed algorithms will be evaluated by automatic speech recognition system for Slovak language.

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Advanced Techniques of Human Interaction in Smart Environments based on Technologies of Virtual Reality

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***Abstract*— From the technological viewpoint, approaches and methods proposed in this work it is contributive to realize methodic of the user interface development for smart environment with reference to higher effectivity and simplicity of communication in the relationship of a human and a computational system. The main goal includes identification of user activities in physical space and definition and extension of a set of gestures for control of smart environment as well as contribution to guidelines for development of this kind of user interface.**

***Keywords*—ambient intelligence, HCI, natural user interface, smart environment, virtual reality system**

I. Introduction

The evolution of the user interfaces (UI) is affected by development of information technologies as well as the change of the UI development approaches. Human interaction in smart environments is inspired by interaction with physical world and communication between human beings. From times of inventions of computer mouse and keyboard to invention of computer control using body movements we could define user who is capable to master new techniques of interaction but (s)he also demands their evaluation for acceptance.

Smart environment (SmE) includes components such as sensors and actuators which offer "off screen" interaction. We can control and monitor physical environment where we live using posture, gestures, speech and hand writing. Realization of such a interface is possible by involvement of known input and output devices which are widely used in navigation in variety of virtual worlds. Technologies of virtual reality (VR) are supposed to be used to simulate SmE to evaluate new ways of interaction and also to become a part of the SmE itself. It is obvious that the development of the UI for SmE is not straightforward and making provision for this fact it is appropriate to create opportunities for involvement of as many known types of interaction as possible. Particular type of control should be offered to the user but it should not limit him by choosing the other way.

This work is aimed at recognition of user activities and control by body movements. It is supposed to be a contribution to the guidelines of the user interface development and evaluation for closer undefined smart environment.

II. User - centered view of the smart environment

Initial stages include research of smart environment phenomena and fields of research which contribute to its development. New ways of interaction are affected by technological and non-technological changes of our society. Most of them are related to enlarged reliability and stability of new technologies as well as new generation of computer users capable to lay out new requirements on computational system.

During this phase were identified areas such as *human - computer interaction (HCI), artificial intelligence, computer networks and middleware, sensors and actuators, ambient intelligence,* which were summarized in [1]. The field of interest were reduced to HCI view on smart environment, where we can divide components into three main groups; *sensors, controllers* and *actuators*. They are integrated into smart devices, robot agents and electric appliances operating on local area network with remote access [2]. This work brings insight into definition of parts of SmE, which will be virtualized in further stages. Significant effort was dedicated to studies of HCI and technologies which affected UI development the most. It leads from first application software with graphical user interface (GUI) and HCI aimed at human factors and cognition to technologies of virtual reality and internet of things (IoT). Full list includes phenomena such as *desktop metaphor, web technologies, diversification of mobile devices and social networks, technologies of virtual reality, internet of things and smart environment.* [3]

Technological changes required new approaches in UI development which depend on perspective views on essence of information. This fact led to definition of three paradigms described in [4].

III. Localized information and Contextual data

According to new trends in HCI it is supposed a change from user - centered approach (UCA) to human-centered approach (HCA). Susan Gasson describes insufficiencies of technologies developed using UCA because of shallow understanding of human activities and processes which occur as the parts of activities. HCA gives priority to support and fulfillment of human activities, skills, creativity and potential

within specific activities of interaction with technologies. UI design is more and more oriented to human in a role of a consumer, a creator or a player rather than the immediate user of information technologies. [5]

It is appropriate to consider HCA perspective in UI design for SmE. Suitable view on development of such an interface is supposed to be paradigm of localized information including methods and approaches of human factor engineering and cognitive processing. It is important to notice that UI for SmE based on human body movements and activity recognition is strictly bound to contextual data describing conditions under which activities occur [6]. Content of contextual data defines extended information like timestamp, status of physical environment in the meaning of measurable data and biochemical and physiological data of the user.

IV. Activity recognition and Evaluation methods

John M. Carrol defined cycle of understanding of tasks and artifact creation, which are continuously evaluated. He describes defining of requirements and scenario creation as endless process in a long term. New artifacts lead to new requirements and new tasks which require new approach, adjustments and new solutions.[7] This theory was applied in development of semi-immersive virtual reality system *VRPITA*. Its further adjustments according to areas of deployment were described in [8][9][10][11].Further research of activities which occur in control of virtual system by touch user interface on surface reveal challenges similar for activities in physical space. [12] All human activities of interaction with physical space and other people are significant through properties:

- activities are continuous and nested,
- activities are abruptly interrupted,
- activities rarely have exact starting and ending point,
- exchange of particular steps could describe the same activity.

For appropriate activity determination there is a need to create associative information model [2], which will be the subject of further research.

Significant attention was paid to UI evaluation methods. Known evaluation techniques were compared according to qualities of user interface, which are evaluated; requirements on time and finances; development phases, in which evaluation is possible and evaluators (user, professional, computational system). Evaluation methods were compered in [12]. Choice of appropriate evaluation is the subject of further research and UI development stages.

V. Proposed hardware and software solution

Connection between natural user interfaces of SmE and technologies of virtual reality was identified during initial research stages of HCI, paradigms, methodic and approaches to UI development. Considering this fact was developed concept of virtual reality system with natural user interface for SmE shown in Fig. 1. Whole system is divided into two modules according to their functionality, *Alpha* and *Beta*.

Module *Alpha* is dedicated to segmentation and analysis of contextual data which includes input data from the user (primary his/her body movements), input data generated by sensors from physical environment and input data generated by virtual sensors from *Beta* module. This module provides outputs based on recognized activity. The user is informed about this fact through web UI, mobile application or avatar model in virtual scene of module *Beta*. The user is capable to add control of SmE to particular activities using these interfaces. In the case that particular activity is repeatedly recognized and its function is known, this detection causes change of physical environment using actuators or a change of virtual scene.

Module *Beta* is used for generation of inputs for module Alpha (virtual sensors delivering computer generated data), avatar model updates and changes of virtual scene. [3]

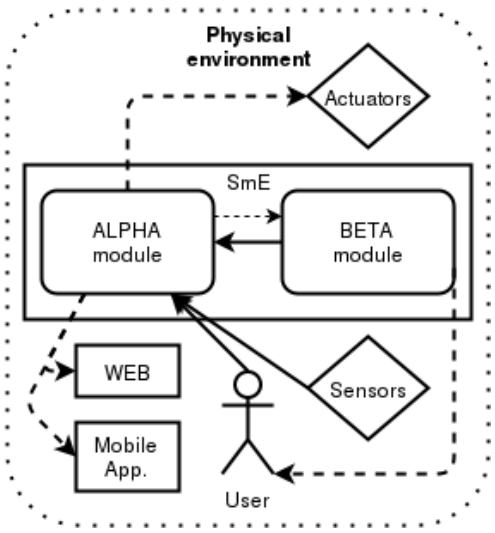

Fig. 1 Infographic of VR system for SmE

VI. Conclusion

This article introduces initial stages of SmE research from HCI perspective. Further effort was dedicated to studies of most influential technologies and significant paradigms of UI development. This part describes requirement on localized information and contextual data of SmE. UI based on human body movements and recognition of activities in physical space require appropriate method of recognition and associative information model which will be the subject of further research. Planned work also includes definition of UI evaluation methods. This paper concludes with proposed conceptual solution of VR system for SmE and description of its components which will be further defined in more detailed way.

Acknowledgment

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Ambient Robotics in Intelligent Space

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***Abstract*—The paper provides an overview of our proposed guiding scenario based on technologies like the Internet of Things, Intelligent Space and Ambient Robotics. A description of these technologies is also provided and it also summarizes the work done in the last year.**

***Keywords*—Internet of Things, Intelligent space, Ambient robotics.**

I. Introduction

The integration of computers and information technology into our everyday lives grows more and more with each passing day, from our phones and computers to our cars and appliances as well. As the number of intelligent devices grows a so does the desire to combine their utilities and abilities. This has given a rise to concepts and applications such as intelligent homes, smart offices, ambient robotics and the internet of things. These allow us to combine our homes with various technologies to make them adapt to our current needs making our lives easier and work more efficient.

In our work we would like to combine these possibilities with robotic applications and therefore propose an initial guiding scenario that will take advantage of them.

II. Internet of Things

The Internet of Things (IoT) represents a network of physical objects and devices that are embedded with electronics, software and sensors that are able to collect and exchange data among themselves. IoT allows remote control of objects across existing network infrastructure and enables a more direct integration of the physical world and computer-based systems. Every object in the IoT can be uniquely identified through the embedded computing system. When augmented with sensors and actuators, IoT becomes an instance of a more general class of cyber-physical systems [1]. The term 'Internet of Things' was coined in 1999 by Kevin Ashton and was also known as pervasive computing, ubiquitous computing, and ambient intelligence [2].

From the perspective of technical standardization, IoT can be seen as a global infrastructure connecting physical and virtual things and enabling advanced services based on existing and evolving information and communication technologies (ICT) [3]. The IoT makes use of "things" to offer services to all kinds of applications, while fulfilling the requirements of security and privacy. By "things" we understand objects of either the physical world or of the virtual world which are capable of being identified and incorporated into a communication network. Information associated with "things" can be static or dynamic in nature. Physical things are capable of being sensed, actuated and connected while virtual things are capable of being stored, processed and accessed.

Another way to look at IoT is as an environment in which objects, animals or people are provided with unique identifiers and the ability to transfer data over a network [4]. From this perspective, a "thing" in the Internet of Things may be a person with a heart monitor implant, an animal with a biochip transponder, an automobile with built-in sensors or any other object with an assigned address and the ability to transfer data over a network.

III. Intelligent Space

Intelligent space (ISpace), also referred to as intelligent environment, is a room, a series of rooms or an area equipped with an array of sensors, embedded systems, information and communication technologies and other devices that allow it to perceive and understand what is happening inside of it. This allows people and systems within the ISpace to use additional functions provided by it. The purpose of ISpaces is to utilize these perceptive abilities to improve, adjust, or in some cases completely control, the activities that take place inside of them. As such they have a wide variety of applications ranging from smart homes and offices to factories etc. [5]. In regards to IoT, ISpace does not necessarily need to be connected to the internet. However recent trends have shown the advantages of this combination.

The basic building elements of such an ISpace are known as distributed intelligent network devices (DINDs) and consist of sensors, processors, and network devices [6] (**Figure 1**).

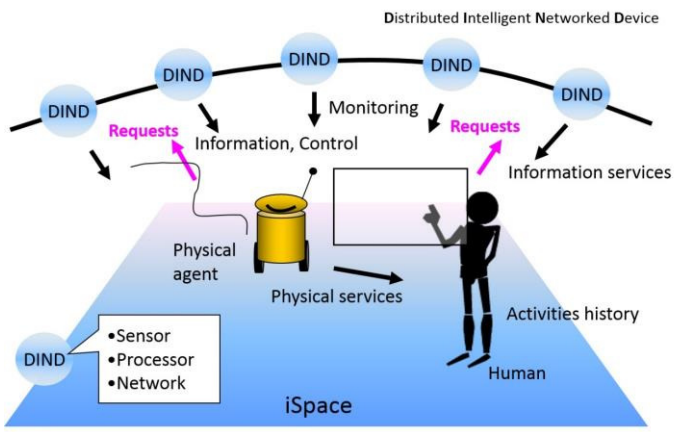

Figure 1 – Intelligent space example [7]

IV. Ambient Robotics

As can be deduced from above ambient intelligence refers to environments capable of sensing and responding to the presence of people. It describes a vision in which devices work together to aid people in performing their daily task and activities [8]. By combining the paradigms of ambient intelligence with robotics, we get ambient robotics. The purpose of this combination is to allow the robots to utilize the embedded network systems in the environment to navigate more precisely and to more intelligently respond to the events within the environment. As such an ambient robot includes three components [9]:

1. **Virtual software robot** – used for decision making and action planning
2. **Real-world mobile robot** – for performing actions in the real world
3. **Embedded sensor system** – gives additional information to the decision making part that physical robot is unable to provide

Another way to look at an ambient robot is as a part of a Ubiquitous Robotic Space (URS) [10]. The URS consists of three major conceptual spaces whose purpose is to provide more suitable information to robots and users. They are:

1. **Physical URS** maintains the sensor network, robot, and objects in the environment.
2. **Semantic URS** manages domain knowledge and converts raw sensing data into contextual information based on intelligence.
3. **Virtual URS** provides the communication interface between the URS and its users.

V. Guiding scenario

For our on-coming research, we plan to develop a guiding scenario utilising the aforementioned technologies. The first step is to build an intelligent space equipped with all our chosen sensors (**Figure 2**). Additional sensor types are being considered as well [11].

Figure 2 – Floorplan of our ISpace

Apart from the physical requirements, there will be a number of problems that need to be solved. Firstly once all the sensors are connected to the network, all of them will need to be managed. Since managing them individually is inefficient, we plan to design a central managing system based on IoT and cloud technologies. This system will also handle the necessary data integration from the various sensors.

The second step is the design of the scenario itself. Our plan is to create a system that would allow one of our robots to detect guests coming into our building and then to escort them into one of our laboratories. The integration of a mobile robot platform and a sensor network will result in an Ambient Robot system. For our robot to be able to guide a guest, a navigation method will need to be developed. This method will need to be able to determine an efficient path for the robot to take according to the sensors placed on the robot itself and those embedded in the environment. Since the amount and availability of sensor data may vary depending on the robot's location within ISpace, the system will have to be able to work with what is available. A system based on a Fuzzy cognitive map may be suitable as it is able to make decisions regardless of how many of its input nodes are active [12]. Our navigation method will need to be able to make sure that the guest is following, navigate the robot between rooms and to avoid obstacles and other occupants in the room.

In the end this will result in a semiautomatic agent that will be evaluated compared to manual teleoperation.

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Analysis of High Frequency Elements from the View of Different Materials and Technologies Applications'

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***Abstract*— This paper is summarization of last year of post gradual study. Solved research tasks and published articles are presented here. This work involves microstrip methods for measurement of dielectric properties in high frequency area following by measuring of dielectric properties by microstrip resonators in the GHz frequency. Next part is aimed on influence of various multilayer LTCC systems on dielectric properties stability in GHz frequency range. Last part of this paper is dealing with influence of accelerated ageing on LTCC and PCB substrates in GHz area.**

***Keywords*— dielectric properties, filters, LTCC, microstrip structure, scattering parameters**

I. Introduction

With evolution of information technology, the frequency applied to electronic devices has become higher to handle the growing volume of data. These devices are used in various types of environments (temperature, humidity, etc.) and they are working in high frequency range.

Because of high frequencies it is not possible to use typical electronic elements (resistors, capacitors, inductors), for that reason all devices for high frequency applications are designed and constructed using planar transmission lines, mostly by microstrip lines. Microstrip structures' design is strictly depending on dielectric properties, dielectric constant and loss tangent, of used substrate.

The most significant problems caused by higher frequencies are losses as well as stability and reliability of mentioned dielectric properties. For that reason it is necessary to find out behavior, stability and reliability of dielectric substrates in different environments loaded by high frequency [1].

II. Initial Status

Nowadays, there are a lot of PCB and LTCC dielectric substrates available on the market but not all of them are suitable for high frequency applications. Only few of these substrates were designed and have sufficient properties for high frequency applications, which means they have high dielectric constant and low loss tangent. However, in general each application has unique requirements which have to be fulfilled. Except suitable dielectric properties their stability in high frequency area and different environment is very important. For these reasons it is necessary to find suitable dielectric substrates and characterized their behavior, because no research in this area was done so far.

After studying theoretical background about complex permitivity, dielectric polarizations and losses [2] these PhD theses were solved:

1. Design methodology for measurements of dielectric properties in high frequency area.
2. Dielectric properties analyses' of PCB and LTCC materials using planar structures in high frequency area.
3. Microscopic analyses of crystallization process in various processing conditions' and their impact on dielectric properties.
4. Analyses of accelerated ageing on dielectric properties of PCB and LTCC materials.
5. Applique analyses results' in fabrication of selected high frequency element based on PCB and LTCC.

III. Solved Tasks in The Previous Year

A. Microstrip Methods for Measurement of Dielectric Properties in High Frequency Area

Microstrip methods for measuring dielectric properties were introduced, they are represented by ring and T-resonator. Matlab scripting language was employed for implementation of all equations for calculations of physical dimensions and dielectric properties, as well as for creating user friendly, intuitive GUI. New software tool was originated and it is designated for measuring dielectric properties of solid materials (substrate board) where microstrip transmission lines could be applied. These methods are suitable for measuring dielectric properties in wide frequency range up to tens of GHz.

This free software tool will be available at web page: http://web.tuke.sk/fei-ldipv/microstrip/ and it will be used in our future work for investigating dielectric properties of various types of PCB and LTCC materials [3].

B. Measuring of Dielectric Properties by Microstrip Resonators in the GHz Frequency

This paper presents measuring of dielectric properties by microstrip resonators in the GHz frequency range of four different PCB substrates' (Rogers RO3003C, Rogers RO4003C, Rogers RT/duroid 5880, Rogers RT/duroid RO6010LM). Ring resonator with primary resonance tuned at 1 GHz and 1.7 GHz and T-resonators with primary resonance tuned at 1 GHz and 2 GHz were designed, fabricated and measured.

Measured dielectric constant of Rogers RO3003C and Rogers RT/duroid 5880 is in correlation with dielectric constant stated by manufacturer. On the other hand, measured dielectric constant of Rogers RO4003C and Rogers RT/duroid RO6010LM are 10% higher than manufacturer specifies. After analysing loaded Q factor of all measured PCB substrates Rogers RT/duroid 5880 can be consider as material with the lowest losses which correspond with manufacturer's datasheets.

Measuring of dielectric properties by microstrip resonators is suitable method for substrates with dielectric constant up to 3. Suitability of this method for measurements dielectric properties of substrates with higher dielectric constant (3.38, 10.2) is questionable. It will be verified in our future work where dielectric properties of Low Temperature Co-fired Ceramic substrates (dielectric constant 7.1, 7.7 and 7.8) will be measured. Inaccuracies between measured and manufacturer stated value of dielectric constant could be caused by substrates' physical damage (bending, ageing, etc.). Influence of these factors will be investigated as well [4].

C. Influence of various multilayer LTCC systems on dielectric properties' stability in GHz frequency range

This work describes various multilayer LTCC substrates from the view of dielectric properties in GHz frequency range and analyses dielectric constant and dielectric losses by ring resonators microstrip measurement method. Ring resonators from five different types of substrates were designed, fabricated and measured to obtain dielectric properties of these substrates in the area up to 10 GHz.

By inserting Murata LFC between DuPont GreenTape 9K7 or DuPont GreenTape 951 new composites were originating. The middle layer of Murata LFC has significant influence on shrinkage value of composites. DuPont GreenTape 9K7 has shrinkage in axis X and Y 9.1 +/- 0.3 %, in axis Z 11.8 +/- 0.5 but in combination with Murata LFC it has changed to 1.6 +/- 0.2 % in axis X and Y, and to 21.8 +/- 0.5 in axis Z. DuPont GreenTape 951 has shrinkage in axis X and Y 12.7 +/- 0.3 %, in axis Z 15 +/- 0.5 but in combination with Murata LFC it has changed to 17.1 +/- 0.3 % in axis X and Y, and to 7.9 +/- 0.5 in axis Z. Murata LFC raises shrinkage in axis Z and reduces shrinkage in axis X and Y in combination with DuPont GreenTape 9K7 but on the other hand in combination with DuPont GreenTape 951 reduces shrinkage in axis Z and raises shrinkage in axis X and Y.

Middle layer of Murata LFC has no significant impact on dielectric constant of both composites. In one case dielectric constant of both substrates, which create composite are almost the same (Murata LFC 7.77 +/- 0.2, DuPont GreenTape 951 7.8 +/- 0.2) therefore, no important change is reasonable. However, in the second case, when dielectric constant are different (Murata LFC 7.77 +/- 0.2, DuPont GreenTape 951 7.1 +/- 0.2), any changes of composites' dielectric constant were assumed, but they were not proved. For this reason, we can conclude, that major impact on dielectric constant has top layer of composite, where microstrip ring resonator was applied.

Q factor of composites is influenced by inhomogeneity of the substrates. For that reason during signal's transition between single layers dielectric losses are increasing and influence Q factor of measure LTCC substrates. The impact of inhomogeneity is the most significant at frequency around 6 GHz [5].

D. Influence of Accelerating Ageing on LTCC and PCB Substrates' Dielectric Properties in GHz Area

This paper is focused on investigating stability of dielectric properties, dielectric constant and loss tangent, after exposing dielectric materials to accelerated ageing tests. Two types of Low Temperature Co-fire Ceramics (LTCC) substrates and four types of printed circuit boards (PCB) substrates were exposed to temperature loads. DuPont GreenTape 951 and DuPont GreenTape 9K7 represent LTCC substrates and Rogers 3003C, Rogers 4003, Rogers RT/duroid 5880 and Rogers RT/duroid 6010/LM represent PCB substrates. Thermal shock chamber and temperature humidity chambers provided two types of accelerating ageing test, temperature cycling and High Temperature Operation Life (HTOL) tests. Dielectric properties of these LTCC and PCB substrates were measured by combination of Vector Network Analyzer (VNA) and split cylinder resonator. This measuring method provided dielectric properties at two frequencies, which depend on concrete material, the first frequency is around 10 GHz and second about 12.5 GHz. Preliminary results show better stability of LTCC substrates after accelerating ageing test. It is caused by composition of these substrates which minimalizes moisture absorption, because moisture has major impact on degradation of dielectric properties [6].

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Analysis of Layers Based on Silver Nanoparticles Realized by Inkjet Printing Technology

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***Abstract*—This paper is a summarization of last year of post gradual study. Solved research tasks and published articles are presented here. This work involves the surface analysis of polymeric substrates used for inkjet printing technology, such as polyimide (PI), polyethylene terephthalate (PET) and polyethylene naphthalene (PEN) as well as the impact of surface properties of polymeric substrates on the nano-ink behavior. The paper also describes the developed software tool for scripting and image processing applied in inkjet printing technology.**

***Keywords*—Inkjet printing, nano-ink, surface treatment.**

I. Introduction

The unstoppable development of nanotechnology brings new possibilities in the area of electronics technology. One of these technologies is inkjet printing technology that offers a lot of advantages, such as creation conductive, semi conductive, isolation or other function layers onto various flexible polymeric substrates. Described non-contact printing method presents the digital printing that works with small ink quantities with very low viscosity based on nanoparticles of special materials. This printing technology is suitable especially for applications, where the precise printing with high accuracy is desirable [1].

Inks, used for inkjet printing technology may be divided into 3 groups. The first, most used inks are based on nanoparticles of conductive organic poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) or inorganic (Ag, Au, Cu) materials. The second group consists of semi conductive inks, which are based on carbon nanotubes, as well as on organic materials, such as poly(3,3'''-didodecyl quarterthiophene) (PQT-12) or poly(3-hexylthiophene-2,5-diyl) (P3HT). The last group of inks serves to creating of isolation layers. For this purpose, organic polyvinylpyrrolidone (PVP), poly(methyl methacrylate) (PMMA) and inorganic (Zr, TiO_2, SiO_2) materials are used [2], [3].

II. Initial Status

Nowadays, deposition of special nano-inks onto the flexible polymeric substrates with high accuracy and precision is required in the lot of field of electronics. The line edge, relief of the printed structure and the structure of necks play a key role for final quality. On the other hand, printing of the viscous liquid drops contain nano-particles of noble metals requires the controlled surface's properties of polymeric substrates. The substrates' temperature, surface tension and the wettability of substrates have a significant impact on the deposited structure [1], [5].

Printing the structures and lines with width less than 50 µm is extremely difficult. There are many technological factors that affect the quality of printed structures. For this purpose, the quality of surfaces is needed to analyze. The roughness, wettability and surface tension of substrates play a significant role to drop spreading. Surface treatment represents an important step to optimize the technological process of printing [3], [4], [5].

After studying theoretical background about inkjet printing technology, substrates' surfaces and their modifications as well as drop spreading we want to solve these PhD theses:

1. Optimization of technological factors affecting the structure of silver layers realized by inkjet printing.
2. Analysis of adhesion mechanism between layers based on silver nanoparticles and substrates and proposal for methodology of their measurement.
3. Analysis of properties of silver layers realized by inkjet printing technology and analysis the impact of various parameters to the quality.
4. Application of analysis' results for the design of 2 selected electronic components on a flexible substrate by inkjet printing technology.

III. Solved Tasks in The Previous Year

Tasks which are summarized in the following section were solved in the last year of postgraduate study based on dissertation thesis.

A. Surface analysis of polymeric substrates used for inkjet printing technology

This paper has compared two methods for the surface analysis of polymeric substrates. In the first, the wettability of the polymeric substrates was analyzed by using contact angle measurements. The measurement of surface roughness was also applied. For optimization of the wettability of polymer substrates used for inkjet printing technology, substrate surfaces were treated by chemical agents. The experiments proved the correlation between the wettability of a substrates and the work of adhesion [5].

The results show that toluene and acetone decreased the contact angle of all analyzed substrates. Isopropyl alcohol and ethanol had no significant impact on the wettability of the polymeric substrates. In the case of the PI substrate, DuPont™ Kapton® HN, the chemical agent EGC-1720 increased the contact angle to 110°. The untreated PI substrate had a contact angle of about 60°. The maximum contact angle measured was on a PET substrate, FlexIso®, at 78.5° [5].

The surface roughness measurements showed that the PI and PET substrates had similar roughness at approximately 0.046 µm. The PEN substrate had the lowest roughness at about 0.020 µm [5].

The achieved results will be applied to optimize the adhesion mechanism between nano-inks and polymeric substrates for use with inkjet printing technology [5].

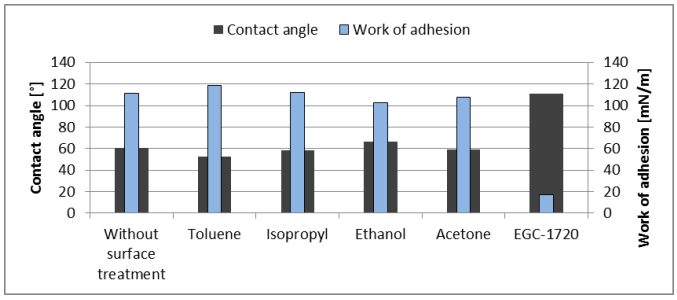

Fig. 1. Comparison of the contact angle and work of adhesion after surface treatment of the PI substrate Kapton® HN.

In the Fig. 1 is shown that the non-treated polyimide substrate DuPont™ Kapton® HN has a contact angle about 60°, toluene decreases the contact angle, ethanol increases the contact angle, moreover the chemical agent EGC-1720 causes the rapid contact angle increasing to the 110°. The optimal contact angle for inkjet printing depends on the particular technological requirements but the experimental results show it is about 80° [5].

B. The Impact of Surface Properties of Polymeric Substrates on the Nano-Inks Behavior

The aim of this paper is analysis of the nano-ink behavior onto the polymeric substrates' surfaces immediately after the deposition process. For this reason, three types of commonly used polymeric substrates for inkjet printing technology, PET, PEN and PI were analyzed. The impact of the surfaces' temperature on the ink spreading was also analyzed by using the microscopic methods. The roughness of the surfaces has a significant impact on to the properties of deposited silver layer, such as the adhesion mechanism, ink spreading, the shape of the deposited structure and also the thickness of layer. The highest temperature of substrate causes the fast evaporation process of the ink onto the substrates surface as well as causes the viscosity increasing of the nano-ink. For this purpose, 5 various silver based nano-inks were deposited by inkjet printer Jetlab 4xl-A with orifice diameter 70 µm. The main benefit of this paper lays in the optimizing of the spreading effect of several silver based nano-inks through the surface temperature changes and investigation of the deposited structures' shapes after the curing [6].

C. Software Tool for Scripting and Image Processing Applied In Jetlab InkJet Printers

The aim of the next solved challenge is the development of the additional scripting software for Jetlab® 4xl-A inkjet printer used at the Dept. of Technologies in Electronics. The developed software significantly contributes to the simplification of the technological process and thereby eliminates the main disadvantages of the control software provided with the device. The developed software in Matlab allows changing the main properties of designed structures such as the resolution of image, resize the image, set the offset and deposition parameters. Before the development of the scripting software, all parameters of the image or deposition process had to be written manually in the script form which caused the mistakes in the deposition process [7].

IV. Future Work

In the future work we will focus on the optimization process of inkjet printing technology, surface treatment of several kinds of polymeric substrates by chemical agents and on their analysis. After optimization of substrates' surfaces, the obtained results will be implemented into the inkjet printing technology with respect to PhD thesis.

Awards

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Analysis of electro physical processes in high-voltage insulation materials

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***Abstract*— The main goal of power engineering is production of electric energy and to supply electricity to all customers. Therefore, great emphasis is placed on a reliable electricity supply while ensuring the lowest possible costs of its transmission. It is therefore necessary to look for new materials in order to ensure reliable operation of the power engineering equipment and simultaneously reduce electric losses. Since the magnetic fluids could replace transformer used oilsin the future, it is necessary to examine electro physical processes of arising in of these substances on effect electromagnetic field.**

***Keywords*— electro physical processes, magnetic fluids, new materials, electromagnetic field.**

I. Introduction

Since the power engineering equipment requires a suitable insulation for its operation and proper utility, a searching forany new insulation materials, which would replace the used insulation systems in order to improve the operational capability and reduction of electrical losses in electric devices, has started. Magnetic nanofluids appear to be such materials, by which the main idea was use these nanofluids in the insulation system of a transformer, which would provide a cooling function and improve the offtake of a waste heat, which would reduce the losses. The materials used in power engineering as well as the magnetic fluids succumb to effect of aging resulting in degradation of their insulation qualities. Reduction in electric strength due to effects of aging may cause a breakdown of the electric device insulation. In consideration of the fact, that a reliable supply of energy is one of the main aims in the power engineering, several diagnostic methods for detecting the state of insulation materials were developed to consequently predict the life expectancy of electrical devices by these tools. When diagnosing these composite materials is important to realize that behave differently than other commonly used insulation materials. In these compounds arise electro physical phenomena that It influences measurement results. It is therefore necessary to find out how much these electro physical phenomena It influences individually measuring methods so that we can determine the degradation of the magnetic fluid. The magnetic fluids are composite materials consisting of several elements, which production is very expensive, therefore it is necessary to determine, whether it is possible to determine the state of these fluids by the conventional diagnostic methods, or the development ofany new specific methods and apparatus for their diagnosis is needed.

II. Magnetic fluids

Magnetic fluids are stable colloidal suspensions of single-domain magnetic nanoparticles having a size of tenths nanometres. Magnetic nanoparticles are uniformly dispersed throughout the volume ofa liquid medium. They consist of three basic components, namely: magnetic particles- which determine the magnetic properties of the fluid, of a carrier liquid -which provides liquid properties of the substance and a surface-active substance- surfactant, which serves to stabilize the magnetic fluid. The properties of individual fluids are mostly influenced by a volumetric representation of the magnetic particles and their size. Other features determine the used supporting liquid and the manner of stabilization[1]-[6]. First of all,the sufficient electrical strength and appropriate viscosity of the magnetic fluids are essential for the power engineering. It is possible to achieve the desired properties by the appropriate percentage of the individual components. The resulting liquid would not have sufficiently high electrical strength and desired viscosityby using too high percentage of magnetic particles (4% or more). Therefore, it is necessary to find a proper balance of these particles in order to achieve desired dielectric and viscous qualitiesof a final liquid. The liquids with volumetric representations from 0.5% to 2% are used in the electrical devices [1][2][3][7][9].

III. Electro physical processes in magnetic fluids

A. *Thermomagnetic convection*

For usage in electric engineering is interesting usage of these fluids like replacement conventional inhibited transformer oil.

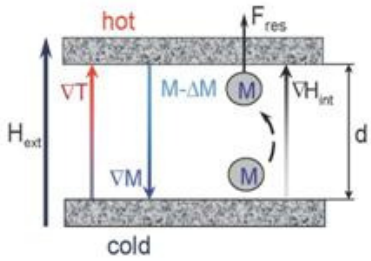

Fig. 1. Thermomagnetic convection [6]

The main advantage should be improved heat conduction, what is caused by effect of thermomagnetic convection and with content of iron oxides. Thermomagnetic convection is

based on fact, that magnetization of magnetic fluid rises with decreasing of temperature. Consequently, if the gradient of magnetic field is applied antiparallel to gradient of temperature, the flow of colder fluid is created to places with higher temperature. And there will be the fluid heated and this causes a more effective cooling [12][14][17][20].

Condition for this phenomenon is presence of temperature gradient and magnetic field. For use in power transformer are conditions for thermomagnetic convection satisfied. The source of temperature gradient is heat produced by AC current in windings. Thus heat generated by winding and core of transformer creates in area inhomogeneous magnetic field temperature gradient. The velocity of transmission of heat from inside of power transformer to walls of the vessel and dissipation of heat to surrounding environment determines highest currents in the windings therefore in part determines a size and weight of power transformer for a given power.. Accordingly more efficient cooling could bring smaller dimensions of power transformers and less amount of cooling fluid. Equally important is decreasing of windings temperature, which can be up to 10% [5][16][18][19].

B. Magnetophoresis and Dielectrophoresis

One of specific cases of creation of foreign substances in insulation system of power transformer is releasing of free copper ions. These ions are created by process of copper dissolution. Dissolution is caused by presence of trace acids in volume of transformer oil. These acids are products of degradation. Other factors which are causing this dissolving are nitrogen compounds, moisture, oxygen, corrosive sulfur etc. From view of creating bridges, these ions are not affecting these processes due to conditions for dielectrophoresis and magnetophoresis. In contrast with bridging, copper ions can create local clusters, due to presence of charge of ions. As result of these facts, resistance and therefore also conductivity can be negatively affected in places of occurrence of copper ions in volume of transformer oil. It should be noted, that degradation by process of copper dissolution is different from bridging. But in both cases there are structural changes in insulation system, which are similar and which leads to degradation of insulating properties [8][9][11][12][20].

Magnetophoresis

One type of mechanism of creating bridges is bridging due to presence of magnetic field. General principles of magnetophoresis can be briefly explained by few equations. Potential energy of a particle can be written as:

$$U = -\frac{(\chi_p - \chi_n)}{2\mu_0} V B^2 \tag{1}$$

Where:
V- Volume of particle, χ_p- Magnetic susceptibility of particle χ_m- Magnetic susceptibility of medium, μ_0– Magnetic permeability of vacuum, B – Magnetic flux density

Equation for magnetic force, which is acting on particle, can be written as:

$$F = -gradU = \frac{(\chi_p - \chi_n)}{2\mu_0} V (B \cdot \nabla) \cdot B \tag{2}$$

Due to (2) an inhomogeneous magnetic field can create a force, which can act on particle in liquid. The drag force which acts on particle during a movement can be described as:

$$F_D = -6\pi\eta r v \tag{3}$$

Influence of environment viscosity is given in (3) by η. Thus force acting is directly proportional to viscosity of environment and to radius of particle.

$$F = \frac{2}{9}\frac{(\chi_p - \chi_n)}{\eta\mu_0} r^2 (B \cdot \nabla) \cdot B \tag{4}$$

This equation shows that velocity of particle is directly proportional to difference between magnetic susceptibility of medium and particle. Magnetophoresis can be in general divided into two types. Positive magnetophoresis appears in case, when permeability of environment (fluid) is lower than permeability of particles. In this case are particles attracted to local maxima of inhomogeneous magnetic field and repelled from minima. For negative magnetophoresis is necessary, that permeability of environment is higher than permeability of particles. Particles structuralisation in magnetic fluids, with particle size is approx. 10 nm can be also described by process of magnetophoresis. As mentioned above, in case of ferromagnetic particles ($Fe_3 0_4$) which are suspended in nonmagnetic medium (inhibited transformer oil), it is a positive magnetophoresis. Except bridging due to positive magnetophoresis, there is also possibility of creating bridges because of orientation of nanoparticles into direction of stationary magnetic field. This phenomenon is mainly possible in magnetic fluids, where are nanoparticles dispersed in homogeneous way. For bridging, hence for creation of long chains is necessary sufficient long time of magnetic fieldpresence. Experimentally was found, that for origin of long chain with length of 100 µm and more is necessary time approx. 100 s [10][11][14][15][16][18][20].

Dielectrophoresis

Whereas magnetophoresis occurs under influence of magnetic field, for dielectrophoresis is necessary presence of electric field. This phenomenon can be short described as force acting on particle during exposition of inhomogeneous electric field. For presence of dielectrophoresis is required presence of inhomogeneous electric field. This field creates a gradient which causes migration of dipole particles. It should be noted, that particles must be dipoles, but they needn't have charge. Degree of dielectrophoresis and thus velocity of particles migration is dependent on particle size and shape, properties of environment and on properties of acting field [3][8][19].

One of the cases of dielectrophoresis is contamination of transformer oil with cellulose fibers. These fibers can be considered like dipoles without charge. Equation for force acting on fibers can be written as :

$$F = \frac{\pi\varepsilon_n\varepsilon_0}{12} D^2 L \left[\frac{\alpha}{\alpha - 1} - f(\beta)\right]^{-1} \nabla E^2 \tag{5}$$

In this equation (5) is relative permittivity of environment represented by ε_m. Equation for this model assumes that particles are prolate spheroids with diameter D and length L. Ratio between relative permittivity of fibers and environment is represented by α. Aspect ratio between diameter and length is represented by β [4][8].

For conductive fiber we can write equation for fiber velocity :

$$F = \lim_{\beta \to \infty} \frac{\varepsilon_n \varepsilon_0}{24\eta} L^2 \frac{\ln(2\beta) - 0{,}5}{\ln(2\beta) - 1} \nabla E^2 \tag{6}$$

The influence of fiber aspect ratio is provided only for β>5. Equally, β must be for this approximation>2. Velocity is directly proportional to square of the length [16][17][20].

Bridging of cellulose fibers under applied DC voltage

For confirmation of theory, are in this chapter showed two examples of influence of DC voltage and time, which are acting on particles. For the purpose of the demonstration is not necessary to give all details about carrier fluid and cellulose fibers. As is shown in equation (5), force which is acting on particle under influence of inhomogeneous electric field is directly proportional to square of intensity of this field.

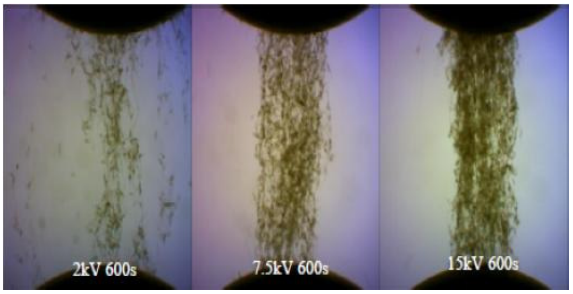

Fig. 2. Dielectrophoretic bridging of cellulose fibers under applied DC voltage[9].

Measurement was realized for three voltage levels from 2 kV to 15 kV, and application time was in every case 600 s. Also the concentration of cellulose fibers was same in all samples. The results are shown at figure 2.

Applied voltage significantly affects amount of cellulose fibers between electrodes. It has to be mentioned, that after 600 s is difference between amount of fibers well recognizable, but after sufficient long time, between every electrodes will be the same amount of fibers. So the voltage level changes only dynamic of this process [3][9].

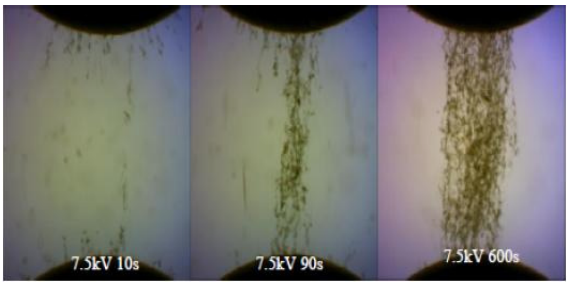

Fig. 3. Dielectrophoretic bridging of cellulose fibers under applied DC voltage after different time[9].

Dynamics of this process is shown on fig. 3, where is DC voltage set to 7,5 kV and pictures were taken three times, after 10 s, 90 s and 600 s. At first figure after acting of voltage for 10 seconds are visible only small clumps of fibers around electrodes and few clusters of fibers in direction of electric field, between electrodes. After 90 seconds clusters began to emerge. But after 600 seconds, is whole area between electrodes filled up with clusters from fibers [1][3][9].

C. Magnetodielectric anisotropy

Magnetic particles contained in the magnetic fluid without of external magnetic field they are a chaotic distribution of carrier liquid. Under the influence of an external magnetic field act on the magnetic fluid, they begin to sort the nanoparticles in the direction of magnetic field gradient. With this arrangement, particles the aggregate in creating microscopic chains that is formed into its final length after a certain time (about 80-100s). In forming clusters, and migration of the particles were reduced electric strength of the magnetic fluid, resulting in a sharp increase in the current value and the subsequent decline in the value of the conduction current. In the process of forming stages, initially creating microscopic chains whose size is smaller than the wavelength of light, and after a certain time is formed macroscopic chains whose length is greater than the wavelength of light. The macroscopically chains are arranged in the direction of the magnetic field and, consequently, that the bridges have a substantially higher magnetic energy as individual magnetic particles, and the repel each other and form a stable ordered structure. This stable arrangement constitutes an obstacle to the free charge carriers that move between the electrodes in a straight line. Track free charge carriers are extended, thereby improving the dielectric strength of the magnetic fluid. The orientation of the magnetic field perpendicular to the electric $B \perp E$, apply procession in which the magnetic particles are caused by magnetic field, move in a spiral (Fig. 4), which extend the runway of free charge carriers, and this process improves the electric strength of the magnetic fluid [3][7][9][11][14][17].

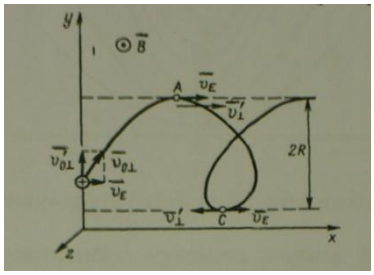

Fig. 4. The movement of particles in a spiral (B ∥ E) [17].

Size dielectric anisotropy, it depends on the external magnetic field, a representation of the volume of the magnetic particles.

IV. Experiment in the next period

One of the non-destructive methods of diagnostics of high voltage insulation system in general is dielectric spectroscopy. This method is based on measurement of current in time and frequency domain. Stability of microstructure and composition of the insulating material is changing due to degradation processes. As a result of these changes is changing behaviour of insulation material from view of polarization processes. Based on this fact, is possible to characterize degree of degradation of specimen. Our sample can be mentioned as a capacitor with pair of electrodes and dielectrics between them. Thus after connecting voltage to our specimen current starts flow thru dielectric. In case of ideal dielectric the current hasn't re a component. But in practice is real component of current caused by processes of polarization

and conductivity. These processes are dependent on kind of dielectric in which they are occurs. Based on existence independent Debye's polarization processes and Maxwell – Wagner equivalent model is possible to formulate total polarization current as:

$$i_c = \frac{U}{R_i} + \sum_{i=1}^{n} I_{m_i} e^{\frac{-t}{\tau_i}} \tag{7}$$

This equation can be used if for measurement is used electric field with intensity approx. 10^5 Vm^{-1}. The macroscopic view is descripted by current i_c which represents mutually independent polarization processes in magnetic fluid. U is applied voltage on the specimen, R_i is DC insulation resistance after infinite long time, I_{mi} is amplitude of i – th component of Debye's elementary current, τi is relaxation time constant of i – th component. Usage of dielectric spectroscopy for examination of structuralisation processes and processes of creating clusters of Fe_3O_4 nanoparticles is suitable because of measurement time provides sufficient view of ongoing polarization processes. It's possible to recognize these processes by increase of polarization current. It should be noted, that magnitude of current is changing by acting of magnetic field with different vector orientation. Also by usage of this method for diagnostic magnetic fluids it's necessary to apply external magnetic field before start of measurement. Because structuralisation of particles takes a short time (approx. 60 s) [12][15][17][19].

Measurement circuit

For measuring of test specimens is necessary to prepare test bench which allows various setup of acting external stationary magnetic field. In our case, is external magnetic field provided by pair of NdFeB magnets with magnetic induction 40 mT. Specimen was place in vessel with volume approx. 100 ml which is made from PTFE. For measurement of *i(t)* characteristics was used electrode system consisting of pair of parallel cylindrical electrodes with made from copper. By reason of comparison is indispensable use for measurement specimens with different concentration of magnetic nanoparticles. For confirmation of ongoing phenomena we use fluids with different concentration based on same carrier fluid. Therefore for measurement we use two specimens. Both of them are made on common inhibited transformer oil as carrier fluid. Likewise as surfactant is used oleic acid. For measurement of anisotropy is helpful to use two different concentrations [13][18][19].

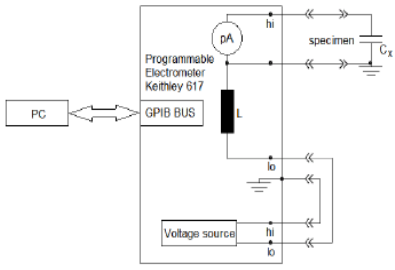

Fig. 5. Circuit configuration for measurement [18].

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Android-based application for visually impaired people

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***Abstract*—Visual impairment is a state, that removes one of the more important, if not the most important human sense. The number of people who suffer from visual impairment is not negligible. Approximately 250 million of people around the world are completely blind or suffer from partial loss of sight. This number is increasing every year, which is an alarming fact. Author of this paper, together with the Slovakian Union of Blind and Visually Impaired in Košice are trying to find a solution, with the use of available technological devices, that will ease daily life of such people. Currently, the solution uses popular touch smartphones with Android OS, for which is the application developed. The application is specially adapted for the specific target of audience. The solution uses designed graphical interfaces, with adjusted control, special gestures, state controllers, etc. Implemented parts, which make the basic set of applications are: contacts administration, messages, phone calls, quick action and settings.**

***Keywords*—accessibility, Android application, user interface, vision impairment**

I. Introduction

In the prologue it is necessary to define basic definitions, what blindness and visual impairment are.

"Total blindness is the inability to recognize light from dark, or the total inability to see". "Visual impairment or low vision is a significant reduction in vision that cannot be corrected with standard glasses or contact lenses and reduces a person's ability to function at certain or all tasks" [1].

The next important step is the knowledge of the most common diseases of an eye and their influence on sight. The most common eye diseases are:

a) Macular degeneration
b) Glaucoma
c) Cataracts
d) Color blindness

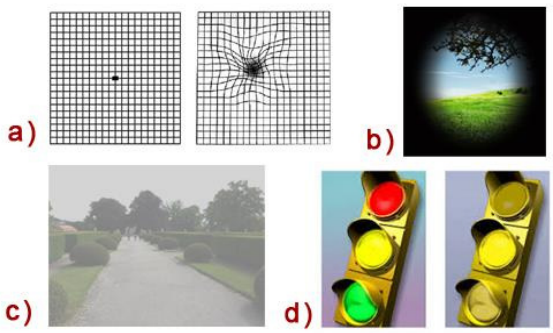

Fig. 1. Examples of vision with mentioned diseases.

A. Macular degeneration

This type of disease mostly occurs with older people. It is an impairment of macula lutea, which is the point for the clearest sight. It is located in the middle of a retina [2]. The disease brings the following sight deformations:

- Loss of sight clearness
- Loss of central sight
- Overlap, deformation or waving of scene
- Complete loss of sight

Simple detection of the illness is possible with the use of Amsler grid, which is shown on *Fig. 1. a*.

B. Glaucoma

It is an eye disease, which causes degeneration or necrosis of the optic nerve. It is caused by increased pressure inside of the eye [3]. Effect of the disease is visible on *Fig. 1. b*. People affected by this disease see similar like looking through the barrel tube of a rifle and have a less broad angle of the view.

C. Cataracts

The disease is caused by clouding of the lens in the eye [4].

Impacts of the disease on vision are:

- Blurred image
- Hazy image
- Impaired color perception

An example of this vision is similar as looking through a frosted glass (*Fig. 1. c*).

D. Color blindness

It is a defect of colored sight or color recognition at normal light [5].

There are two types:

- Partial color blindness – some colors or color combinations are incorrectly perceived.
- Complete color blindness – every color is perceived in a hue of grey.

An example of color blindness with absence of perception of red and green color is seen on *Fig. 1. d*.

II. Existing Solutions for Android Devices

One of the publication parts is an analysis of the existing solutions running on Android. I will look at the most common applications and specially modified smartphone. All the applications dispose of more functionalities. The list of analyzed applications can be seen in TABLE I.

TABLE I
THE LIST OF ANALYZED APPLICATIONS AND THEIR SPECIFICATIONS

Observed specification	**Mobile Accessibility [6]**	**GeorgiePhone [7]**	**Ray APP [8]**	**SmartVision**
Input	Touch screen, STT	Touch screen, STT	Touch screen	Touch screen, keyboard, STT
Output	TTS, vibrations, system sounds	TTS, vibrations, system sounds	TTS, vibrations, system sounds	TTS, vibrations, system sounds
Special gestures	One finger move in different directions	No	No	No
Custom call screen	Yes	No	No	Yes
Multiple languages	Yes	No	Yes	Yes
Price	75,90€	1,65€ / module	Free, language versions 16,57€	290€
Actual version	2.108	4.4	3.53	-

A. *Mobile Accessibility*

This mobile application is a fusion of a screen reader and a set of basic and extended functions. These functions are: management of contacts, phone calls, messages, emails, web browser, calendar, etc.

One of the benefits of this application is the use of Speech-To-Text (STT), which allows users to speak and intuitively enter an input. A user can therefore create a new message without searching and pressing the symbols on the touchscreen. A benefit of the application is the support of communication between the application and Brail devices. The application is equipped with multiple languages and their home web page offers many manuals, which make your learning process of being used to the application, much quicker.

B. *GeorgiePhone*

In contrast to the previous application, GeorgiePhone extends the set of users to include seniors, whereas the application includes a wide pallet of environmental settings. It is possible to use Text-To-Speech (TTS), set the way of settings, set the size of fonts by the type of user, which is using the application. Developers divided the functionalities in the individual modules. Users can buy modules, that they want and do not have to pay for those, that they do not.

The application benefits are: modularity, low module prices, easy and intuitive use and wide range of modifications.

C. *Ray App*

Developers of the application came with a new type of control. This type of control recalls a joystick of a gaming pad. Users can set functions by finger swiping from the center to the edge of the screen in a set direction.

An advantage of the app is the use of a remote assistant, which can save all useful data to the server. Another advantage is the price. The application is free in English language.

D. *SmartVision*

SmartVision is a helper for visually impaired, blind and seniors in the form of a specially modified Android device.

In comparison to the previous solutions, this approach adds an option of control with the use of hardware buttons (Fig. 2.).

The device contains many applications, that help handicapped people to bridge different obstacles. The phone holds the most modern technologies and algorithms, such as optical character recognition (OCR) for text acquirement from images or near field communication (NFC) technology, which is used to detect objects. Users have the possibility to install additional applications to the pre-installed pack from the official shop - Google Play.

The back part of the device contains a hardware button SOS, which instantly calls a pre-defined telephone number and sends the actual GPS coordinates in the case of a button press (Fig. 2.).

Fig. 2. The front and rear side of the SmartVision from KAPSYS.

III. PROBLEMS OR INSUFFICIENCIES OF EXISTING SOLUTIONS

With the analysis of existing applications and a list of requirements from the Slovakian Union of Blind and Visually Impaired we can offer a set of issues, or insufficiencies, that are present in the existing solutions. The collected issues can be divided in three categories:

- Elements, that are lacking in all applications
- Elements, that are absent in some applications
- Elements, that are not sufficiently implemented

A. *No support for Slovak language*

The basic issue, which I found by analyzing existing applications is the absence of Slovak language in all the applications. This is currently one of the requirements of the union, which I cooperate with. This issue contains the absence of Slovakian text and Slovakian speech in the applications.

B. *Quick action*

The absence of quick action means the inability to perform tasks quickly. The union also has a requirement for this functionality. Quick action is a way of the fastest and easiest execution of the tasks. For example quick dial of a phone contact or number.

If we want to issue a new phone call, in the most existing cases we have to proceed in this manner: find the phone book – find the desired contact – find the option to engage a call.

C. *Quicker or easier to use control*

This is an insufficiency, that was observed in all analyzed existing applications. In the case that the user wants to go back to the previous screen, he has to search and click a back

button, that can be difficult for a visually impaired person. In the case of listing through a huge list of contacts, to get to the next page, the user has to go through the whole list or find a button to skip to the next page.

D. *Modified interface for phone calls*

Standardly Android offers a graphical interface for incoming and outgoing calls, that is not suitable for visually impaired people. From these interfaces blind persons cannot find out who is calling them or which element to push to accept or decline a call.

This insufficiency was processed by the developers of Mobile Accessibility. However, their interface only allows people to accept a call by a simple double click and it does not support functionality of TTS to say the name or the number of the incoming caller.

E. *Control of device states*

The control of device state, for example detection of the start or end of battery charging, low battery state or display state is very important for the targeted group of users, because they have no other option to guess these states.

The only application, in which these states are implemented, is GeorgiePhone.

F. *Notifications*

The insufficiency, that I saw in all the applications is connected to the absence of informing the users about a new notification. The Android system offers a set of traditional icons that inform a user about a new message or a missed call (Fig. 3).

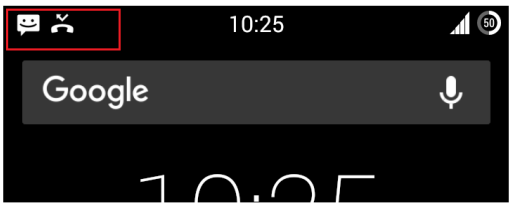

Fig. 3. Panel of notifications on the Android system.

G. *Position in the app*

This insufficiency means the absence of functionality, which would tell the users, where they currently are in the application. For example an user wants to create a new message, but in the process of creation someone disrupts him and he forgets, where he was in the application.

IV. Proposed Solutions

In this section I propose solutions for the issues mentioned above - in the section III.

A. *No support for Slovak language*

This solution is necessary to be divided into two sub-sections. The first, easier one is to add a file that contains all strings in the Slovak language. In the second sub-section I need to find or create a sufficiently tool that can transform text to Slovak language speech.

B. *Quick action*

This insufficiency can be removed by creating an interface, in which the users can create their own set of options that they frequently perform and they want to execute them as fast as possible. They assign unique identificators to the options, that will represent them. After that, users can execute a special gesture – two fingers pinch out, which will execute a touch listener. If some user has set up an action for the number of presses the corresponding action will be executed.

C. *Quicker or easier to use control*

Quicker control can be achieved by creating special gestures that the users can easily define via a fingers swipe on their touch screen. An example of these gestures is a two or more fingers swipe in different directions, two fingers touch, pinch in, pinch out, double click with two or more fingers, etc. Afterwards it is possible to connect the created gestures to a functionality e.g. two fingers swipe will return an user into the previous screen.

D. *Modified interface for phone calls*

To get rid of this problem is simple, I create an interface, which will allow the users to read name or phone number and by adding buttons with a speech feedback the users can manage to accept or decline the calls (Fig. 4.).

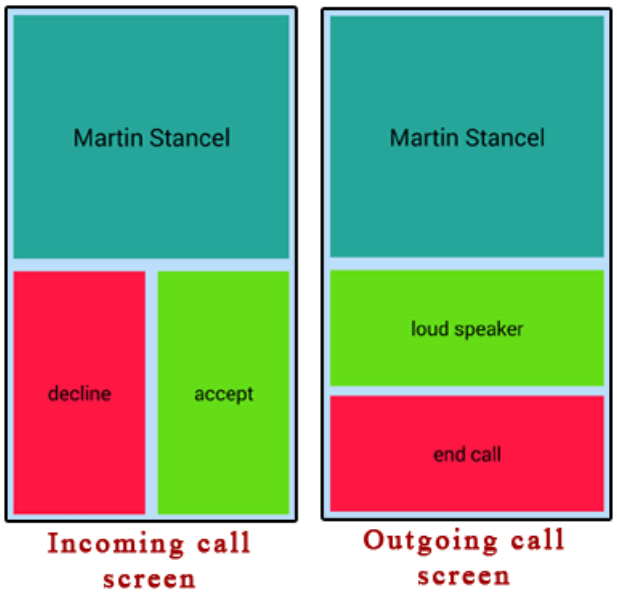

Fig. 4. Interfaces for incoming and outgoing calls.

E. *Control of device states*

The best solution is to implement detectors like it is implemented in the GeorgiePhone application (III.E).

F. *Notifications*

Notification can be created from a different process, which in certain period of time would control important notifications, such as missed calls, accepted messages or battery status (Fig. 5.). In case of one positive notification, the appropriate sound or vibration feedback would be performed.

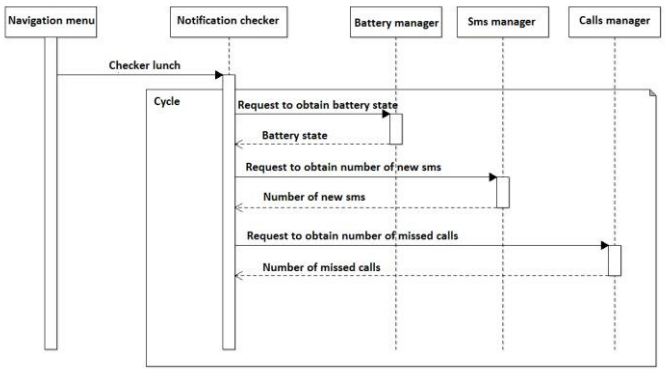

Fig. 5. Sequence diagram of alert notifications.

G. *Position in the application*

To determine, where the users currently are in the application is possible via implemented gesture - by holding two fingers, wherever on the screen.

V. Application Prototype

The aim was to design and implement an application, which would allow people with a vision impairment to control mobile devices with a touch screen and to perform basic and common functions. Since the source codes of the existing solutions are not available for public, it was necessary to create a new application, which would meet the requirements of the union and get rid of the found insufficiencies. For the implementation I chose the most popular platform – Android.

The application is controlled by selecting and confirming various elements of the graphical interface with a simple finger movements on the touch screen. When a finger is located on the element, which can be selected, the element provides a description of it via voice feedback. After that, the functionality, which the selected element has can be performed by a double tap on the touch screen.

The main menu of the application is a basic point, from where the users start after the launch of the application as well as it is an end point, when they want to go back. It contains five implemented components, such as management of contacts, phone calls, messages, quick action and settings. It also contains all of the installed applications in the system. On the bottom of the screen there are navigation buttons, which allow the users to switch among the pages. For the faster navigation among the pages, it is possible to use special gestures - two fingers swiping to right or left. On the top of the screen there are buttons, which signalize current time, mobile network and battery (Fig. 6.).

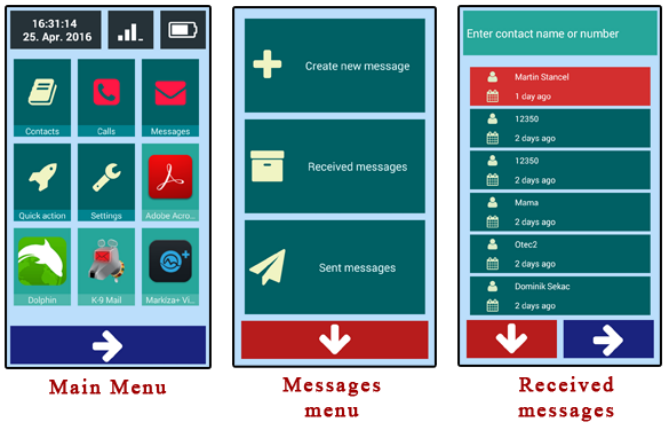

Fig. 6. Example of the application interfaces.

Manager of contacts allows the users to add a new contact, get the list of available contacts or to perform some action with the selected contact – call, send message, show details, edit and delete.

Phone calls component gets the information about incoming, outgoing and missed calls.

Messages component takes care about the functions over the messages. These functions are create a new message, get the list of accepted and sent messages and various actions – read, answer, show detail and show message text.

Quick action can launch touch listener, register new custom touch or it can get the list of options.

Settings component allows users to switch among the languages, change a speech options, colors, etc.

The application also contains all of the described solutions in the part IV, which are special gestures, custom interfaces for calls, state controllers, notifications and determination where the users currently are in the application.

VI. Future Work

As was mentioned earlier, nowadays the application contains only basic functionalities. Modern and smart mobile devices have a big amount of various technologies already built in, such as GPS, NFC, WiFi, Bluetooth, etc., that can be used for implementation of new interesting components to our application.

Interesting improvement would be implementation of a speech to text converter or control of a mobile device only with voice commands.

Another add-on could be implementation of central server, where all the custom data from the application would be saved. In the case that an user would buy a new mobile device, he wouldn't need to make all his custom commands all over again, but they would be automatically downloaded to his new mobile device.

Also possible improvement would be implementation of a custom text to speech converter right in the application, because right now, there must be a converter installed as an individual application. This feature is bonded with a support for more languages or adding new translations and voices.

VII. Conclusion

In this publication I briefly describes the most common eye diseases and their influence on a sight. In the next part I analyzed existing applications and compared them according to the given criteria.

With the knowledge I gained during the process I used it to design and implement the application. My desire was to create the application, which would be suitable for visually impaired people. I put an effort to cover as much eye diseases as possible as well as minimize or at the best remove identified problems from the existing solutions.

The result is the application, which can be used by Slovakian users too. It implements the components, which I observed at the existing solutions and it also contains new features, which allow an user to better interact between his mobile device and him.

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Annual Report of the Image Steganography and Steganalysis Research

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***Abstract*—The article represents a summarization of my last year´s scientific research. The main fields of my work are image steganography and steganalysis. The aim of a steganography is to embed a secret message into a cover data without causing degradation neither to the cover information nor to the secret message taking into account that this process must be necessarily reversible. When a cover media has form of a static image we are considering image steganography. On the other hand, there is steganalysis which is utilized to break upper mentioned system by various attacks. The goal of this work is to acquaint a reader with my contribution in both field as well as with the thesis of my next research steps.**

***Keywords*—classifier, image steganography, steganalysis, summarization.**

I. Introduction

One of the sophisticated methods of secret communication is steganography. Steganography deals with establishing the covert channels in order to communicate through them. In comparison to cryptography, such communication do not arouse suspicion. Thus in specific applications is better to choose steganography rather than cryptography. The covert channels can be established in any type of multimedia data (i.e. video, audio, image, and text). Data utilized for that use is called cover data. There are combinations of steganography and cryptography, too. It means the secret message is encrypted before the embedding process. Such systems are characterized by improved security.

The main role of steganalysis is to detect the secret message hidden by steganographic system. Steganalysis is based on the fact that embedded bits of the secret message affect some typical characteristic features of the natural multimedia data. Differences between cover data and affected data are used in the training process of steganalysis to learn/train the classifier. Classifier is a machine learning tool producing the model used to detect presence of the secret message in the testing suspicious data [1]. The article was aimed for image steganography and steganalysis. In other words, for the methods used static images as a cover data.

II. Current Status

The most popular method of steganography is LSB method (Least Significant Bit). LSB bits of the cover image pixels are substituted with bits of the secret message. Such system is relatively easily to be detected by histogram attack. More sophisticated methods preserve original histogram after the embedding process (e.g. algorithms F5, MBS, PQ, MHF). Other methods use spreading of the secret message by DSSS (Direct Sequence Spread Spectrum). Embedding process represents modulation of the cover image by such secret message. Special classification of steganography methods is from the embedding domain point of view. The basic methods operate in spatial domain, whereas more sophisticated techniques work in a transform domain. The most often domains are domains after Discrete Cosine Transformation (DCT) and Discrete Wavelet Transformation (DWT).

III. Ups and Downs

A. Image Steganography Based on Combination of YC_bC_r Color Model and DWT

The proposed last year´s steganographic method [2] was designed for an embedding of the text secret message into the color static image. Proposed tool solves lossless conversion between color space models RGB and YC_bC_r although embedding of secret message influences chrominance component C_b. This component was selected according to the perceptual invisibility, which was the highest in this case. Chrominance component C_b is not modified directly, but 2D Haar LDWT is applied to it and subsequently LSB bit plane of sub-band HH (alternatively also LH, and HL) is modified by bits of the secret message. In the Table I, the proposed method is compared with LSB and DCT steganographic methods.

TABLE I
COMPARISON OF PROPOSED STEGANOGRAPHIC METHOD WITH LSB AND DCT STEGANOGRAPHIC TOOLS

		proposed method	LSB [6]	DCT[7]
image size [pixel]	size of secret message [bit]	PSNR [dB]	PSNR [dB]	PSNR [dB]
256×256	49 004	47.31	42.34	NA
512×512	4 096	52.02	46.31	50.06

The secret message with size 49 004 bits (maximal capacity $C_{HH+HL+LH}$ in cover image 256×256) is embedded by these three tools. Our method achieves PSNR value 47.31 dB, while PSNR value of LSB tool was lower about 5 dB. Secret message with this size was not possible to insert by DCT

method. Next comparison test was performed by image with resolution 512×512 and message with size 4 096 bits. The best result was achieved by the proposed method with PSNR value 52.02 dB.

This article was published in the proceedings ELMAR-2015 and presented by me at the 57th International Symposium ELMAR-2015 in Zadar, Croatia. The paper was already posted to the IEEE Xplore database.

B. The Comparison of Classifiers in Image Steganalysis

My other articles were focused on a problem of classification in steganalysis [3]. In the first, there were tested two different classifiers, Support Vector Machines with Linear kernel function (L-SVM) and Naive Bayes Classifier (NBC).

Fig. 1 shows that the better accuracy of detection was achieved by SVM classifier for all types of tested steganographic tools. On the other hand, the advantage of a Bayes classifier consists of a smaller computational complexity and smaller time required for a training of model. For example, Bayes classifier was able to perform training of *model Cover - MB2* with the 2 000 images in less than 30 seconds. On the other hand, SVM classifier achieved training time 10 minutes in the same case. Specific test was executed using Intel Core i5 with the clock frequency 2.5 GHz.

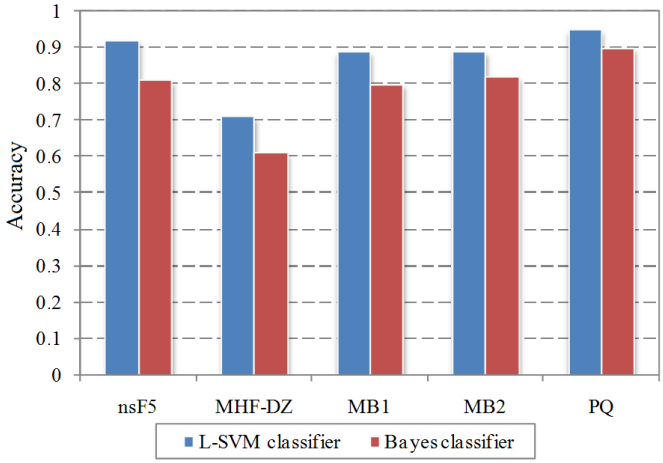

Fig. 1. Comparison of accuracy for specific steganalytic model using L-SVM or Bayes classifier.

The article was published in Acta Electrotechnika et Informatica. At least one publication in Acta is required for a PhD. student during the PhD. study at our faculty so I´ve already done it through this.

C. Kernel Types Benchmark of Support Vector Machines in Image Steganalysis

In the next article aimed on a steganalysis, detections of four different steganographic algorithms with three sizes of secret message (payload) were measured. Depending on the kernel function, SVM classifier utilized two modes – SVM with linear kernel function (L-SVM) and radial basis kernel function (R-SVM). It is possible to read more about the experiment conditions in [4].

The TABLE II shows an Accuracy (ACR), True Positive Rate (TPR) and False Positive Rate (FPR) of the detection of two kernel types of SVM classifier.

Payload 100% means maximal embedding capacity of the certain steganographic method. The table shows that better accuracy of detection was achieved by L-SVM classifier for each method.

TABLE II
ACCURACY (ACR), TRUE POSITIVE RATE (TPR) AND FALSE POSITIVE RATE (FPR) OF TRAINED MODELS FOR DIFFERENT ALGORITHMS, PAYLOADS AND KERNEL TYPES

Testing algorithm	Payload	L-SVM			R-SVM		
		TPR	FPR	ACR	TPR	FPR	ACR
nsF5	25%	0.63	0.15	0.74	0.54	0.26	0.64
	50%	0.95	0.15	0.9	0.87	0.26	0.81
	100%	1	0.15	0.93	1	0.26	0.87
MHF-DZ	25%	0.52	0.15	0.68	0.54	0.26	0.63
	50%	0.55	0.15	0.7	0.55	0.26	0.64
	100%	0.72	0.15	0.79	0.59	0.26	0.67
MB2	25%	0.85	0.22	0.82	0.69	0.19	0.75
	50%	0.93	0.22	0.86	0.73	0.19	0.77
	100%	1	0.22	0.9	0.9	0.19	0.86
PQ	25%	0.96	0	0.98	0.96	0.08	0.94
	50%	0.95	0	0.97	0.99	0.08	0.96
	100%	0.91	0	0.96	0.97	0.08	0.95

On the other hand, the difference between them was significant in terms of training time. R-SVM classifier was trained much earlier than L-SVM. For instance, 30 minutes to 30 seconds for 3 000 input patterns.

IV. NEXT STEPS AND CONCLUSION

The next steps in my research correspond with thesis of my minimal thesis. They were as follows:

- Proposal of new modifications of the image steganography and steganalysis.
- To test the properties of the proposed algorithms and compare their effectiveness with current methods of image steganography and steganalysis.
- Proposal of a new cover generation method.
- Modification of existing methods of steganalysis for effective detection of the originated method.

My present research is closely connected with Radioelektronika 2016, 26th International Conference, which is collaborated with my home department, where our article "Image steganography with using QR code and cryptography" was already accepted.

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Application methods based on Deep Learning in solutions based on Internet of Everything

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***Abstract*— Cisco defines the Internet of Everything (IoE) as bringing together people, process, data, and things to make networked connections more relevant and valuable than ever before. This paper deals about aggregating and mining frequent patterns and important factors in data by using state-of-the-art techniques. Deep learning is one of the fastest-growing fields in machine learning. These methods are composed of multiple processing layers to learn representations of data with multiple levels of abstraction. They have dramatically improved error rate in speech recognition, visual object recognition, object detection and many other domains. Combination of these trends offers many new possibilities. We are presenting some of our results that can be used in one of IoE healthcare scenarios.**

***Keywords*— Big Data, Deep Learning, Internet of Everything**

I. Introduction

All prediction says that volumes of collected data will be increasing in next years. It is necessary to investigate the usability of suitable approaches from the field of Big Data, i.e. large data storage with sufficient scalability and access speed, high performance computing infrastructure not only on hardware but on software level too, etc. Many systems are not ready to manage Big Data due to the lack of smart analytics tools. It is important to use the best methods for data mining.

II. Research topic

Every year, in the Gartner's Hype Cycles are defined more than 2,000 technologies that are grouped into 112 areas. Those technologies can reveal the basic laws of the evolution of technological innovation chain [1]. As technology advances, we all get over-excited about new buzzwords, trends in technology and then disappointed when expectations of results go down. Some of these emerging technologies do make tremendous changes and a huge shift. The hype cycle gives us an idea of which of these technologies actually survive the market hype and have a potential to become a part of our daily life. Last year in the Gartner's Hype Cycle for Emerging Technologies Big Data drop out and was divided into several Big Data related technologies such as Machine Learning, Autonomous vehicles, Internet of Things and others [2].

A. From Internet of Things to Internet of Everything

Internet of Things (IoT) vision has evolved due to a convergence of multiple technologies to Internet of Everything, which is the networked connection of people, process, data, and things [3]. Internet of Everything has become a catch-all phrase to describe adding connectivity and intelligence to just about every device in order to give them special functions. Those special functions are related with data analytics and machine learning.

B. Modern methods of machine learning

Artificial neural networks have recently evolved into Deep Learning networks, whose advances have been enabled by access to fast computers and vast amounts of data for training. Deep Learning (DL) is the fastest-growing field in machine learning. It allows computational models that are composed of multiple processing layers to learn representations of data with multiple levels of abstraction [4]. There are huge number of variants of deep architectures. Most of them are branched from some original parent architectures. DL is a fast-growing field, and new architectures, variants, or algorithms appear every few weeks. Some of the most used architectures are [4]:

- Deep neural networks (DNN)
- Deep belief networks (DBN)
- Convolutional neural networks (CNN)
- Deep Boltzmann machines (DBM)

There are many areas that have already been transformed by the successful use of DL technology, such as speech recognition and computer vision [4]. Nowadays almost everyone from leading IT companies have research centre focused on DL. For example, one from applications using DL is DeepFace by Facebook presented in the paper [5]. Currently application areas that have the potential to be impacted significantly by DL and that have gained concentrated research efforts, including natural language and text processing, information retrieval, and multimodal information processing empowered by multi-task DL.

III. Deep learning in Internet of Everything

With IoE solutions are often mentioned smart devices which are connected to the Internet and using clouds where data can be analyzed with analytics services and so on [3]. One of big changes coming with IoE solutions is change to remote control where we can build models based on historical data. Control process is changing from feedback to feedforward control. We think that not only for these purposes can be used powerful machine learning algorithms such as DL.

During last year, we focused on application of DL methods in IoE and data analytics. We have been working with various DL frameworks such as H2O, Theano, Deeplearning4J, which we have been using in Java, R and Python.

A. Classification with deep neural network

Classification is one of the most common assignments in data analytics. We used DL for fake follower detection on Twitter during internship in company Socialbakers. This task was representing binary classification. Number of followers can express influence on social networks so it is interesting to find out how many of these followers are real or fake. We have built DL model based on DNN architecture in H2O framework [6]. For validation purposes, we created profile and we paid for fake followers. Some of these fake followers were hacked profiles that showed all signs of good profiles. This made our classification more complicated. We collected about 5000 profiles and labeled them as good or fake. Those data was used for training of our DL model. Then we downloaded list of all followers from our profile and then we classified them by our DL model. For comparison we scanned this profile with two specialized web sites. Results from this binary classification are summarized in the next table.

TABLE I
Classification of Twitter Fake Followers with Deep Learning

Method	Follower	
	Good	Fake
H2O - Deep Learning	42 %	58 %
twitteraudit.com	93 %	7 %
fakers.statuspeople.com	93 %	7 %

We realized strength of DL and we compared it with other methods, which are available as services on Microsoft Azure Machine Learning [7]. These results were published on conference K&I 2016. We trained our models on letter recognition data from the UCI repository [8]. Final values were computed as mean from precisions and recalls that we got for every class. These results are in the next table.

TABLE II
Comparison between Multi-Class Classifiers and Deep Learning

Method	Precision	Recall
H2O - Deep Learning	0,965352	0,964948
Azure - Neural Network	0,927802	0,923980
Azure - Decision Forest	0,926524	0,925641
Azure - Decision Jungle	0,811269	0,801819
Azure - Logistic Regression	0,739890	0,740231
Azure - SVM	0,669623	0,661849

B. Deep auto encoder in IoE protocols

Other possible applications of DL in IoE scenarios could be in data transfer. A deep auto encoder (DAE) can compress data, encode them, then these features will be send via internet to cloud and there they will be decoded. We have used methods from Deeplearning4J for DAE. It was composed of two, symmetrical DBN that had four shallow layers representing the encoding half of the net, and second set of four that make up the decoding half. In our first experiments, decoded output was very similar to original input. Proposal of usage DAE during data transfer in IoE is on the next figure.

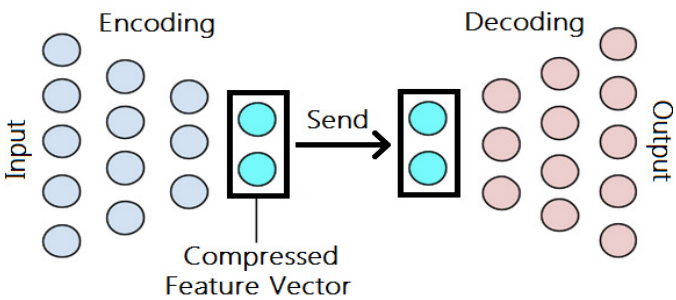

Fig. 1. Proposal of deep auto encoders in data transfer in IoE devices

IV. Future Work

In my future work, I want to focus on other machine learning algorithms and use them for data mining [9]. We want to develop services on cloud that will be available for IoE devices. We had meetings with companies like FPT that is planning focus on IoT technologies, Betamont specializing on road data and so on, where I can contribute with data analyses. I am also planning focus on healthcare field. We made proposal and won FPT Summer School with idea of smart insulin pump that can monitor and predict levels of blood sugar. In the papers [10] [11] authors deals about similar problem. We have already discussed this idea with company BayZoltan from Hungary.

Acknowledgment

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Arnold's Cat Map and Its Usage in Steganography

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***Abstract*—In this paper we are investigating the technique known as Arnold's cat map, its various modifications and several published usages in the field of steganography. Arnold's cat map has also some interesting mathematical properties, which result from the fact that it is one of chaotic maps. By using one of these properties, the periodicity, we can map the coordinates of image pixels in many ways. After reaching certain number of iterations, which is the same as the period of the map, the modified image, known as scrambled, or encrypted image becomes the original one. This process can be used for purposes of image steganography, which tries to transmit secure information in form of the scrambled image embedded in other cover image.**

***Keywords*—Arnold's cat map, chaotic map, image encryption, periodicity, steganography.**

I. Introduction

One of many contributions of Vladimir Igorevich Arnold to current state of mathematics was made during his after graduate study at Moscow State University in the 1960s. Even though the Arnold's cat map (hereinafter ACM) is not the most known of Arnold's works, it has found several applications to date [1]–[5]. The map itself is used for mapping the set of two dimensional coordinates into set with different valued coordinates. After certain amount of these iterations, the coordinates become the same as they were before the first iteration. Such a system is called dynamical (due to existence of its changes) and it is further studied in the chaos theory [6], [7], which was one of Arnold's interests.

The name of ACM comes from the first two dimensional signal, which was used by Arnold for his experiments. It was the picture of a cat [8]. At that time, the purpose of ACM was not as clear as it is nowadays. However, with the development of digital media, such as images it was also desirable to hide the content of these pictures.

This is still possible by using quite simple steganographic technique as LSB. In this case the bits with smallest importance in so-called cover data are changed with bits from embedded data. However in the case of LSB steganography, the steganalysis is also simple enough, and if the data are considered as suspicious, the embedded data could be easily extracted. Because of these concerns, the idea of scrambling the secret image prior to its embedding by the discrete version of the ACM was proposed in several papers [4], [5], [9]–[11].

II. The Principles Behind Arnold's cat map

The discrete version of ACM can be used for permutation of pixels inside a digital image with resolution of N x N pixels. Each of these pixels has its own coordinates and one (grayscale image), or more values of so-called intensity function (in the case of color images). The pixels of color images have usually three color components, for example red, green and blue component (thus RGB color model), or luminance component Y' and chrominance components Cb and Cr (together forming color model Y'CbCr).

The mentioned coordinates of the image pixels are changed at each iteration of ACM. If we denote the present values of coordinates on axis x and y as x and y, and coordinates after next iteration of ACM as x' and y', we can illustrate the process of coordinate calculation as (1):

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} (\mathrm{mod}\ N), \qquad (1)$$

where $x, y, x', y' \in \{0, 1, 2, \ldots, N\text{-}2, N\text{-}1\}$, N is the height, and also the width of square image (with resolution of N x N pixels).

The geometrical approach to (1) can be done in a manner that is shown at Fig. 1. At first the square image with resolution N x N is chosen. The operation of shearing is then performed, in directions of x and y axis respectively. The shearing ratio depends on used matrix for ACM, for (1), it is N for direction on x axis and $2N$ for direction on y axis. Then the sheared image is divided to 4 regions – four triangles. Finally, the image with same dimensions as the original had is constructed from the set of four triangles.

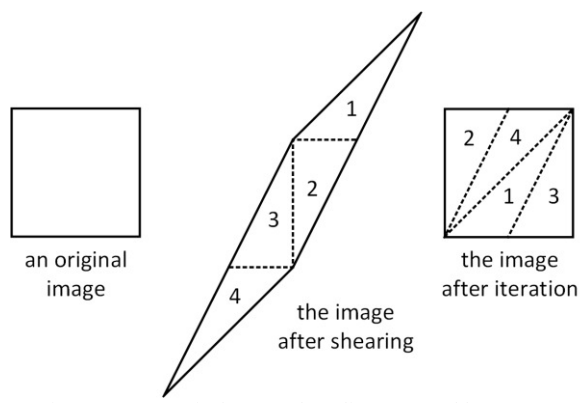

Fig. 1. A geometrical approach to discrete Arnold's cat map.

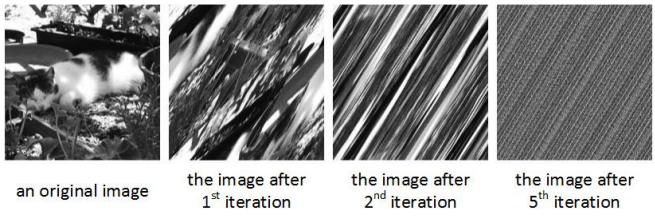

Fig. 2. Example of some iterations of discrete Arnold's cat map.

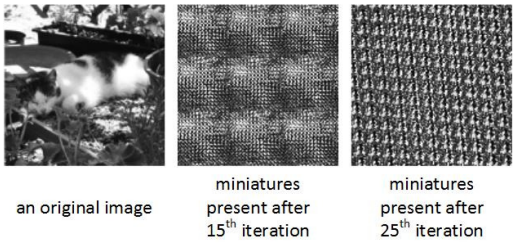

Fig. 3. The presence of miniatures in the case of some iterations.

Fig. 4. Rotated original image as the result of certain iteration.

An example of several iterations of ACM is shown on Fig. 2. From this figure one could think that with larger amount of iterations the resemblance between original image and image after the mapping is getting smaller. However, this is not true for all cases, because the ACM has a property of so-called *periodicity*. This feature causes the mapping into the original image after certain amount of iterations. The number of iterations, which are needed for getting the original image is known as the *period*. The problematics of period of ACM is further described in paragraph A.

Other problems, which could happen in the case of using ACM are known as the miniatures, and the rotation of the original image [3]. The miniatures are multiple smaller versions of the original image which could be present in the image after certain iteration. Existence of miniatures depends on the resolution of the original image. An example of miniatures is illustrated on Fig. 3, the resolution of used image is in this case 132x132 pixels.

The presence of rotated original image after some of the iterations also depends on the value of original image resolution. Fig. 4 shows a rotated version of the original image after 10 iterations of ACM. This image had resolution of 123x123 pixels. Please note that pixels in first row and first column of the original image are not mapped in the same fashion as the rest of the image.

A. *Period of discrete Arnold's cat map*

Length of the period p depends on value of number N which is the resolution of the square image (the resolution is N x N). The period of ACM can be calculated by several ways. Ref. [12] provides a set of rules which use properties of N for computing the period. However, in the case that N is a composite number, these rules need to compute its factors. Other approach is presented in [13], where the relation between period of ACM, Fibonacci sequence, and the so-called Pisano period is described. If the ACM would not use the modulo operation, the coordinates of pixels used for mapping would create a sequence of rising numbers. With first coordinates $x = 0$, $y = 1$, the first few elements of this sequence would be {0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, …}. This sequence is exactly the same as the Fibonacci sequence, with its elements F_m given by (2):

$$\begin{aligned} F_m &= F_{m-1} + F_{m-2} & & m \geq 2 \\ F_m &= 1 & \text{if} \quad & m = 1, \\ F_m &= 0 & & m = 0 \end{aligned} \tag{2}$$

where m is sequence number of each element, m ε {0, 1, 2, …}.

If we would use the modulo operation (with certain value of N) on the Fibonacci sequence, the resulting sequence will consist of one repeating sequence. For example, if we would use $N = 4$, we will get the sequence {0, 1, 1, 2, 3, 1, 0, 1, 1, 2, 3, 1, 0, …}, which is clearly periodic with its period of 6 elements. This period of Fibonacci sequence after modulo N operation is known as the Pisano period [3]. However, the period of ACM is not the same as Pisano period. Because ACM uses two coordinates for x and y axis, the period of ACM is one half of the Pisano period. This rule is not true in one case, if $N = 2$, when Pisano period $\pi(2) = 3$ and period p of ACM is also equal to 3. Since the maximal Pisano period for arbitrary integer n is $\pi_{max}(n) = 6n$, the maximal period of ACM for an image with resolution N x N pixels is $p_{max} = 3N$ [3], [14].

Another way for determining the period of ACM with certain value of N is the construction of its *orbit*. The orbit is a set of mappings of a certain image pixel after each iteration of the ACM. Example of an orbit for pixel with coordinates $x = 0$, $y = 1$ in an image with resolution of 4x4 pixels is given in Fig. 5. We can see that the value of pixel with mentioned coordinates moves to pixel with coordinates $x = 1$, $y = 2$ after first iteration, and it moves to the original place after three iterations. If we would use other starting coordinates, we could get different period of ACM. In these cases, the length of the longest orbit is taken as the period of ACM.

The periods of ACM for certain set of image resolutions are shown in Table I.

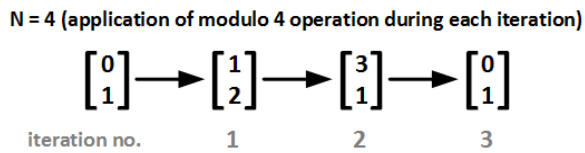

Fig. 5. Example of an orbit of a certain image pixel.

TABLE I
EXAMPLE OF PERIODS OF ACM FOR CERTAIN IMAGE RESOLUTIONS

resolution of the image	period of ACM for given N	resolution of the image	period of ACM for given N
120x120 pixels	60	129x129 pixels	44
121x121 pixels	55	130x130 pixels	210
122x122 pixels	30	131x131 pixels	65
123x123 pixels	20	132x132 pixels	60
124x124 pixels	15	133x133 pixels	72
125x125 pixels	250	134x134 pixels	204
126x126 pixels	24	135x135 pixels	180
127x127 pixels	128	136x136 pixels	18
128x128 pixels	96	137x137 pixels	138

III. Modifications of Arnold's cat map

Various possible uses of ACM motivated the creation of multiple modified versions of ACM. For better overview of these techniques, each will be introduced in its own paragraph.

A. Other definition of Arnold's cat map

In some of earlier papers, the matrix for ACM was not defined as (1), but instead as (3) [4], [15], [16]:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} (\text{mod } N), \tag{3}$$

where x, y, x', y' ε {0, 1, 2, …, N-2, N-1}, N is the height and also the width of square image.

This difference changes the appearance of the image after iterations, however it has the same period of ACM as defined by (1). Also the values from orbit of pixel with coordinates $x = 0$, $y = 1$ are different to those yielded with usage of (1), but if we would switch the pair of coordinates, the resulting coordinates are equal to switched coordinates from Fig. 5.

B. Pell's cat map

Ref. [3] mentions even another change in matrix used for performing the ACM. In case of the Pell's cat map, the matrix is given by (4):

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 2 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} (\text{mod } N), \tag{4}$$

where x, y, x', y' ε {0, 1, 2, …, N-2, N-1}, N is the height and also the width of square image.

This modification of ACM is called as Pell's because it uses coordinates calculated from elements of Pell and Pell-Lucas sequences at each iteration. The x axis coordinate is taken from the Pell sequence and the operation of modulo N is carried out afterwards. Equation used for calculation of elements of Pell sequence P_m is denoted as (5):

$$\begin{aligned} P_m &= 2P_{m-1} + P_{m-2} & & m \geq 2 \\ P_m &= 1 & \text{if} \quad & m = 1, \\ P_m &= 0 & & m = 0 \end{aligned} \tag{5}$$

where m is sequence number of each element, m ε {0, 1, 2, …}.

The second coordinate, for y axis uses an element of Pell-Lucas sequence Q_m which can be computed using (6):

$$\begin{aligned} Q_m &= 2Q_{m-1} + Q_{m-2} & & m \geq 2 \\ Q_m &= 2 & \text{if} \quad & m = 1, \\ Q_m &= 2 & & m = 0 \end{aligned} \tag{6}$$

where m is sequence number of each element, m ε {0, 1, 2, …}.

After the element of Pell-Lucas sequence Q_m is chosen, it is divided by 2 and the modulo N operation takes place.

One of the main differences between ACM given by (1) and Pell's cat map is the length of period. This is caused by other sequence of numbers, which are used as coordinates after each of the iterations. For example, images used in this paper as the original images in Fig. 2, Fig. 3 and Fig. 4 have resolutions of 391x391, 132x132 and 123x123 pixels. Their periods of ACM are 72, 60 and 20 iterations, while their Pell's cat map periods would be 176, 24 and 40 iterations.

C. Generalized versions of Arnold's cat map

Some published works present the possibility of enlarging the number of outcomes after employing ACM by introducing certain number of parameters [3], [17]. In the first case, one parameter denoted as a is used and second version uses two parameters – a and b. The matrices used for calculation of these generalized versions of ACM are (7) and (8) respectively:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & a \\ a & a^2+1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} (\text{mod } N), \tag{7}$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & a \\ b & ab+1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} (\text{mod } N), \tag{8}$$

where x, y, x', y' ε {0, 1, 2, …, N-2, N-1}, a, b ε {1, 2, …, N-2, N-1}, N is the height and also the width of square image.

Matrices with these elements could be still used for the purposes of ACM, because their determinant is equal to 1, thus they have the property of *area preserving* [3], [18]. If the matrix used for ACM would have absolute value of its determinant not equal to 1, the case of mapping multiple pixels into pixel with coordinates $x = 0$, $y = 0$ could occur. Otherwise, only the pixel with starting coordinates $x = 0$, $y = 0$ could be mapped into the same position.

D. Three dimensional modifications of Arnold's cat map

Papers [17], [19] and [20] show the possibility of an extension of ACM to three dimensions. Thus the 3D ACM maps coordinates of elements in a cube. An example matrix used for this approach taken from [20] is denoted as (9):

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} 1 & 0 & a \\ bc & 1 & abc+c \\ bcd+b & d & abcd+ab+cd+1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} (\text{mod } N), \tag{9}$$

where x, y, z, x', y', z' ε {0, 1, 2, …, N-2, N-1}, a, b, c, d ε {1, 2, …, N-2, N-1}, N is the maximal value of coordinate on axes of the cube.

All of the 2D cat maps presented in this paper used a square image for the operation of mapping. In the case of 3D maps the problem of the same set of coordinates {0, 1, 2, …, N-2, N-1} for all axes is even bigger. If we would like to perform a 3D cat map on several images with resolution of N x N pixels, we would need to provide a set of N images. This property also makes scrambling of only one image, where the third coordinate would be intensity value of pixel, not possible by using this technique. Thirdly, the number of used parameters results in relatively high values of period of this modification of ACM, which could be not desirable in the processes of image scrambling, or its reconstruction.

IV. Usage in Steganography

The tool of ACM found its applications with further development of digital signal processing (DSP). First published uses were in field of so-called image encryption in 1990s [1], [2]. However the key space (number of possible keys) was found as not sufficient [19]. There were attempts to solve this problem with the usage of 3D cat maps [17], [20], but the evolution in cryptography provided newer and more efficient ciphers, and the interest in the image encryption has since fallen.

The second application of ACM was created in early 2010s when ACM was considered for usage in steganography. These steganographic systems usually use ACM for scrambling of the image, which would be later embedded to the cover data. The mapping can change an image, which contains visible information (such as text) to an image, which seems not to have any meaningful content. In some cases this scrambled image even resembles noisy image, which could be viewed as a result of lossy compression, or some image processing. These features could be exploited by steganographic systems, for example by one which uses images as cover data. One of examples of these systems is [4], which uses key for setting up the number of ACM iterations for scrambling image prior to its embedding to LSB bit plane. The combination of Canny's edge detection, ACM and LSB flipping is proposed in [5]. ACM with block processing is used in [10]. An approach, which merges the benefits of ACM and cryptographic algorithms was proposed in [11]. Field of digital watermarking has its techniques with usage of ACM described in [9].

V. Conclusion and Possibilities for Future Work

We provided a study of principles of Arnold's cat map, its properties and briefly mentioned its usage in steganography in this paper. From the survey of research papers which we have made, we can state that majority of steganographic algorithms, which apply ACM for image scrambling, use spatial domain for embedding or extraction of secret image. The embedding of image scrambled by ACM in other domains, namely transform domains as DFT, DCT, or DWT domain seems possible. This combination should theoretically result in lower capacity of the proposed steganographic system, however it should provide better value of other parameters, such as robustness of the proposed system.

Also further research in periodicity of ACM with different modulo divisors for each of the image coordinates should be pursued. If these divisors could be different and this modified version of ACM would still be periodic, it could be used for mapping three coordinates of an image, thus it should provide similar results as the transform of the image. Other task to solve is the extension of ACM to image with other dimensions than square image (N x N pixels).

The other field of scientific interest should be concentrated in study of periodicity of ACM. Smaller periods can greatly reduce the computational difficulty in the processes of image scrambling, or its reconstruction. Also steganographic algorithms employing mappings for image scrambling could benefit from smaller number of necessary iterations.

Next idea was partially proposed in [10]. In this case, the image is divided into six possibly overlapping blocks and various number of ACM iterations is performed on each of these blocks. It seems that this algorithm can be modified for using images with arbitrary size and also the number of blocks can be function of the input image dimensions. This approach would partially solve the problem of the square image dimensions, which are needed for performing the ACM.

Finally, the performance of steganographic systems which uses ACM should be evaluated by the means of steganalysis features. Also some new features, which would be especially effective against these systems should be proposed.

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Automatic traffic signs inventory system with use of optical correlator

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***Abstract*—This article describes a principle of automatic inventory process. The main processing part in the inventory system is replaced with an optical correlator. It's main function is to signalize the similarity between comparised shapes and individual shapes from reference database. Higher probability of success signalization is provided by improved multifactor image preprocessing. It is possible to specify the exact position of traffic sign using a combination of GPS coordinates and distance between the traffic sign and inventory vehicle.**

***Keywords*—Inventory process, optical correlation, recognition, traffic sign**

I. Introduction

Automatic traffic signs inventory can significantly decrease the cost of the periodic maintenance of transport communications. The combination of suitable image filters and Fourier transform is the main precondition for automatic traffic signs recognition. Electronic Fourier transform process is replaced by optical Fourier transform process in this system. It is realized using the optical correlator, which obtains the Fourier transform results using the optical principles. Since the result of optical correlation is obtained for every pixel in parallel process (in the one moment), this processing is independent from the image resolution. Thanks to this independence, the speed and accuracy of the correlation process is defined only by limit parameters of the optical correlator (Space Light Modulator resolution and CMOS sensor frame rate).

The image preprocessing for correlator input consists from multiple steps. Combination and comparison of multiple methods provides the higher accuracy of success traffic sign recognition. Position of the recognized traffic signs is described by GPS coordinates. Since the GPS receiver is installed in the inventory vehicle during the inventory process, it's needed to make a correction of GPS coordinates of the vehicle. Subsequently we can specify the exact GPS coordinates of the current traffic sign. This correction is based on adjustment of GPS values in individual axes, according to distance between traffic sign and vehicle and also according to it's position, related to position and orientation of inventory vehicle.

Controlling of the whole inventory process is provided using the graphical user interface windows. Graphical user interface allows to set the inventory parameters and to monitor the whole inventory process using the computer screen.

II. Structure of Automatic Inventory System

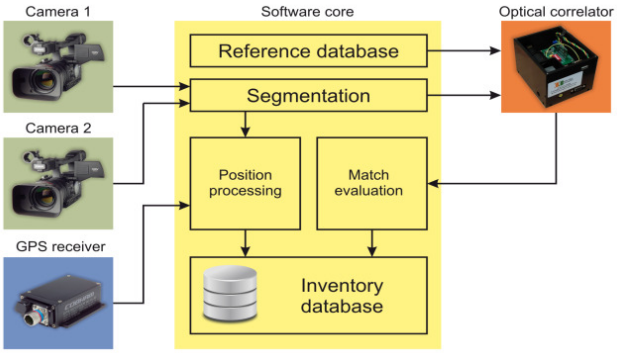

Fig. 1. Block diagram of automatic inventory system with use of optical correlator.

A. Sofware core

The main part of inventory system is the software core. The core provides a processing of data from peripherals, communication between peripherals and also provides the interface for setting the parameters and monitoring the inventory process. The additional function is a recording of stereoscopic images set with specific GPS coordinates. It serves for later processing without need to install the optical correlator in the inventory vehicle.

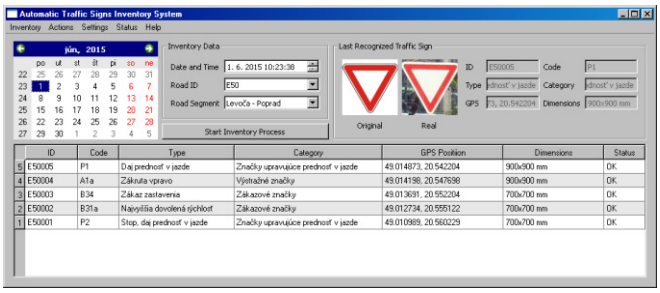

Fig. 2. The main graphical user interface window of inventory system.

B. Optical correlator

Optical correlator provides the Fourier transform in a high speed. It's input parameters are shape samples from recorded input scene and shape samples from reference database. The output consists from image with correlation peaks. The intensity of correlation peaks describes the rate of similarity.

The relative position of these peaks specifies the relative position of compared samples from the input image. Thanks to this information it is possible to provide the optical correlation with several reference samples in one step and subsequently to confirm the wanted shape according to relative position of correlation peaks.

C. *Stereoscopic camera system*

The camera pair with stereoscopic configuration is the main input point of the inventory system. Thanks to this point, the inventory system is able to obtain the image of input scene. The increasing resolution of camera sensors contributes to the higher final shapes accuracy. These shapes are obtained during the image preprocessing for optical correlator input. Stereoscopic record provides the information about the position of the current object in a space. Thanks to this information, the core of the inventory system is able to make the GPS coordinates correction and to process the exact position of traffic sign. This correction is needed since the GPS receiver position isn't the same as the traffic sign position during the recording, but it's placed in some specific distance from the recorded traffic sign, in the vehicle the inventory process is realized from. [2]

D. *GPS receiver*

The position of recorder traffic signs is described by GPS coordinates. They are obtained periodically in short intervals using the GPS receiver installed in inventory vehicle. GPS receiver provides the coordinates for the software core, which provides the final correction of these coordinates. It is possible to find the vehicle orientation using the difference of GPS coordinates for individual axes. Information about actual position and orientation is displayed in information window named "GPS Status". This information is graphically completed with the segment of near periphery, which is periodically obtained using the Google Maps service. [3]

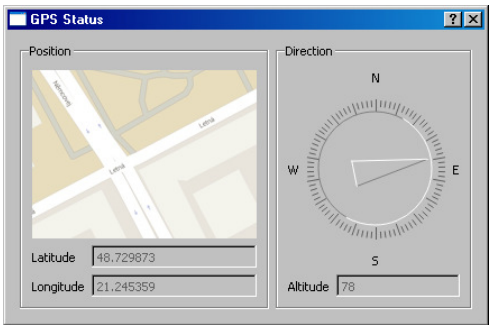

Fig. 3. The window titled "GPS Status".

III. The Multifactor Image Preprocessing

The original image obtained from the camera is affected by lighting conditions during the recording of traffic signs. It may cause the different quality of results during the image preprocessing. We can affect the quality and probability of exact preprocessing by reliable choice of preprocessing algorithms combination.

A. *Color filters*

Color filters in the image preprocessing are based on image thresholding according to defined limits. Conditions of color filter can varies according to used color space, the color is defined in. The result of preprocessing is the binary image which contains only pixels of original image which belong to thresholding image range.

B. *Edge detectors*

The edge detectors process a sharp transitions in input image. The sharp transition is a place with significant difference in the color, or intensity between neighboring pixels on the image. The result of edge detection process is the binary image, which represents a borders between places with different color properties.

C. *Depth map*

It is possible to obtain the depth map by a global comparison of parts of images from stereoscopically configured cameras. Individual objects with different distances are represented by different color intensity in this depth map. Since the traffic signs are separate objects, which have different position from another objects, we can suppose the separate depth area for each traffic sign during the processing of images with traffic signs. [1]

Fig. 3. The shape of traffic sign obtained by depth map processing based on images from stereoscopic camera system.

IV. Conclusion

The multifactor image preprocessing increases the probability of success traffic signs recognition. Inclusion of the shapes from the depth map can be a big benefit for this purpose. However the tested forms of depth map processing in real time are limited by electronic computing power. The future plan is testing the other forms of the effective depth map processing and researching more factors for increasing the probability of success traffic signs recognition.

Acknowledgment

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Big Data Analysis in Selected Logistics Process

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***Abstract* — It is generally assumed that data mining is very important for modern logistics management and should lead to improvement of the quality of decision making, resulting in increased sales, reduced costs and so on. The article describes my future research which aims to verify the validity of the above mentioned general presumption in selected logistics process and to find a suitable data mining methodology to improve this process.**

***Keywords*—big data, analysis of big data, logistics, decision support system**

I. Introduction

Big data is a relatively popular term used in connection with the exponential growth and the availability of various types of data, both structured and unstructured [1]. Therefore, if logistics companies want to get the value from such data they must choose the appropriate way to process them. Big data and logistics hang together perfectly. Logistics companies manage often huge flow of goods, generating a large amount of data [2] [4]. These data probably hold great potential for new business models.

The main objective of our research is to propose a model, based on analysis of available big data of the logistics company, incorporating all the factors affecting the performance of the driver. Subsequently, we will create and validate the decision support system for matching the drivers to the delivery routes and we will measure the impact of the system after its deployment in practice.

II. Data Analysis in Logistics

Logistics system is a very complex system comprising, on the one hand, the quantity of goods and, on the other hand, the quantity of information flows. However, for logistics companies is difficult to mine valuable information from large amounts of data, to perform timely and accurate decisions which are used to control the process and operational activities of logistics and it is difficult to reduce logistics costs and improve the company's revenue [4].

A. Analysis of the current status in logistics and actual research problems identification

Since 2000, logistics is becoming one of the highly developed industry sector at the all levels of operation [5]. However, usage of the available data for analysis may have a particular impact to improve the processes for management or strategic level.

In recent times, several research studies have shown the benefits of using the processing and analysis of big data in logistics and supply chain management. Tan, K. H. et al. have suggested analysis of big data infrastructure to enhance the capability for innovation in the supply chain [6]. Çakıcı came up with the idea of using RFID data for optimal reprocessing policy of supplies [7]. Zhong came up with a proposal how information from big data can be used for effective planning of logistics and production planning [8]. Dutta and Bose introduced the management of large amounts of data through logistics networks [9]. Waller and Fawcett argued that the use of data, predictive analysis and big data can help managers of logistics to fulfil internal needs and adapt to changes in the supply chain. Simply put, deployment of big data analysis for logistics and supply chain management should increase the added value for customers, where an integrated production and distribution processes throughout the supply chain include manufacturers, suppliers, retailers, logistics service providers who are supported by using large amounts of information [10].

Areas of big data application in logistics analyzed in the research can be summarized as follows [11]:

- coordination of the supply chain using big data and business analytics,
- the role of big data in product development,
- the role of big data to improve supply chain performance and complexity management in a dynamic environment,
- improvement of the accuracy of forecasts using big data and business analytics,
- visualization of big data for supply chain logistics.

III. Decision Support System

Decision support system in the logistics can provide for managers of logistics companies valuable information to make effective decisions.

One of the key challenges and often solved tasks in logistics company is the decision about suitable assignment of drivers to particular routes. Allocation of the drivers in the selected logistics company is currently carried out manually depending on where a driver is and whether he is entitled to time off. Depending on the job, the driver is called back for the trip, which lasts approximately 20 - 25 days. For the decision about allocation of drivers are also important other characteristics that are currently not taken into account. Some of them can be obtained from the analysis of available big data, the other by methods of collecting tacit knowledge, such as structured interview or questionnaire. To improve the allocation process of drivers for delivery routes we want to use both sources of knowledge.

There is already available quite huge quantity of data about the individual drivers such as drivers' performance, the number of kilometers travelled and fuel consumption for individual

vehicles / drivers in a given time period, as well as many other parameters, that can provide information about the style of driving, average speed, etc. We will get an overall view through which we can compare, analyze, compile models and perform experiments for different drivers and vehicles [12].

Based on the acquired, collected and analyzed data, together with the model settings, we will create a decision support system which will simplify and improve the choice of drivers for the specific trip, depending on the purpose of the planned route [13]. Since each driver has a different driving habits and experience gained by driving on the highway or driving in the alpine environment, a system selects a suitable driver for the planned route.

IV. Actual Results

Due to the available data from the logistics company, we conducted the first basic analyses. The basic data analysis was aimed to determine the dependence of the individual attributes. Measurements were made in the programming tool RapidMiner.

In Figure 1 we can see part of the obtained correlation matrix. From this we can read the strength and direction of the dependency of individual attributes.

Attributes	Celkový čas (h)	Celková vzd...	Priemerná r...	Priemerná ...
Celkový čas (h)	1	0.895	0.289	-0.033
Celková vzdialenosť (km)	0.895	1	0.560	-0.193
Priemerná rýchlosť (km/h)	0.289	0.560	1	-0.449
Priemerná spotreba paliva (l/100km)	-0.033	-0.193	-0.449	1
Celkové splodiny CO2 (ton)	0.865	0.895	0.377	0.222
Využitie vozidla (%)	0.985	0.909	0.284	-0.028
Celkové hodnotenie	0.056	0.168	0.246	-0.187
Predvídanie	-0.038	-0.003	-0.040	-0.166
Voľný dojazd	-0.005	0.027	-0.037	-0.117
Pomer brzdení/zastavenia	-0.166	-0.150	-0.015	-0.245
Využitie motora a prevodovky	0.045	0.137	0.291	-0.246
Neúsporná jazda	-0.026	0.070	0.248	-0.416
Úsporná jazda	0.353	0.554	0.673	-0.154
Najvyšší prevodový stupeň	0.129	0.358	0.779	-0.596
Zaťaženie motora	-0.036	-0.013	0.050	-0.704

Fig. 1. Correlation matrix (shortened)

According to the results in the table (Fig. 1) we can say, that with the increasing total time will also rise usage of the vehicle, total distance and total amount of exhaust fumes. The linear relationship between total time and total exhaust fumes can be seen in Figure 2.

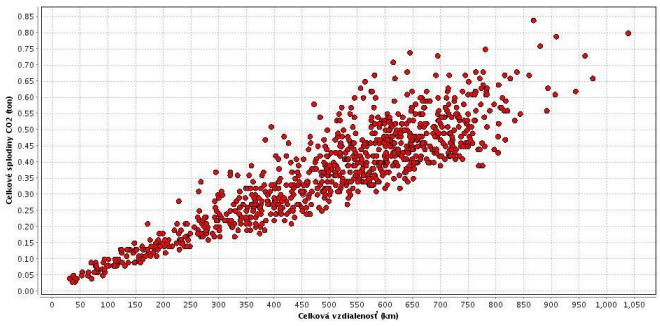

Fig. 2. Linear dependence of attributes: total time and total exhaust fumes.

If the engine load rises, the average fuel consumption per 100 km will decrease. This case of the negative correlation is shown in the following Figure 3.

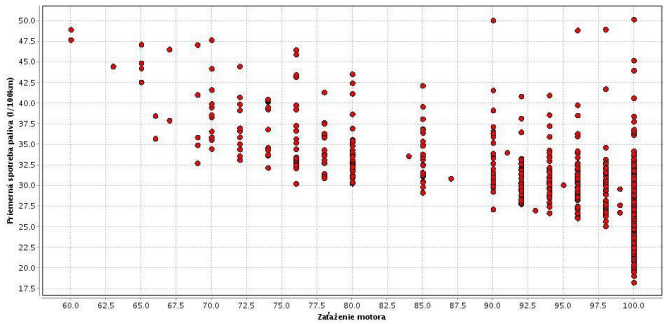

Fig. 3. Nonlinear dependence of attributes: engine load and average fuel consumption.

V. Conclusion and Future Work

Data analysis, as a type of information technology can help the company to get, from large amounts of data, many unknown and valuable information. Subsequently, the company can convert these valuable information into knowledge that can provide various decision-making information for the enterprise logistics management. So the company is able to raise the level of management and decision-making.

Future research will focus on the creation and verification of the model of driver and delivery routes. Based on the analysis of big data and conducted interviews with drivers and other relevant process actors, we will compile the model incorporating all the factors affecting the performance of the driver, respectively the characteristics of delivery routes. Then we will create and experimentally verify the decision support system for allocation of the drivers to the delivery routes in the selected logistics companies. By measuring performance of organization before and after the deployment of the decision support system, we will determine the extent to which this system is beneficial for the selected logistics company.

Acknowledgment

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Buck-boost DC to DC converters comparison for photovoltaic purposes

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***Abstract*— this paper provides brief analysis about all well known DC-DC buck-boost converters and new possibility to control them. The converters are compared in an experimental environment. For each converter is created input and output characteristics (voltage and current). From this characteristics is in the next explained which converter is more suitable for photovoltaic systems. Also the paper mentions a difference between single phase and multiphase buck-boost converter. The paper in final mentioned two types of microprocessor that can be used for controlling such of system.**

***Keywords*—Buck-boost, CUK, DC-DC, multiphase converter, SEPIC, single phase converter, ZETA**

I. Introduction

In recent years a photovoltaic panels become more popular. The main reason of that is a capability of photovoltaic panels to produce energy with higher efficiency. But the high quality of photovoltaic panel is not enough for achieving better efficiency of whole photovoltaic system. Photovoltaic system is composed from three main parts. First part is photovoltaic panel itself. The second part is DC to DC converter and third part is MPPT (Maximum Power Point Tracking) algorithm. This algorithm is needed because of nonlinear characteristic of photovoltaic panel [1]. Second and third part has also high impact on resulted efficiency.

Many MPPT algorithms and DC-DC converters were proposed and most of them are working with good efficiency [2-4]. But no one of DC-DC converters is changing basic topology depending on input power. In practice this type of converter is useful where the input power vary. In real conditions the input power can highly vary during day. A photovoltaic system in this case must provide quicker responses and work with maximum efficiency in any environment conditions. Due of that this is the main reason why is neccessary to propose such of DC-DC converter with properly control strategy. Proposing this kind of converter is not simple task. Because of changing topology the appropriate control system is needed. The first idea was based on multiphase DC-DC converters that can produce lower output current ripple than single phase converter with same filtering electronic component (inductance and capacitance). The difference between single and multiphase buck-boost converter is shown in Fig. 2.

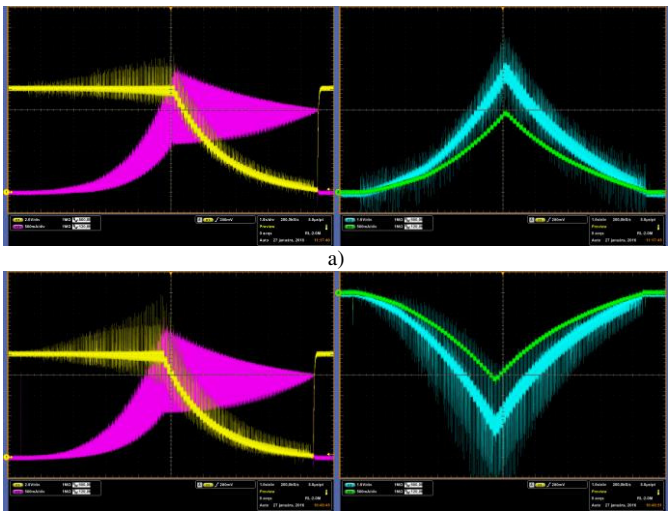
The next task is to proporse appropriate control system that can handle desired actions. The high speed microprocessor is needed to be use in the control system. The conclusion describes which microprocessor is better to use. The chapter does not describe controlling itself.

In many cases the battery is used as a load. Hence it is better to use a buck-boost converter. Because this type of a converter can handle vary input voltage also in the case when the input voltage is lower than a battery voltage.

II. Characteristics of buck-boost DC-DC converters

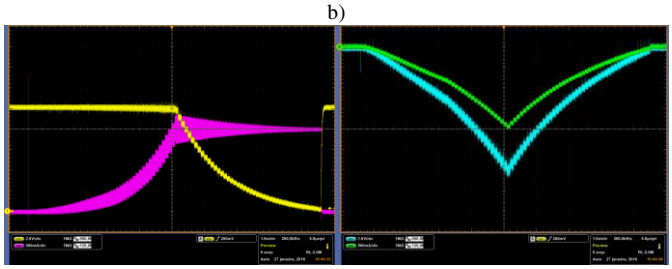
The main question was which type of buck-boost converter is better to use for tracking maximum power point. Therefore was provided more simulations and experimental measurements where the input and output characteristics of well known converters where compared. Among these converters belongs: noninverting buck-boost converter, classic buck-boost converter, CUK, SEPIC (**S**ingle **E**nded **P**rimary **I**nductance **C**onverter) and ZETA. These converters have specific properties. Describing of each converter will be beyond of this scope. More information about these converters is possible to find in [5-7].

The best way how can be compare all previously mentioned converters is to compare input and output characteristics in whole range of duty cycle. For this reason the simulation and experimental model with changing duty cycle in time was created. Because of limited range of this paper, the simulation results are not presented. The following oscillograms show characteristics achieved in experimental environment as can be seen in Fig. 1.

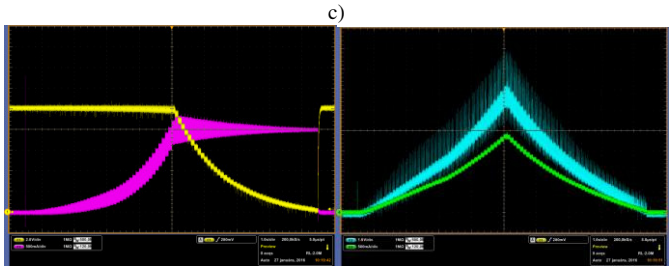


a)

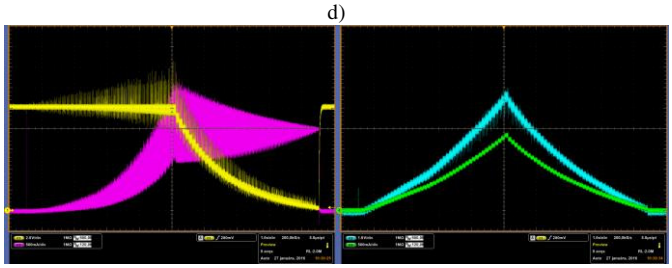
b)



c)



d)



e)

Fig. 1 Current and voltage (input voltage-yellow color; input current – pink color; output voltage- bright blue color; output current – green color) characteristics of buck-boost converters : a) noninverting buck-boost, b) classic buck-boost, c) CUK, d) SEPIC, e) ZETA

For correct comparison results were used the same switching devices, inductors and capacitors for all converters. The switching frequency is set to 20 kHz. The input voltage is 10 V and power source shunt current is set to 2 A. Control device creating time depending duty cycle which is based on ARM microprocessor unit STM32F446RE. From above illustrated oscillograms can be seen that lowest current and voltage ripple is producing by a CUK converter in both side (input and output). According to these results the CUK converter is best choice where the minimal current and voltage ripple is required. In case of tracking maximum power point where a current and voltage needed to be measured precisely the CUK converter represents best option. It is possible to increase filters for others converters but this intervention unfortunately increases a cost.

This converter can be next involved by adding more phases. Adding more phases can easily increases overall rate of photovoltaic system without using expensive electronic components. There can be also used smaller filters because the multiphase converters produce smaller current and voltage ripple than singlephase one. The following oscilograms in Fig. 2 prove this statement. Both figures have same Y-axis range.

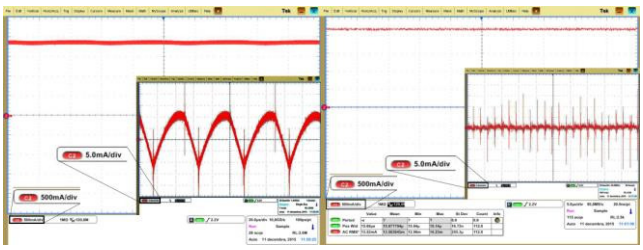


Fig. 2 Output current of single phase (left) and multiphase (right) noninverting buck-boost converter

The shown oscilogram on Fig. 2 illustrate output current characteristics of single and multiphase noninverting buck-boost converter in experimental environment. CUK converter in multiphase mode seems to be best choice for photovoltaic purpose.

III. Conclusion

As it was mentioned before the control system will be changing topology of converters depending on input power. Therefore the more powerful microprocessor is needed. The experimental tests were created with help of two programmable microprocessors units. In first case it was used DSP (Digital Signal Processor) type of TMS320F2808 which is working on frequency at 90 MHz. The second processor unit was ARM (Advanced RISC Machine where RISC (Reduced Instruction Set Computing) type of STM32F466RE which works on frequency at 180 MHz. The costs of these processors units are deeply different. ARM processor of this type is much chipper and faster than processor from Texas Instruments. ARM processor works on higher frequency and has some DSP functions because of M4 cortex core. More about the ARM processor can be seen in [8]. For this reason it is better use the ARM processor.

Acknowledgment

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CAVE in Education and Research

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***Abstract* — Laboratory of Intelligent Interfaces of Communication and Information Technologies (LIRKIS) at DCI FEI TU of Košice provides access to several advanced virtual reality technologies. Recently, LED display based CAVE system was installed in this laboratory. In this article, we will have a closer look at its capabilities, advantages and disadvantages in comparison to Head Mounted Display (HMD) solutions as well as its possible course of integration into education and research ongoing in the laboratory.**

***Keywords* — virtual reality, cave automatic virtual environment (CAVE), head mounted display (HMD), human-computer interaction, 3D interface**

I. Introduction

Head Mounted Displays (HMDs) like the Oculus Rift [7] or HTC Vive [8] are available at very affordable price compared to CAVE solutions. HMDs achieve high level of immersion by using small display screens that move with the viewer, close to the viewer`s eyes. This allows great 360-degree dynamic field of view but effectively blinds the user to the real world around him. Such real world isolation can be highly intrusive and disorienting, causing user to get so called motion sickness. On top of that, HMDs require to use distortion and color correction, making it uncomfortable for long term usage. In order to share VR experience, each user must wear its own headset. On the other hand, this gives each user correct perspective, which is not easily doable in CAVE environments. One possible workaround is described in paper [1].

The CAVE was developed to overcome some of the limitations of HMDs. The CAVE makes use of large, fixed screens more distant from the viewer. This allows multiple users to share the VR experience and allows interactions with real world objects (e.g. use a notepad or a use-case designed controller). Moreover, the user can still see his own body which helps to understand dimensions in virtual space. When intuitively judging the dimensions of things, we use our own body as a scale. The viewer is still aware of the real world which decreases the chance of nausea. It has also been shown that tracking errors and tracker latency in the CAVE are less distracting then in HMD systems.

II. Related Work

A cave automatic virtual environment (CAVE) is an immersive virtual reality environment consisting of a cube-shaped room which the walls are screens. CAVE installed at LIRKIS laboratory provides real-time viewer-centered head-tracked binocular (stereo) perspective with a large angle of view, and interactive control. It features multichannel audio and marker-based multi-target infrared tracking system.

Figure 1. CAVE at LIRKIS laboratory.

CAVE display area is made of 20 autonomous LED displays [Figure 1]. Fourteen of them are placed to form a circular wall around the user. Two groups of three displays are used on floor and ceiling. Those on floor are protected by armored glass, so user can stand over them, hence getting picture also under his feet. Rendering is driven by cluster of 7 computers in total. One of them is used as master whose job is to synchronize rendering computers, process multichannel audio and input from infrared tracking system. Displays are divided between 6 rendering computers by 4 groups of 3 units and 2 groups of 4 units.

Cluster is driven by virtual reality toolkit SuperEngine, which is used for large screen stereoscopic rear projection system, located in the same laboratory as well. More details about this toolkit can be found in paper [2]. Stereoscopy is based on circular polarization of light, so user is forced to wear very lightweight passive glasses.

As it was mentioned in the beginning, there are some fundamental differences between HMD and CAVE based VR systems and resulting experience. The table [Table 1] provides some more insights into these differences. Green color highlights better parameter for the desired aspect.

	HMD	CAVE at LIRKIS
Resolution	~ 1 Mpixel per eye	Full HD per display, total of 20 displays used
Image Quality	Requires distortion and color correction	Pixel perfect
Immersion	Completely immersive	Immersive
Field of View	100 degrees per eye, 360-degree dynamic	170 degrees per eye, 210-degree dynamic
Presence	Isolating	Excellent, see your own body
User Volume	Movement limited, mostly seated experience	Precise wireless tracking, move around freely inside CAVE`s volume
Users	Single user	Multiple viewers, one of them tracked
Comfort	Bulky, tethered, sweaty	Lightweight glasses, wireless
Small Group Collaboration	Impossible without advanced telepresence	Ideal for face-to-face meetings
Tracking Error/Latency	Sensitive, often leads to motion sickness	Less sensitive, motions sickness less likely
Accommodation	Closed screens cause eye discomfort over time	Large, fixed screens comfortable with extended use time
Cost	Very low cost	High cost

Table 1. HMD vs CAVE at LIRKIS.

By looking at this table, one can say that CAVE outperforms HMDs in almost every aspect, so it must be much better solution in general. But that is actually not true at all. HMDs are simply useful in different set of use cases, where they can probably do even better job than such a complex and high cost CAVE system. Another comparison can be found in paper [3] and [4].

CAVE was already used in education for students attending the Virtual Reality course, providing them with insights into understanding of such complex VR system. Besides practical revealing of technical requirements needed to build and run it, they are allowed to create their own applications that can run in this CAVE by utilizing Ruby scripting language of aforementioned VR toolkit SuperEngine [2].

As for research, we have two main course of actions of how to utilize CAVE VR system. First of them is our continual work on integration of several advanced human-centered Natural User Interfaces [5][6] in order to allow users to effectively work in VR environment for an extended period of time. Second one is to utilize VR environment in research and personnel training for industrial use cases. Typical example is to extend current user interface of CAVE by touch-screen table top where control panel is being displayed. User sitting on a chair inside the CAVE can then interact with virtualized enterprise environment surrounding him. Such system can help to understand effective UI layouts to serve data in optimal way, and measure the rate of fatigue and stress without the risk of hazardous situations which can occur in real workplace.

III. Conclusion

Recently installed CAVE VR system at LIRKIS laboratory allows us to effectively continue our long term research on advanced human-centered Natural User Interfaces in area of Human-Computer Interaction. As it was said in previous sections of this paper, CAVE system let us take actions in different use cases when compared to tightly connected HMD systems. On the other hand, this does not stop us from our research on HMD based solutions. Each use case needs detailed analysis in order to decide which system is the most effective one to be utilized for it.

Focus of our future research is on effective utilization of virtual reality systems based on modern advanced 3D interfaces with respect to the user and environment they are deployed into. One of the main goals is wider acceptance of such systems in an enterprise environment.

Acknowledgment

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Calculation of operating temperature of the transmission line with different operating voltage

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***Abstract* — this work deals with the transmission and distribution of electric energy focused on the calculation of operating temperature on the wire of transmission line, which is loaded by the current. Current loaded in the transmission line is limited allowable operating temperature. The operating temperature is determined by the type of material and operating condition. From mechanical point of view the operating temperature must not exceed the allowable operating temperature of the wire. These calculations were released by more equations. The aim of this work was simplify of calculation of operating temperature for normal operating condition and also for short circuit. Result of this work is also program for fast calculation, with using Matlab software.**

***Keywords* — high voltage, load, operational temperature, transmission line;**

I. Introduction

One from important operating problems of conductive lines is their temperature [1]. The electric current flowing through the wire gives rise of temperature. The losses on isolation in the isolated wires or losses in air by surface discharges in bare wires gives rise of temperature too. The heat is diverted from the wire to the environment. Spread heat by conduction occurs mainly in the isolated wires and convection and radiation at the bare conductors, and convection and radiation at the bare conductors [3] [6] [9]. Whereas the maximum of the surface temperature is relative small, the share of the heat radiated by radiation is relatively small on compared to convention and conduction. The resulted operating temperature of wire is given by balance between produced heat and heat consumed to heating of the wire, heat divert to environment.

II. Equation for operating temperature

When a current I flows through the wire in time dt produce the heat dQ´ and losses on isolation in the isolated wires and loses in air by surface discharges in bare wires produce heat as dQ´´. Part of heat consumed to heating of the wire as dQ_1 and part of the heat divert to environment as dQ_2. When a current I flows through the wire with resistance R_ϑ then in time dt develop the heat dQ´ defined by equation [5].

$$dQ' = R_\vartheta\, I^2\, dt = R_0\, I^2 \left(1 + \alpha_R\, \Delta\vartheta_0\right) dt = \frac{\rho_R\, l\, I^2}{S}\left(1 + \alpha_R\left(\Delta\vartheta + \Delta\vartheta_W\right)\right) dt \quad (1)$$

The voltage U_x is the voltage to ground. Heat generated by losses on isolation in the isolated wires or losses in air by surface discharges in bare wires is defined by the equation.

$$dQ'' = G_i\, U_x^{\,2}\, dt = \gamma_i\, \frac{S_p}{l_i}\, U_x^{\,2}\, dt = \gamma_i\, \frac{o\, l}{l_i}\, U_x^{\,2}\, dt \quad (2)$$

Part of the heat dQ_1 consumed for heating the wire and temperature change about $d(\Delta\vartheta)$.

$$dQ_1 = m\, c\, d(\Delta\vartheta) = V\, \rho_m\, c\, d(\Delta\vartheta) = S\, l\, \rho_m\, c\, d(\Delta\vartheta) \quad (3)$$

And part of the heat dQ_2 divert to environment in time dt.

$$dQ_2 = \lambda\, S_P\, \Delta\vartheta\, dt = \lambda\, o\, l\, \Delta\vartheta\, dt \quad (4)$$

Here is defined perpetual balance of heat energy by differential equation.

$$dQ' + dQ'' = dQ_1 + dQ_2 \quad (5)$$

Then we solve differential equation. For all conditions we solve integral between boundaries $\Delta\vartheta_E$ and $\Delta\vartheta_P$. After a few steps we get this new equation [6] [3].

$$\vartheta_P = \frac{\frac{\rho_R\, I^2}{S}\left(1 + \frac{\vartheta_W - \vartheta_0}{\vartheta_f + \vartheta_0}\right) + \gamma_i\, \frac{o}{l_i}\, U_x^{\,2}}{\lambda\, o - \frac{\rho_R\, I^2}{S\left(\vartheta_f + \vartheta_0\right)}}\left(1 - e^{-\frac{t}{\frac{S\, c_V}{\lambda\, o - \frac{\rho_R\, I^2}{S\left(\vartheta_f + \vartheta_0\right)}}}}\right) + \left(\vartheta_W - \vartheta_E\right) e^{-\frac{t}{\frac{S\, c_V}{\lambda\, o - \frac{\rho_R\, I^2}{S\left(\vartheta_f + \vartheta_0\right)}}}} + \vartheta_E \quad (6)$$

III. Calculation for wire

For next calculation is necessary to ascertain properties of the wire. For calculation will be used ACSR 750/43 as two bundles wire and three bundles wire. All necessary properties we can see in table [3] [10] [11].

TABLE I
PROPERTIES OF ACSR 750/43

Material	-	ACSR 750/43 two bundles wire	ACSR 750/43 three bundles wire
Specific resistance	ς_R	$3{,}076608.10^{-8}$ Ω.m	$3{,}076608.10^{-8}$ Ω.m
Dense	ς_m	3035,0272391 $kg.m^{-3}$	3035,0272391 $kg.m^{-3}$
Specific heat capacity	c	832,6669366 $J.kg^{-1}.°C^{-1}$	832,6669366 $J.kg^{-1}.°C^{-1}$
Volumetric specific heat capacity	c_V	2527166,834 $J.m^{-3}.°C^{-1}$	2527166,834 $J.m^{-3}.°C^{-1}$
Fictive superconducting temperature	ϑ_f	228 °C	228 °C
Elementary temperature of environment	ϑ_0	20 °C	20 °C
Temperature coefficient of resistance	α_R	$4{,}032258064516129.10^{-3}$ $°C^{-1}$	$4{,}032258064516129.10^{-3}$ $°C^{-1}$
Coefficient of thermal expansion	α_L	$2{,}11.10^{-5}$ $°C^{-1}$	$2{,}11.10^{-5}$ $°C^{-1}$
Coefficient of heat transfer	λ	30 $W.°C^{-1}.m^{-2}$	30 $W.°C^{-1}.m^{-2}$
Specific conductivity of isolators	γ	$1{,}4.10^{-9}$ $S.m^{-1}$	$1{,}4.10^{-9}$ $S.m^{-1}$
Ionization distance from the wire	l_i	0,1 m	0,1 m
Section	S	$1{,}6024.10^{-3}$ m^2	$2{,}4036.10^{-3}$ m^2
Circuit	o	0,2293362638 m	0,3440043957 m
Radius	r	0,0365 m	0,05475 m

In these graphs we can see calculated operational temperature ϑ_P in different time t. Here is used last equation. These graphs are made for current I is 3000 A. We will use voltage U for transmission line 220000 V between phases. Voltage U_x for transmission line will be 127017 V between phase and ground. Initial temperature of wire ϑ_W is same than temperature of environment ϑ_E. First graph is for two bundles wire and second is for three bundles wire.

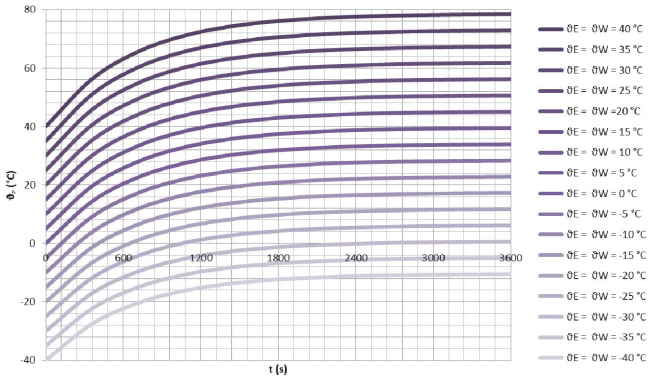

Fig. 1. Calculated temperatures for two bundles wire

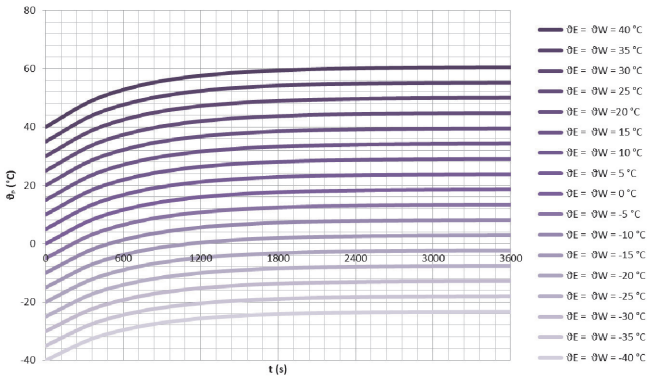

Fig. 2. Calculated temperatures for three bundles wire

In these graphs we can see calculated operational temperature ϑ_P in different time t. Now we will use voltage U for transmission line 400000 V between phases. Voltage U_x for transmission line will be 230940 V between phase and ground. First graph is for two bundles wire and second is for three bundles wire.

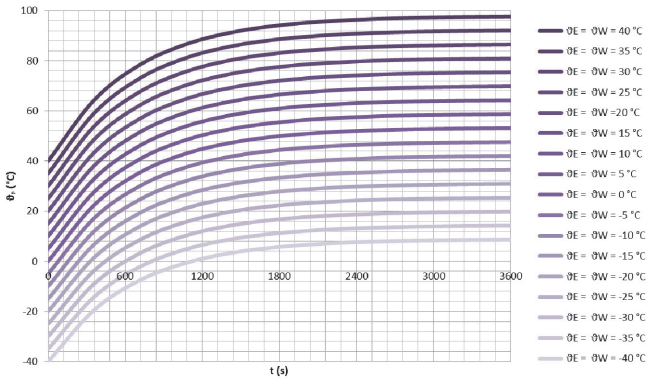

Fig. 3. Calculated temperatures for two bundles wire

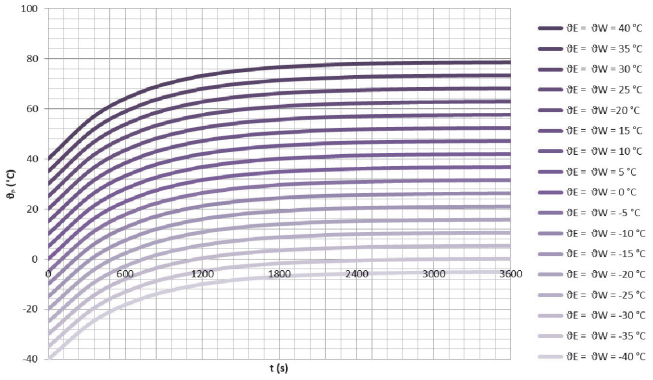

Fig. 4. Calculated temperatures for three bundles wire

IV. Conclusion

In these graphs we can see increase of operational temperature ϑ_P in time t. The current I and voltage U_x between phase and ground, have important impact to increasing to operational temperature ϑ_P.. This new equation successfully shows influence temperature coefficient of resistance α_R to operational temperature ϑ_P.. These calculations simulate results for ACSR wire. The ascertaining of operational temperature ϑ_P is important for design transmission line [7]. For the transport of electric energy with considering to technical parameters of the actual transmission lines, more than 30 percent of the energy is lost in the high voltage transmission lines for longer distances. In the future, the high voltage transmission will cooperate with renewable resources to a larger extent [8]. The operational temperature of high voltage transmission lines has very important influence to their resistance. On the other side, resistance of transmission lines influences their energy losses, thus the economy of their operation, and therefore the operational efficiency of the entire power system. In my future research activities derived equation will be used to optimize costs of operation of high voltage transmission line.

Acknowledgment

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Circuit simulation using MATLAB and modeling of real elements

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***Abstract*—This paper deal with study the possibility, approach and the correct procedure for nonlinear circuit simulation using mathematical tool MATLAB. Especially, paper describes nonlinear circuit simulation, modeling of nonlinear elements and creating application using graphical user interface in MATLAB. Application described in this paper is using for nonlinear circuit simulation.**

***Keywords*—nonlinear circuits, circuit simulation, Matlab, graphical user interface.**

I. Introduction

Circuit simulation is a technique for checking and verifying the design of electrical and electronic circuits and systems prior to manufacturing and deployment. It is used across a wide spectrum of applications, ranging from integrated circuits and microelectronics to electrical power distribution networks and power electronics. Circuit simulation combines mathematical modeling of the circuit elements, or devices, formulation of the circuit equations and techniques for solution of these equations [1].

Many different kinds of network element are encountered in network analysis. For circuit analysis it is necessary to formulate equations for circuits containing as many different types of network elements as possible. There are various methods for formulation of circuit equation.

My research in this topic consists of these parts:

1. Description of real circuits and their elements.
2. Design of real electrical and electronic components models.
3. Selection of appropriate methods to solve mathematical models of real electrical circuits.
4. Create application to solve nonlinear electrical and electronic circuits using MATLAB.
5. Choosing a suitable method for applications testing.

II. Initial state

Initiation state is the state of research one year ago. These are all the results of research were found between the beginning of my PhD study and period one year ago.

The first step was study the literature with simulated circuit theory. I was focused on methods of linear circuit simulation and modeling of linear circuit elements. Nonlinear circuits consist of linear and nonlinear elements.

The next step was the creation of linear elements models. Were created and describes the basic ideal linear elements models. Subsequently were created all active and passive linear elements models for AC and DC steady-state circuits.

Before the start of circuit simulation chooses the method of preparation circuit equations is needed. The process of selecting a suitable method is described in [2]. Sparse Tableau Analysis (STA) with system of circuit equations (1) was selected. Subsequently the linear elements models were adjusted for Sparse Tableau Analysis.

$$\begin{bmatrix} \mathbf{A} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} & -\mathbf{A}^{\mathrm{T}} \\ \mathbf{Z} & \mathbf{Y} & \mathbf{0} \end{bmatrix} . \begin{bmatrix} \mathbf{i} \\ \mathbf{u} \\ \mathbf{v} \end{bmatrix} = \begin{bmatrix} \mathbf{0} \\ \mathbf{0} \\ \mathbf{s} \end{bmatrix} \tag{1}$$

Linear STA equation system (1) will be extended of nonlinear elements equation written in the vector of nonlinear element equation **G(x)**. **G(x)** consists of nonlinear functions. This extension system called nonlinear STA system (2) is used to simulate nonlinear circuits.

$$\begin{bmatrix} \mathbf{A} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} & -\mathbf{A}^{\mathrm{T}} \\ \mathbf{Z} & \mathbf{Y} & \mathbf{0} \end{bmatrix} . \begin{bmatrix} \mathbf{i} \\ \mathbf{u} \\ \mathbf{v} \end{bmatrix} + [\mathbf{H}][\mathbf{G}(\mathbf{x})] = \begin{bmatrix} \mathbf{0} \\ \mathbf{0} \\ \mathbf{s} \end{bmatrix} \tag{2}$$

We must find solving of nonlinear equation system (2). There are numerous approaches to solving nonlinear systems, most based on using some type of approximation involving linear functions. Methods are described in [3].

In addition to the above activities options of MATLAB were examined, in particular MATLAB graphical user interface.

III. Description of tasks and results

I continued the research simulation of nonlinear circuits using MATLAB. My last year research can be divided into several parts:

A. Description and creating models of real linear elements.
B. Description and creating models of real nonlinear elements.
C. DC, AC and time simulation of linear and nonlinear, ideal and real elements.

A. *Models of real linear elements*

Basic real linear elements are resistor, capacitor and inductor. We need to know more than one main parameter (R, L, C) to describe those elements. For example to enter the value of the real resistor can be used ambient temperature and temperature coefficient or geometric dimensions (Fig. 1).

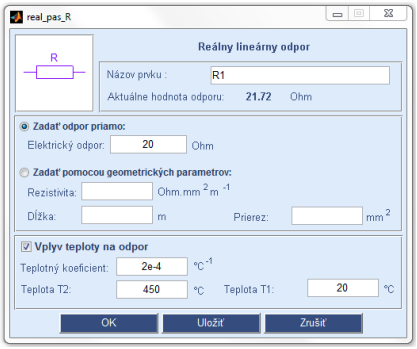

Fig. 1 Example of entering parameters of real resistor.

B. *Models of real nonlinear elements*

They are many of real nonlinear elements with many of possible applications and different characteristics. Industrial devices consist of more elements, from basic semiconductor diodes to field control elements.

We want to find suitable models of real nonlinear elements for circuit simulation, especially for circuit simulation using Sparse Tableau Analysis. We are looking for models consisting of ideal circuit (linear and nonlinear) elements.

Piecewise linear model consist of ideal linear elements only. Element called Ideal Diode is necessary element for creating piecewise linear model. For negative voltage polarity between the anode and cathode of ideal diode applies (3) and for positive voltage polarity between the anode and cathode applies (4). Circuit symbol and I-U characteristic of ideal diode is shown in Fig. 2 case a) and models of semiconductor diode in Fig. 2 cases b), c), d) [1].

$$u_{ID} < 0 \quad i_{ID} = 0 \tag{3}$$

$$u_{ID} = 0 \quad i_{ID} > 0 \tag{4}$$

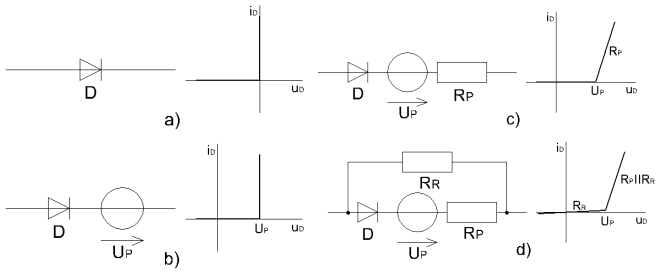

Fig. 2 a) Model of ideal diode and b) c) d) piecewise linear models of real semiconductor diode.

An example of entering static parameters of semiconductor diode is shown in Fig. 3. The user can choose one of the available models and then can enter the parameters of ideal elements in model's equivalent circuit.

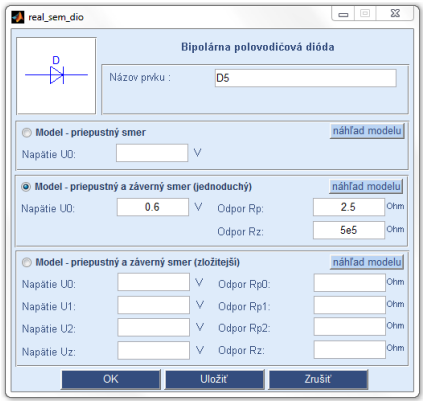

Fig. 3 Example of entering parameters of real diode model.

C. *Simulation outputs*

They are two types of outputs in this application: numerical output for AC and DC simulation of work point and graphical output for DC, AC and time simulation of circuit. Numerical output example (show in Fig. 4).

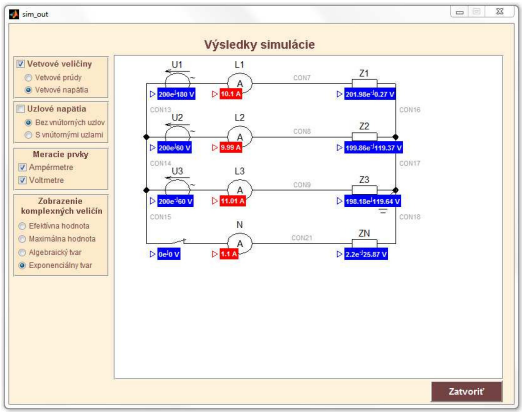

Fig. 4 Example of numerical output of AC work point simulation.

Branch voltage of element, branch current of element or node voltage can be shown in graphical output. Graphical output example is shown in Fig. 5.

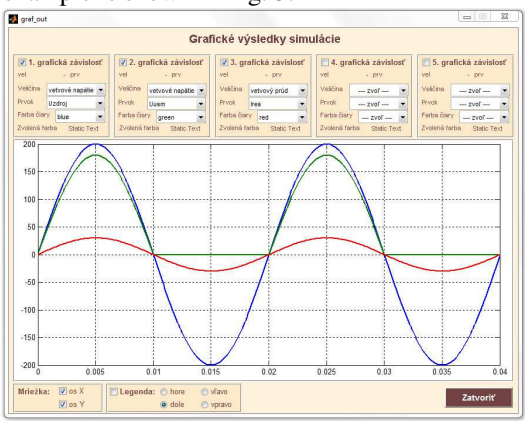

Fig. 5 Example of time simulation graphical output.

IV. Conclusion

Application is using for nonlinear circuit simulation. They consist of linear and nonlinear, ideal and real elements models. Models are used for constructing the electric circuit. Next step is simulation of circuits. User can use DC and AC simulation of work point, DC and AC simulation and time simulation. Numerical and graphical results can be used for his further research or solving of engineering problems.

Acknowledgment

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Classification Using MF ARTMAP Neural Network in the Cloud Robotics

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***Abstract* - In this paper, we provide a concise summary of progress and reached results in the domain of cloud-based classification using ARTMAP neural networks. We are focusing on the MF ARTMAP network and its advantages. The most significant benefit is one-shot incremental supervised learning, what means that MF ARTMAP can gain new knowledge without forgetting already learned information. Also, straightforward knowledge representation predetermines the MF ARTMAP as a suitable algorithm to employment in the domain of cloud robotics for solving a broad spectrum of classification tasks. Moreover, this algorithm has a great research and scientific potential towards to the generation of semantic expressions about similarities and dissimilarities between classes.**

***Keywords* - MF ARTMAP, cloud robotics, cloud computing, modular system, semantics.**

I. Introduction

This paper follows and extends a paper [1], in which we introduced a proposal of the modular cloud-based system usable by humans and agents. The core technology of described system is cloud computing. It means that every part of the system is developing as a cloud service in conformity with principles of cloud computing defined in [2], [3]. Since the introduced system is cloud-based and is usable by both, humans and robots, then fulfills requirements to be classified as a system of cloud robotics [4].

Let's zoom into the structure of the proposed system. The core is a set of independent software modules deployed in the cloud environment. We can consider each module as a library responsible for solving one particular task. Some modules can implement methods of artificial intelligence; others can fulfill supporting functions with no intelligence. However, each module should provide some functionality for connected devices and agents. It is a reason, why those modules should be accessible by API, for instance, WEBAPI [5] or SignalR [6]. Since we want use advantages of cloud computing in robotics, many of those modules should implement methods suitable for robots. There is a possibility to interconnect several software modules into one collaborative modular system, which can solve the more complex and challenging tasks. We described those modules in detail in [7].

We decided to demonstrate the system using a classification task. Specifically, we are using an MF ARTMAP classifier, which is a supervised version of the Adaptive Resonance Theory (ART theory) [8][9] neural networks. In the future, we are planning to classify objects captured in the visual static images into one of known classes, what is an equivalent of the objects recognition.

II. A brief introduction to the MF ARTMAP

We provided the basic architecture of the cloud-based modules and appropriate state of the art, including cloud computing, cloud robotics, cloud-based software modules, object recognition introduction and a few words of the MF ARTMAP as a classifier in the [1]. Therefore, here we will concentrate on the classification part of the system.

We use MF ARTMAP [10][11] neural network, which belongs to the group of neural networks based on ART Theory, which uses supervised learning.

Such neural networks cluster inputs based on the similarity between them. Moreover, ART based networks can extend their knowledge base almost unlimitedly without forgetting already gained knowledge. It allows us to add new classes or new input patterns from unclustered part of the feature space with no or very small impact on already known clusters.

An abbreviation MF in the name of the network means Membership Function. As the name implies, MF ARTMAP poses a symbiosis of a fuzzy sets theory and adaptive resonance theory. Thanks to a usage of fuzzy sets in this algorithm, we can calculate a membership of the input pattern to each fuzzy class. Then the networks output is not one particular class, into which the input sample belongs, but the output is a vector of membership values of input sample to the each class. It gives us information, how much the input belongs to each category.

III. Weak and strong points of the MF ARTMAP

This section, we built on our observations of how the MF ARTMAP behaves in different situations, with various inputs and various settings. The goal of all experiments was to identify its weak and strong points. In this section, we provide a concise overview of identified issues and solutions.

A. Weak points

First, at all, we compared a classification performance with the Multi-Layer Perceptron (MLP) using several data sets. We used standard benchmark dataset, which is available online [12]. For an evaluation of the classification precision, we used

a Holdout method [13] and we tested different ratios between train and test set. We compared classification accuracy using normalized and not normalized datasets. MLP outperformed MF ARTMAP for each data set, but there were some cases, in which the MLP was only slightly better. A detailed evaluation is in [7]. It implies that MF ARTMAP is not the strongest classifier.

Moreover, we noticed a high dependency on the order of the training patterns and the classification performance. It is also related to the number of the input patterns in the training set. In general, bigger train sets allows us to reach higher accuracy.

The last but not least issue is related to the setting of the MF ARTMAP input parameters. The input parameters were the vigilance parameter, recognition layer threshold, and cluster's initial parameters (variance σ and steepness of cluster F). We employed variance *(σ)* calculation by using an incremental equation. (See [7]). Since the vigilance parameter, de facto means the distance of the input pattern from the center of the cluster we can use a *3σ rule*[12], instead hard-set vigilance. This way we do not have to set a vigilance parameter. The F parameter we firstly placed randomly and then we optimized it by Simulated annealing algorithm [13]. This step improved a classification accuracy. The last parameter which is necessary to set manually is the recognition layer threshold. It is a minimal threshold of the membership to be able to assign input pattern to the appropriate cluster. Now we need to set the only one input parameter manually.

B. Strong points

The most valuable advantages are a possibility of one-shot incremental learning and output in the form of transparent information concerning to relations between the observed point in the feature space and all known classes.

The knowledge representation of the MF ARTMAP is in the form of cluster's parameters (center of cluster X_s, σ, F) for each established cluster. This representation allows us performing post-processing operations in two ways:

1. ***Manipulation of the number of clusters with the aim to speed up classification process.***

If the number of clusters is large, the classification error can be low, but processing of the network can be very slow because the algorithm has to investigate a large number of clusters [14]. In this case, we can analyze clusters and merge them according to certain heuristic rules e.g. merge two the closest clusters, which represent one class.

Contrariwise, if the categorization error increases, the reason for this can be a lower number of clusters. It means that exists places in the feature space, which are not covered by any cluster. Here, we can use iterative learning, with the aim to fulfill gaps between clusters.

2. ***Generation of linguistic expressions about clusters, classes, their structure or similarities between classes.***

We can acquire knowledge about one class or about relationship between classes. If we try to gain and express knowledge about one class, we say that it is an intra-class knowledge. Otherwise, if we are looking for relationships between classes, we acquire inter-class knowledge. [7] Intra-class knowledge express the variance of clusters belonging to the class in the feature space. This way, we can express a homogeneity of the class. Inter-class knowledge allows us to express class independence or express a similarity between classes. Due to the limited scope of this paper, we recommend [7] for more information. Moreover, there occur more possibilities for semantics generation. For instance by using a contingency table for each cluster separately. This way we can generate expressions like: "The output from the cluster is a class "*0*" with confidence 100%." or "The output is a class *0* more likely than class *1*, but in no case, it is a class *2*." [7]

IV. Conclusion

Despite the preliminary results indicate that MF ARTMAP is not so powerful in the classification as other classifiers, it hides a great potential. Its strong points are that it is not a black box in the strict word sense and gives a possibility to gain semantic information. This information is a base for the post-processing, which is not a common in the field of neural networks. It creates a high research potential and offers outputs which are valuable for the wider context beyond the classification problem. We can conclude that although MF ARTMAP is not one of the strongest classifiers, however, its post-processing potential overcomes many other methods.

Stated words determine our future work. We are planning to alleviate weakness of the MF ARTMAP towards to improvement its classification performance, and we would like to focus and elaborate on the methods for generation of semantics expressions.

Acknowledgment

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Composition of components using linear logic and Petri nets

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***Abstract*—Linear logic is a suitable logical system for showing how program systems can be described. Individual connectives used in linear logic formulae correspond to some fragments of Petri nets, the other tool for modeling behavior of systems. In this paper we use this correspondence between linear logic and Petri nets to show a small working Petri nets and how the composition of small working Petri nets brings new problems. We extend our approach also for coloured Petri nets and their transformation to corresponding provable formulae of simple extension of linear logic.**

***Keywords*—Coloured Petri nets, component system, linear logic, Petri nets**

I. Introduction

The aim of this contribution is to take advantage of the correspondence between Petri nets (PN) and linear logic to illustrate composition of components in compose based systems. We show how it works on primitive functioning Petri nets and we show that if we compose this nets what new type of problems occur and must be solved. Also we express our component system in coloured Petri nets.

Linear logic is a logical system introduced by Jean-Yves Girard in 1987 [3]. It enables to describe processes as they behave in real world. It can describe dynamics of processes, parallelism, external and internal non determinism, consecutive processes and it is able to handle with resources on syntactic level. The detailed features of linear logic is presented in [2].

II. Petri nets

Petri nets were defined for describing concurrent systems in terms of cause/effect reflection. Graphically, they can be represented by a directed bipartite graph, which have two types of nodes: places and transitions [7].

A Petri net (PN) is usually a tuple

$$PN = (P, T, pre, post, m_0), \tag{1}$$

where $P = \{p_1, \ldots, p_n\}$ is a set of places, $T = \{t_1, \ldots, t_n\}$ is a set of transitions, arcs $pre : P \times T \to \{0, 1\}$ and $post : P \times T \to \{0, 1\}$ represent a set of arrows specifying relations between states and events and m_0 is initial marking.

A marking of a place is a function:

$$m : P \to \mathbb{N}_0 \tag{2}$$

that for every place p returns a number of tokens $m(p)$ occurring in the place p. Marking of the whole PN we denote by a tuple:

$$m = (m(p_1), \ldots, m(p_n)) \tag{3}$$

PN is based on two rules:

- *enabling rule* that states the condition under which transitions are allowed to fire. A transition is enabled if every input place contains a number of tokens greather or equal than given threshold;
- *firing rule* defines the marking modification induced by firing a transition. When a transition t fires, it deletes a token from every place in its input set of places and adds a token to every place in its output set [8].

Both rules are specified trough arcs. PN can be described by a possible sequences of markings reached by firing enabled transitions.

A. Interpretation of intuitionistic linear logic by Petri nets

Every formula of intuitionistic linear logic (ILL) can be interpreted by the particular pattern of PN. We denote a place p of PN containing one token by elementary formula p of ILL. Markings can be described using multiplicative conjunction, e.g. if a place p_1 contains one token and a place p_2 contains two tokens, we denote the corresponding marking by the following formula:

$$p_1 \otimes p_2 \otimes p_2.$$

For describing a transition in PN we use linear implication $\multimap$, where the cause is the minimal marking needed for firing t and the effect is the marking produced by this firing of t. Linear implication expresses change of states caused by firing together with consumed resources on the left side and produced resources on the right side of implication [9].

PN we describe by provable sequents of ILL in the form:

$$m, l \vdash m'$$

where

- *m* is the marking before firing;
- *l* is the list of enabled transitions expressed by linear implications defined above;
- m' is the marking after firing,

which means that from marking m by firing a transition from l is produced marking m' [8].

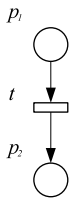
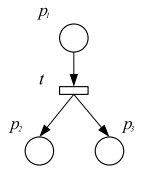
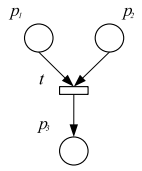
sequence	*furcation*	*rendezvous*
		
$p_1, t \vdash p_2$ *causality*	$p_1, t \vdash p_2 \otimes p_3$ *concurrence*	$p_1, p_2, t \vdash p_3$ *synchronization*
deterministic		

TABLE I
CORRESPONDENCE BETWEEN PN AND ILL. PART I.

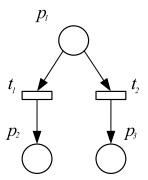
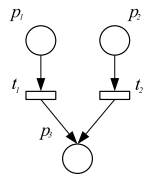
free choice	*dependent choice*
	
$p_1, t_1 \oplus t_2 \vdash p_2 \& p_3$ *internal nondeterminism*	$p_1 \& p_2, t_1 \& t_2 \vdash p_3$ *external nondeterminism*
nondeterministic	

TABLE II
CORRESPONDENCE BETWEEN PN AND ILL. PART II.

The correspondence basic patterns between fragments of PN and formulae of ILL are in tables I and Table II [8]. All other fragments of PN can be derived from them.
The translation of the pattern *sequence* corresponds with the translation of enabled transition t and the result sequent in ILL expresses *causality*. p_1 on the left side of sequent expresses that in p_1 must be at least one token.

In the case of *furcation* is only one enabled transition t and in p_1 must be at least one token. After translation the result sequent in ILL expresses *concurrence*. If p_1 contains a token, firing of t produces one token in p_2 and p_3, simultaneously.

The pattern *rendezvous* corresponds with the sequent *synchronization* in ILL. It assumes at least one token in both p_1 and p_2 and after firing t the production of one token in p_3 on the right side of the sequent.

These three patterns describe *deterministic* patterns of PNs, because they contain only one enabled transition.

The next two patterns express *nondeterminism*. *Free choice* pattern expresses the situation when either t_1 or t_2 can be fired but we do not decide which. We translate this pattern to the sequent with additive disjunction $\oplus$ between formulae describing enabled transitions on the left side. Producing tokens on the right side is expressed by additive conjunction because they depends on previous action: firing of t_1 or t_2.

Dependent (environmental) choice expresses the situation when also only one transition t_1 or t_2 can be fired but it depends on the occurrence of a token in p_1 or p_2. This pattern we translated to the sequent with additive conjunction describing transitions on the left side, because firing of t_1 or t_2 depends on the situation in p_1 and p_2, respectively.

III. COMPONENT COMPOSITION

In this section we use the correspondence between Petri nets and linear logic introduced above for illustrating how the composition of components causes different of systems.

We consider a trivial Petri nets in Fig. 1 that can be considered as "two-hand philosopher". We use the following notation:

- f denotes a place representing a fork;
- p denotes a place representing a philosopher;
- t denotes a transition.

It corresponds with linear formula (4). Every philosopher must have the fork in the both hands. After he eats, he returns the forks.

This trivial pattern consists of three places f_1, p_{1e}, f_2 and two transitions t_{1e} and t_{1f} with initial marking $(1, 0, 1)$ that corresponds to place ordering f_1, p_{1e}, f_2.

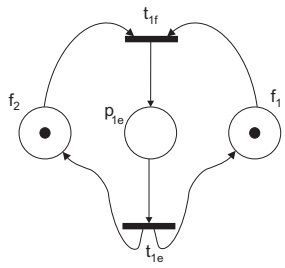


Fig. 1. Two hand dinning philosopher

$$f_2, f_1, (f_2 \otimes f_1) \multimap p_{1e}, p_{1e} \multimap (f_2 \otimes f_1) \vdash f_2 \otimes f_1 \qquad (4)$$

If we consider composition of five two hand philosophers we get the problem of dinner philosophers (Fig. 2.).

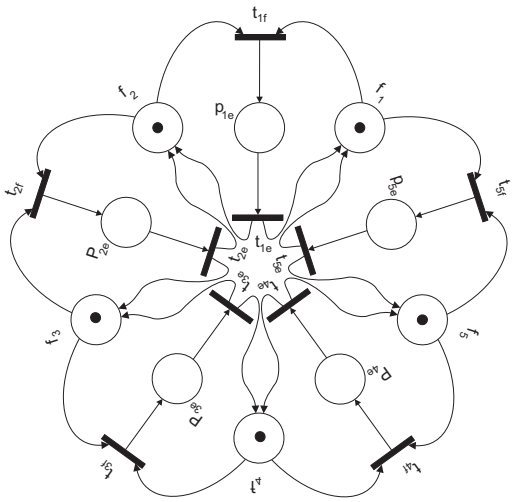


Fig. 2. Problem of dinner philosophers

A new problem arises by this composition. Such PN does not work if every philosopher have only one fork and he waits for the other infinitely. In such situation no philosopher can eat and this problem is known as deadlock. There are the following solutions for avoiding deadlock.

We consider the situation when only one philosopher can eat. The single dinning philosopher situations is expressed by

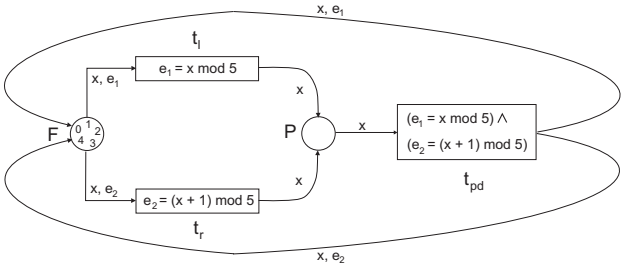


Fig. 3. Dinning philosophers by coloured Petri net

linear formula (5) where we consider that the philosopher p_{1e} eats. This situation occurs after firing the transition t_{1f} which is expressed by linear formula (6).

$$f_1, f_2, f_3, f_4, f_5, f_1 \otimes f_2 \multimap p_{1e} \vdash f_5 \otimes (f_4 \otimes (p_{1e} \otimes f_3)) \tag{5}$$

$$f_3, f_4, f_5, p_{1e}, p_{1e} \multimap (f_2 \otimes f_1) \vdash f_5 \otimes (f_4 \otimes (f_3 \otimes (f_2 \otimes f_1))) \tag{6}$$

All formulae we use in this paper are provable in sequent calculus of intuitionistic linear logic. We do not present all of them because of limited space.

IV. Coloured Petri Nets and Corresponding Linear Formulae

Coloured Petri Nets (CPN) were designed for modeling systems where original PNs fail or become very complex and awkward. Principles and examples of CPNs were published in many papers, e.g. in [5], [6], [4], [1]. CPNs can be also drawn graphically. They also consist of places and transitions, every place contains some number of tokens. Tokens are distinguished by their colour, where a token represents a value and its colour a data type. Every place has a set of enabled colours. Every transition has a condition represented by a booloean expression consisting of variables, constants and operations and has to be evaluated to the boolean value. Every arc has an arc expression, an arithmetical expression that is evaluated to a colour in the colour set of input/output place. A transition is enabled if all following claims are satisfied:

- its condition is evaluated to true;
- the set of enabled colours of output place is subset of the set of enabled colours of input place of given transition;

Arc expressions are evaluated by replacing variables by values. During transition firing:

- input arc expression is evaluated and corresponding colour is removed from the input place;
- output arc expression is evaluated and corresponding colour is added to the output place.

In Fig.3 we present CPN for dinning philosophers.

This CPN contains only two places p for dinning philosophers and f for forks. We have three transitions:

- t_l for obtaining left fork;
- t_r for obtaining right fork;
- t_{pd} for putting down both forks.

We denote colours by the numbers $0, 1, \ldots, 4$ and the set of enabled colours for both places p and f is

$$Colours = \{0, 1, 2, 3, 4\}$$

We use one variable x that can be substituted by elements of $Colours$. Transition conditions are as follows:

- for t_l the transition condition is the boolean expression $e_1 = x \ mod \ 5$;
- for t_r the transition condition is the boolean expression $e_2 = (x + 1) \ mod \ 5$;
- for t_{pd} the transition condition is $(e_1 = x \ mod \ 5) \wedge (e_2 = (x + 1) \ mod \ 5)$

and arc expressions are:

- input arc expressions for t_l are x, e_1;
- input arc expressions for t_r are x, e_2;
- input arc expression for t_{pd} is x;
- output arc expressions for t_l is x;
- output arc expressions for t_r is x;
- t_{pd} has two output arcs, therefore it has two pairs of arc expressions x, e_1 and x, e_2.

The CPN in Fig.3 is simpler as classical PN and works as follows. In the beginning, the place f has all colours of the set $Colours$. A philosopher p can eat if he has both left and right forks computed by $e_1 = x \ mod \ 5$ and $e_0 = (x+1) \ mod \ 5$. In the case $x = 0$, $e_1 = 0$ and $e_2 = 1$. That means, the transitions t_l and t_r become enabled and can be fired. The philosopher obtain token of colour 0, i.e. the philosopher 0 starts to eat. After dinner, he puts down both forks, transition condition is true and the transition t_{pd} can be fired. Arc expressions ensure that correct forks (colours 0 and 1) are returned to the place f. This CPN enables parallel execution, two philosophers, but not the neighbors can eat and deadlock cannot arise.

For translating this CPN to ILL formula we introduce two predicate symbols:

- F - for forks;
- P - for philosopher.

Terms e are constructed according following syntax:

$$e ::= x \mid n \mid e + e \mid e \ mod \ e \tag{7}$$

where x is a variable, n is natural number, $e_1 + e_2$ is sum of terms and $e_1 \ mod \ e_2$ is operation returning remainder of division a value of the expression e_1 by the value of the expression e_2. Let e_1 and e_2 be:

$$e_1 = x \ mod \ 5 \qquad \text{and} \qquad e_2 = (x + 1) \ mod \ 5 \tag{8}$$

We formulate the following predicates:

- $P(x)$ for x-th philosopher;
- $F(e)$ for the fork of colour e.

Transitions we construct as linear implications:

$$\begin{aligned} t_l &\equiv \quad F(e_1) \multimap P(x) \\ t_r &\equiv \quad F(e_2) \multimap P(x) \\ t_{pd} &\equiv \quad P(x) \otimes P(x) \multimap F(e_1) \otimes F(e_2) \end{aligned} \tag{9}$$

The behavior of CPN of dinning philosophers we formulate by the ILL sequent:

$$F(e_1), F(e_2), t_l \otimes t_r \vdash P(x) \otimes P(x) \tag{10}$$

that is provable. Releasing forks and firing p_{pd} we formulate by the sequent:

$$\begin{aligned} P(x) \otimes P(x), t_{pd} &\vdash F(e_1) \otimes F(e_2) \\ t_{pd} &\equiv P(x) \otimes P(x) \multimap F(e_1) \otimes F(e_2) \end{aligned} \tag{11}$$

Now we have translated coloured Petri net for five dinning philosophers to the corresponding provable ILL formulae.

V. Conclusion

In this paper we would like to show a method how to transform a working Petri net modeling behavior of a system to the corresponding provable intuitionistic linear logic formula. We have extended our approach to the coloured Petri nets by simple extension of ILL. On examples we have shown also an actual problem of component composition used in component-based systems which can lead to arising of new problems that need to be identified and solved. Our approach enables to formulate its solutions by corresponding provable ILL sequents.

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Compressed sensing theory, implementation and applications

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***Abstract*—Compressive sensing (CS) came up in recent years as a promising way of sub-Shannon signal acquisition. This paper presents the principle of CS, and reviews basic methods of analog-to-information conversion (AIC). Several practical applications of CS have been published during the last year, an overview of which is included at the end of the paper.**

***Keywords*—Analog-to-Information Conversion, Compressed Sensing, Nonuniform Sampling, Random Modulation Preintegration, Wireless Sensor Network.**

I. Introduction

The task of sending an increasing amount of data in decreasing timespan makes data acquisition a challenging task. The development of faster *analog-to-digital converters* (ADCs) does not hold track with the development of faster *digital signal procesing* (DSP) devices, and will likely become a bottleneck of data acquisition frameworks in the near future. Moreover, increasing dataflow calls for higher demands on communication networks. A possible means of addressing these issues is *compressed sensing* (CS), which utilizes sub-Shannon sampling of sparse signals. Instead of acquiring signal values using equidistant time steps according to Shannon sampling theorem, the signal is condensed into a few values, which is referred to as *analog-to-information conversion* (AIC). Compressed sensing has a wide field of possible aplications, which would benefit from simplified sampling tasks.

II. Theory of Compressed Sensing

The two most important characteristics of a signal that CS can be applied to are sparsity, and the possibility to obtain the signal as a linear combination. Sparsity can be fulfilled for any arbitrary domain, in which the signal of interest can be represented as a linear combination of basis functions. The sparsity of a signal is defined with the number of basis functions that are needed to represent the interesting signal. A signal composed of *s* basis functions is *s*-sparse. We define the *N* basis vectors $\boldsymbol{\psi}_n \in \mathbb{R}^{N\times 1}, 0 \le n < N$ to represent any of the possible input signals. Then the columns of the square basis matrix $\boldsymbol{\Psi} \in \mathbb{R}^{N\times N}$ consist of basis vectors $\boldsymbol{\psi}_n$. Linear combination is conducted by the *s*-sparse vector $\mathbf{x} \in \mathbb{R}^{N\times 1}$, so the input signal vector $\mathbf{f}$ is

$$\mathbf{f} = \boldsymbol{\Psi}\mathbf{x}. \tag{1}$$

A. Analog-to-Information Conversion

Instead of performing a signal acquisition conforming the sampling theorem, the signal is correlated with $M < N$ measurement signals, which are represented in the *M* rows of measurement matrix $\boldsymbol{\Phi} \in \mathbb{R}^{M\times N}$. This step performs the AIC, yielding the information signal

$$\mathbf{y} = \boldsymbol{\Phi}\mathbf{f}. \tag{2}$$

If input signal vector $\mathbf{f} \in \mathbb{R}^{N\times 1}$ is *s*-sparse on basis $\boldsymbol{\Psi}$ with $s < N$, it can be recovered from *M* linear projections onto a second basis $\boldsymbol{\Phi}$. Bases have to be incoherent, meaning that the rows $\boldsymbol{\varphi}_m$ of matrix $\boldsymbol{\Phi}$ cannot sparsely represent the columns $\boldsymbol{\psi}_n$ of sparsity-inducing matrix $\boldsymbol{\Psi}$, and vice versa. Sparse signal can then be reconstructed with $M << N$, providing that *M* is slightly greater than *s*. Inserting (1) into (2) gives

$$\mathbf{y} = \boldsymbol{\Phi}\boldsymbol{\Psi}\mathbf{x}, \tag{3}$$

with the reconstruction matrix

$$\mathbf{A} = \boldsymbol{\Phi}\boldsymbol{\Psi} \in \mathbb{R}^{M\times N}. \tag{4}$$

Fig. 1 summarizes the complete CS framework.

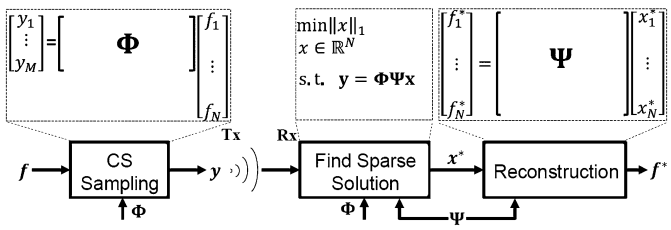

Fig. 1. Complete CS framework

Because $\mathbf{y}$ contains the values that are actually measured, the only unknown quantity is $\mathbf{x}$. If $\mathbf{A}$ was a quadratic matrix, the problem could be solved simply by inverting $\mathbf{A}$, which would mean applying the sampling theorem. But as $\mathbf{A}$ is a rectangular matrix, it cannot be simply inverted. Thus it appears, that an underdetermined system of *M* equations and *N* unknowns is to be solved. At this point, the importance of sparsity turns out, because based on this requirement a unique solution for the system of equations can be found. Due to given sparsity it can be assumed, that out of all the possible solutions, the right solution $\mathbf{x}_0$ is the one that is the most sparse [1], [2], [3].

B. Determination of Sparsity

The sparsity s of $\mathbf{x}_0$ is in general equivalent to the ℓ_0 pseudo-norm of $\mathbf{x}$. The ℓ_0 norm is defined as number of non-zero vector elements:

$$\ell_0 : \|\mathbf{x}\|_0 := \{i : x_i \neq 0\} . \tag{5}$$

Sparsity is an additional information used to find the optimal solution of (3), forming optimization problem

$$\min \|\mathbf{x}\|_0 \text{ subject to } \mathbf{Ax} = \mathbf{y} . \tag{6}$$

It was deduced in [4], that for highly sparse signals the norm

$$\ell_1 : \|\mathbf{x}\|_1 = \sum_{i=1}^{n} |x_i| \tag{7}$$

can be used, and it is preferable since it leads to a convex optimization problem

$$\min \|\mathbf{x}\|_1 \text{ subject to } \mathbf{Ax} = \mathbf{y} . \tag{8}$$

This guarantees a correct optimal solution, if it exists, and more efficient optimization algorithms may be used.

Based on the ideal definition of sparsity, it should be easy to find the sparsity of a signal simply by counting the number of nonzero signal elements in sparse domain. Unfortunately, for all real signals the representation of input signal in sparse domain has non-zero elements. There are a few large values, with other elements small but not zero [5]. To address this issue, in [6] was proposed a new metric called *sparsity number*

$$s_{\mathbf{x}} = \frac{\|\mathbf{x}\|_1^2}{\|\mathbf{x}\|_2^2} = \frac{\left(\sum |x_i|\right)^2}{\sum x_i^2} . \tag{9}$$

To find the sparsity number of a signal we first need to transfer that signal to the sparse domain. For some signals the sparse domain is known, e. g. frequency or wavelet. For many signals there is not a specific domain for this purpose, and we must use dictionary learning to transfer the signal $\mathbf{f}$ to its sparse representation $\mathbf{x}$. Known or correctly trained set of basis functions $\mathbf{\Psi}$ yields high compression ratio and low reconstruction error.

III. Implementation of Analog-to-Information Conversion

The key advantage of AIC is the utilization of sub-Shannon sampling, which with sparse signals yields no information loss. Depending on actual signal sparsity, this allows AICs to have several advantages over conventional ADCs, such as lower power consumption and lower data transfer rate. In applications, where signal frequency bandwidth is very high or not inherently limited, AICs are a potential solution to overcome performance limitations of high-speed ADCs. However, there are practical issues in implementing AICs, that restrain the achievement of these properties and need to be considered [7].

The stability and programmability of DSP systems has motivated the relocation of ADC to the front-end of signal processing system, in order to perform as much processing as possible in digital domain. An AIC as described in chap. II.A is directly implementable in digital domain, but the resulting device would utilize a conventional ADC and a DSP system. This would result in lower data transfer rate, but the power consumption of such AIC would obviously be higher than with conventional ADC alone. AIC therefore needs to be implemented in analog domain in order to tap the most of its potential. There are two most promising methods of AIC, that are widely discussed in literature and have been succesfully implemented: *random modulation preintegration* (RMPI), and *nonuniform sampling* (NUS) [8].

A. Random Modulation Preintegration

Following the AIC description in chap. II.A, we need to obtain M linear projections of input signal $\mathbf{f}$ onto the basis matrix $\mathbf{\Phi}$ (2). For this to be possible to implement in analog domain, RMPI poses additional constraints.

Let the input analog signal be composed of a finite number of weighted dictionary components

$$f(t) = \sum_{n=1}^{N} x_n \psi_n(t) , \tag{10}$$

where x_n are the elements of s-sparse vector $\mathbf{x}$, and $\psi_n(t)$ are analog equivalents of basic vectors $\boldsymbol{\psi}_n$. Although each of the dictionary elements $\psi_n(t)$ may have high bandwidth, with highly sparse $\mathbf{x}$ the signal has few degrees of freedom [9].

The measurement matrix $\mathbf{\Phi}$ used in RMPI is a pseudo-random matrix of ±1's, constructed in such a way so that it has maximum possible rank (equal to M). The randomness and high rank of $\mathbf{\Phi}$ ensure its incoherence with $\mathbf{\Psi}$. Values of elements of $\mathbf{\Phi}$ are chosen to be ±1, so that the multiplication could be simply implemented in analog domain by a switch.

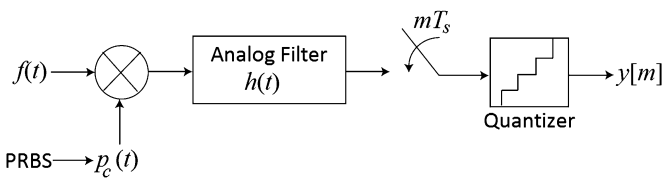

Fig. 2. Pseudo-random demodulation preintegration AIC

As seen in Fig. 2, RMPI AIC consists of three main components: demodulation, filtering and uniform sampling. The input signal is modulated by chipping sequence $p_c(t)$ of ±1's with zero average, obtained from *pseudo-random bit sequence* (PRBS) generator. This sequence must alternate between values at or faster than the Shannon frequency of the input signal. The purpose of demodulation is to spread the frequency content of input signal so that it is not lost in the second stage of the system. Demodulated signal is filtered by an anti-aliasing filter with impulse response $h(t)$, and sampled with sampling period T_s using a conventional ADC. The output $y(t)$ as a result of demodulation and convolution is

$$y(t) = \int_{-\infty}^{\infty} f(\tau) p_c(\tau) h(t-\tau) d\tau , \tag{11}$$

which after insertion of (10) and sampling gives

$$y[m] = \sum_{n=1}^{N} x_n \int_{-\infty}^{\infty} \psi_n(\tau) p_c(\tau) h(mT_s - \tau) d\tau . \tag{12}$$

Elements of the reconstruction matrix $\mathbf{A}$ (4) are now separable, for row m and column n:

$$a_{m,n} = \int_{-\infty}^{\infty} \psi_n(\tau) p_c(\tau) h(mT_s - \tau) d\tau . \quad [10] \tag{13}$$

The effect of quantization may be modeled as additive noise, so we view the measurements as

$$\mathbf{y} = \mathbf{\Phi f} + \mathbf{q} = \mathbf{Ax} + \mathbf{q}, \tag{14}$$

where $\mathbf{q}$ represents the combination of the quantization effect and noise inherent to the measurement process. This must be considered during the reconstruction, with the minimalization problem (8) modified to

$$\min \|\mathbf{x}\|_1 \text{ subject to} \|\mathbf{y} - \mathbf{Ax}\|_2 \le \varepsilon \tag{15}$$

to account for the noise magnitude $\varepsilon \ge \|\mathbf{q}\|_2$.

RMPI is an efficient method of AIC, which can be used on analog signals sparse in any domain. RMPI AICs have 2-10 times lower power consumption than high-speed ADCs, and achievable output data transfer rate may be even lower. But the signal encoding, typically realized by a mixer-like circuit, still occurs at Shannon rate, which limits the bandwidth of AICs to that of high speed ADCs [11]. To overcome this, in [12] was proposed a spread spectrum RMPI, with additional premodulator which allows to lower the modulators' working frequency.

B. Nonuniform Sampling

The NUS exploits the incoherence of time and frequency, in order to subsample the Shannon grid in time. The subsampling is random, meaning that the time points at which the signal is sampled are selected randomly, so there is no coherent aliasing effect. In such case, frequency sparse signals can be recovered via nonlinear processing. With no noise present, *s*-sparse signal (with *s* active frequencies) can be exactly recovered, provided that slightly more than *s* samples are taken [8].

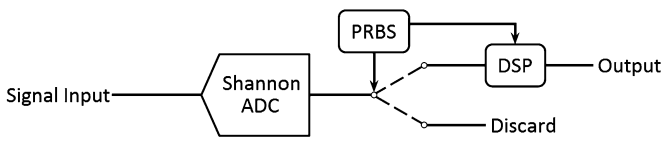

Fig. 3. Nonuniform sampler

Conceptually, NUS takes Shannon-rate samples of input signal, and then randomly discards most of the samples according to PRBS. Sampling is therefore nonuniform, but samples are spaced with integer multiples of underlying Shannon rate. Let $F[\omega]$ be the discrete Fourier transform of uniformly sampled input signal $f[m]$. Given that the input signal is *s*-sparse in frequency domain, $F[\omega]$ has only *s* non-zero entries. Now we collect only a subset Ω of all the elements of sampled input signal, with *M* sample locations chosen at random. According to [13], it is possible to exactly recover the input signal by solving

$$\min \|F'[\omega]\|_1 \text{ subject to} \forall m \in \Omega, f'[m] = f[m], \tag{16}$$

where $f'[m]$ denotes the reconstructed signal.

Power consumption of NUS may be reduced by using ADC triggered by PRBS, rather than discarding samples of conventional ADC. NUS is a less powerful CS approach than RMPI, effective only with signals sparse in frequency domain. The implementation however is much simpler, with minimal analog signal processing needed [14].

Different approaches to NUS were also proposed, such as asynchronous ADC in [15]. As opposed to [14], samples are not taken randomly, but rather at time instants when the signal crosses predefined threshold (quantization) levels. This leads to nonuniformly spaced samples in time, and sample rate which adapts to the rate of change of the input signal, as shown on Fig. 4. As a result, the average sample rate can be much lower than the sample rate of a conventional Shannon ADC, which is restricted to at least twice the input bandwidth.

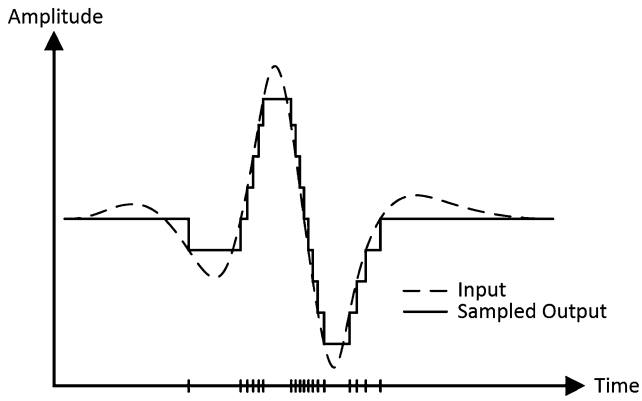

Fig. 4. Nonuniform sampling of a signal by asynchronous ADC

Asynchronous ADCs have potentionally high compression ratio and low power consumption, but they are only effective with signals sparse in time [16]. Major drawback is that hardware phenomenons such as nonideal code transition levels and hysteresis cause shift of the time instants at which the samples are taken. This causes significant distortion, since only the time between samples is actually quantized and encoded.

IV. Compressed Sensing Applications

The advantages of CS are briefly listed in chap. III. For real-world applications, the most obvious advantage of CS over conventional sampling is the ability to reduce output data transfer rate and power consumption of a sensor. Research has proven, that this ability makes CS perspective for implementing *wireless sensor networks* (WSNs). Moreover, since AIC transforms sparse signals to a suitable descriptive domain, CS is also a powerful tool for signal analysis. The possibility of signal recovery from limited number of measurements also makes CS theory applicable in data compression and encryption. Here we present an overview of various applications of CS, that have been studied.

The goal of digital modulation recognition is to identify the modulation format of an unknown digital communication signal. With traditional sensing process based on Shannon sampling theorem, acquiring a signal with bandwidth of several GHz is difficult, and the amount of data to deal with is enormous. Moreover, the information rate of this signal is much lower, and it is sparse in some fixed domain. Since we only need to acquire some signal characteristics rather than to recover the signal itself, AIC is an efficient tool for modulation recognition [17].

In many industrial applications, the acquisition of temperature distribution in some sort of environment is beneficial or needed. A WSN with CS nodes can be used for this purpose, where CS allows to increase the number of sensor nodes without increasing the overall data transfer rate. In [18] such a network was adopted for refridgerated transportation of aquatic products. Temperature was measured in the range of -55°C to 125°C, with total error of 0.56°C

maximum. Direct implementation AIC was carried out by 8051 microcontroller, with N=1620 and M=256 (chap. II).

The task of temperature distribution sensing is to obtain the temperature distribution of a known environment from finite observation data. This may be needed, if the number of sensor nodes and/or their locations is limited for some reason. Several methods can be used to obtain the temperature distribution, e. g. interpolation or principle component analysis. According to [19], CS theory is also applicable, with advanced methods used to exact the basis vectors.

Advances in CS are recently enabling low-energy implementation of sensor nodes, which makes them suitable for biomedical sensing. Low power consumption and low data transfer rate of AICs was utilized in [20] for ambulatory ECG monitoring, using direct implementation AIC with learned dictionaries.

Significant deviation of signal from the template used for dictionary training causes a decrease in sparsity. In biomedical aplications, such deviations usually indicate some sort of disorder, which may be only transient. Monitoring of sparsity can be used for detection of such disorders, like cardiac arrhythmia or epileptic seisures [21].

A typical area, where the decrease of data transfer rates is crucial, is image and video processing. Application of CS theory in image processing has been studied in [22], with image encoded by a forward transform, and resulting sparse data being subsampled by AIC. Similar approach was proposed in [23], with focus on the reduction of acquisition time in magnetic resonance imaging.

To increase the data persistence in WSNs with N nodes, distributed data storage algorithms have been proposed to disseminate sensors reading throughout the network. A data collector can query an arbitrary small subset of M nodes, to obtain all N readings using CS theory. Such algorithms, like the one presented in [24], exploit the spatial correlation in sensors' readings to considerably reduce the total number of transmissions for data storage. Similar approach may be used in cloud-based applications for data encoding. If a pseudo-random sensing matrix is generated, the data are naturally encrypted – the sensing matrix is needed for joint recovery of multiparty data [25].

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Concern Management with Source Code Projections

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***Abstract*—Advances in integrated development environments made source code projections available in many programming tools. The dynamic code views they enable may present an option for working with scattered software concerns. In this paper we report about our work in the area of projectional tools and software concerns, and present a concept for concern-oriented development environment, where it will be possible to leverage identified concerns in tools providing various code views.**

***Keywords*—development environments, program comprehension, projectional tools, software concerns**

I. Introduction

Integrated development environments (IDEs) have become the most complex and complete toolsets for working with the source code. Their goal is to cover all phases of program's life cycle and to increase programmers' productivity. To this end, a contemporary IDE typically contains code editors, code browsers and analyzers, refactoring and build automation tools, debuggers, version control systems, and other tools.

Primarily code editors, various code structure browsers and search tools are used in the process of static code comprehension. In a modern IDE these tools "understand" the structure of the source code [1]: IDE parses the code to create its abstract representation as a form of *abstract syntax tree* (AST) and integrated tools can use it to provide structure-aware visualizations and operations. By this the tools can aid a programmer in code comprehension.

However, there are arguments in the existing research (e.g., [2], [3]) that there is a common deficiency among IDE tools: they do not take into account *software concerns* related to the task a programmer is working on. This results in calls for context-aware tools. There is also the issue of single dominant system decomposition. A programmer creating the code is the one who gets to decide on the structure it is going to have. Other programmers working with the code later must use this imposed structure, or, if it does not suit their needs, perform a permanent refactoring (and again impose a new structure).

Mainly these issues drive our work towards exploring the idea of *code projections* with connection to software concerns management. In this paper we summarize our previous work and present a concept for a concern-oriented development environment that can enhance code comprehension through the use of projections.

II. Managing Software Concerns

To explore possibilities for working with software concerns, we reviewed existing approaches and tools in [4]. In the same paper we described a study we conducted regarding useful concern description granularity in the source code.

A. Concern Management Approaches

The first significant advances in system modularization, separation of concerns and code comprehensibility were initiated by rising abstraction levels of programming languages. But even *concern-focused* programming paradigms specifically designed to capture crosscutting concerns, like *Aspect-oriented programming* or *Language-oriented programming*, do not addresses the issue of single decomposition resulting from the static souce code.

Another take on this problem is present in various approaches and tools supporting concern separation. We identified three types of existing approaches. They either (1) allow to build an external concern model, (2) use manual configuration based on code conventions to set up a remodularizing tool, or (3) use metadata present in the source code to explicitly assign concerns to program elements. Especially the dynamic code views with properties of projections enabled by the first type (e.g., *Concern Graphs* [5]) and third type (e.g., *Concern annotations* [6]) supported creation of views of high-level concerns identified in a system.

B. Determining Useful Concern Granularity

One property common to all found and reviewed approaches is the granularity level they use to describe concerns in the code: *declaration* of classes, class methods and fields. Although there are arguments about a balance between required effort and usefulness of this granularity [5], finer granularities were not evaluated. However, if concern-oriented projection are to be constructed on the basis of concern description, the used granularity is important for the final result.

To find out what granularities would be used by programmers to capture concerns in the code if the used tool had no granularity limitations, we conducted a case study comprising of 5 programmers "tagging" concerns in a known code base with our own simple tagging tool. Tagged codes were written in languages C (participants *C1* and *C2*), Java (participants *J1* and *J2*), and Python (participant *P*).

The resulting distribution of concern granularity levels among tagged code fragments is shown in Fig. 1. We can see that each participant used a significant amount of tags covering a statement or a group of consecutive statements inside methods. And 19 out of all 85 identified concerns had this *statement* tags as their coarsest granularity.

Even though this study was only preliminary, its results indicate that the usage of *sub-method* concern granularities should be further evaluated, despite that existing tools do not use them.

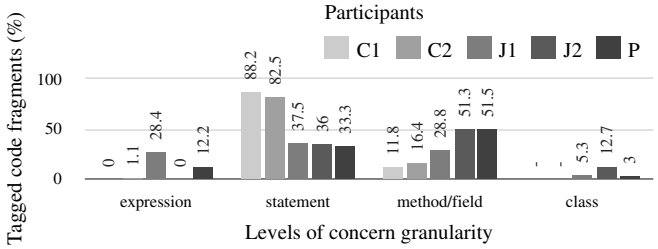

Fig. 1. Distribution of concern granularity levels among tagged fragments

III. The Ubiquity of Projectional Tools

Projectional editing [1] uses manipulation of the base system definition through projections that can provide multiple, dynamically built views of the system implementation. With their help programmers are able to adjust views of the system according to their current needs.

Projections were originally a feature constrained to *AST-based* editors that directly manipulate the abstract representation of a program. However, contemporary IDEs use a multi-layered language representation, where a concrete notation is parsed into an abstract model (AST) and presented through a set of views. Such *parser-based* editors are also capable of projections, because *presentation layer* can be altered independently of the storage format.

In [7] we looked at tools available in modern IDEs, like Eclipse, IntelliJ IDEA, or Visual Studio, from the perspective of projections and found a variety of tools that take advantage of the parsed AST. Reusing the categories established by Fowler in [1], we identified both editable and visualization projections, and we further divided them as follows:

- *Source code projections*, like contextual code highlighting, code folding or inlining, provide projectional features directly in the code editor.
- *Modeling projections* project code as editable diagrams.
- *Structure projections*, represented mainly by various project or file structure views, simplify navigation.
- *Domain-specific projections*, like user interface builders, support various application frameworks.

Apart from these projections, there is a whole group of experimental projectional editors originating in the research community that break traditional *file-based* paradigm. Some of these editors we described in [8]. In [9] we observed that canvas-based editor *Code Bubbles* [10] can be beneficial for programming tasks on a large project.

IV. Concern-oriented Development Environment

We also identified issues of projectional IDE tools. First, the lack of concern-oriented *configurability* of the environment, second, the inability to *compose* captured concerns for projection, and third, a general *reusability* issues. For our next work we want to focus on the *composability*.

We plan to design a solution that uses different sources of concern-related metadata for projection building. The solution would require a universal concern-related metadata structure with associations to pertaining program elements. Multiple projectional tools could be built on the basis of such metadata. This could lead to a *concern-oriented development environment* (CODE), where high-level concerns would have a more prominent role than in contemporary IDEs, because they would be able to directly participate in its tools.

Our initial concept for such CODE is inspired by the software visualization model described in [11] and also by the software concern model from [5]. The concept can be summarized as follows:

1) An IDE-produced AST will be used as an input.
2) This AST, generalized into a graph, will be enriched with additional concern-related information by a set of graph-transforming plug-ins.
3) The transformed graph will be used to extract concern-related subgraph with a *projection query*.
4) The result, an extended structure connected to the source code, will be used by IDE tools to drive their projections.

Although this concept does not address the presentation part of the projections, it provides a common ground for creating them and for experimenting with concern-oriented projections.

V. Conclusion and Future Work

Dynamic properties of code projections make them a promising approach for managing software concerns, but there are still open issues or insufficiently explored ideas.

The main goals of our future work are to develop the presented concept for concern-oriented development environment into a prototype implemented as an IDE plug-in and to design and evaluate code projection built on it. Evaluations will be directed at assessing usefulness of composed concern metadata and of their used granularity.

Acknowledgment

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Contribution to improving joints quality in power electronic

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***Abstract*—This paper is a summarization of last year of post gradual study. Solved research tasks and published articles are presented here. This work involves comparison between simulations of semiconductor temperature in standard power module with DBC substrate and power module with LTCC substrate by using flow water in channels for active cooling of die. Accurate prediction of temperature's power semiconductor devices in power electronic circuits is important for obtain optimum designs and estimating reliability level. The second aim of this paper is to present the method for automatic detection and localization of voids in die attach solder joint.**

***Keywords*—LTCC, power module, channels, die attach, voids detection.**

I. Introduction

The electronic devices used in power electronic applications have to work properly in a very wide temperature range from 20 to 200°C. Great temperature changes generate large thermal stress that affects solder joint reliability. Therefore, solder failure risk analysis has be carried out at the preliminary stage of the manufacturing and design of the new materials, devices and technologies [1].

One of the most important requirement in design of high power modules is to achieve a good thermal conductivity for cooling power chips and a dielectric strength for the isolation between semiconductor devices (IGBTs, diodes, thyristors) and device header (copper base plate). Various methods of temperature control can be used to regulation working temperature of the power electronic modules. For this reason is necessary study the thermal behavior of the power modules.

II. INITIAL STATUS

Nowadays, the most significant problems caused by high power electronic modules are high reliability of die attach at high temperature (> 200°C) as well as the thermal management method of die's cooling. Standard power devices consist of several materials and parts such as copper terminals, DBC substrates, solders, base plate, semiconductors and heatsinks. For this reason it is necessary to study all materials and technological steps which are used to create power electronic devices [2].

Low working temperature of power modules is necessary to achieve high quality and reliability of die attachment. For this purpose in power electronics use ceramic substrates which have high thermal conductivity, high dielectric strength and high reliability. For temperature reduction of die multilayer LTCC ceramic substrate which internal channels can be used. Cooling fluids can flow in these channels [3].

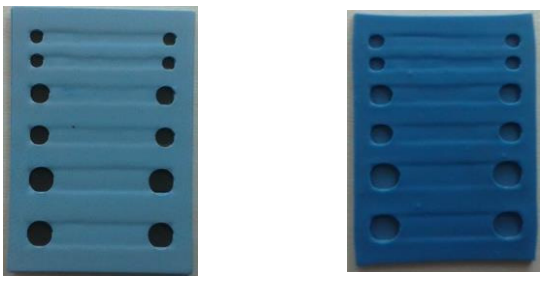
After studying theoretical background about materials, substrates, joints and manufacturing technological steps in power electronic we want to solve these PhD theses:

1. Analysis of thermal joints in power electronic which are created by three technological process.
2. Development, characterization and application of new types of solder alloys prepared by rapid cooling technique and joints created from them.
3. Development, characterization and application of new types of silver sintering joints.
4. Development of prototype of power electronic module based on multilayer LTCC substrate with internal channels.
5. Standard and new developed power electronics' joints analysis after thermal cycling and current loading.

III. Solved tasks in previous year

A. *Multilayer LTCC substrate with internal channels*

For the purpose of optimization of LTCC multilayer substrate's technological process with internal channels, we realized the samples of substrate with different channels' width (1, 1.5 and 2 mm) (Fig. 1).



a) b)

Fig. 1. LTCC multilayer substrate, a) with LTCC carbon tape after lamination; b) with channels after firing

The samples were realized in tree layers from Dupont 951® LTCC ceramic with 254 µm thickness. For temporary filler in central layer with channels LTCC carbon tape was used.

LTCC Carbon tapes have a thickness 200 µm and they are made of specially processed, high purity carbon. Tapes are engineered to burn out cleanly in oxygen atmosphere during firing process, and begin to rapidly sublimate at 600°C. The firing process of multilayer substrates consist of 3 steps. In first step at 350°C for 30 min with oxygen flow is used to burn out organic binder from LTCC and carbon tape. The second step at 820°C for 30 min with nitrogen flow allows for viscous sintering of the LTCC tape, and the final steps at 650°C for 10 min with oxygen flow is used to burn out the Carbon Tape with no residues and leave distortion free channels.

Analyses of created samples will be helpful in future experiment. After analyzing these samples we will be able to create substrates for power electronic module with complex topology structure of internal channels (spiral, meander, etc.).

B. Temperature simulations of power electronic module

Standard power module based on DBC substrate and power module based on LTCC substrate with internal channels was analyzed by Mentor Graphic Flo EFD® simulation software. This power module consist of copper base plate, different solder alloy (SnCu3In0.5, PbSn5Ag2.5, Sn96.5Ag3.5), copper power terminal, two DBC or one LTCC substrate, and two power diodes.

Power loss of diodes was set to 10 W and temperature of environment was set to 20°C. The maximum temperature of diodes on DBC substrates was 186.5 °C. Working temperature is decreased by big heatsinks or fans in standard power modules. However, this heatsink have lot of disadvantages such as high weight, dimensions, low effectiveness and high price. If the DBC substrate was changed for LTCC substrates with internal channels the temperature of diodes was decreased to 38°C. The proposed structure of channels in this simulation have shape of meander. The channels width was 2 mm, the thickness was 0.8 mm and total length was 128 mm. Water flowed in the channels from the left to right side at velocity 0.5 m.s^{-1} / 20°C. Diode on the left side had lower temperature about 0.8°C in comparison with the diode on the right side. This difference was caused by water flow from the left to right side.

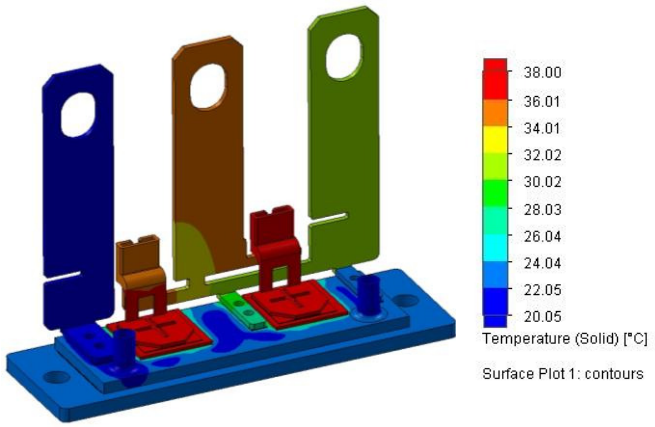


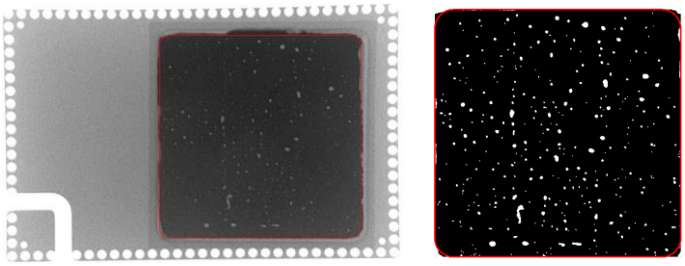
Fig. 2. The temperature simulation of power electronic module based on LTCC substrate with internal channels

The results show that LTCC substrate is suitable and promising technology for cooling of chips by internal channels. This substrate can be used as alternative to a standard DBC substrate in power module [4]. This technology can reduce working temperature of power module.

C. Die attach void detection and evaluation

Die attach in power electronic are the subject of interest because they have to fulfilled the requirements e. g. high thermal conductivity, mechanical strength, electrical conductivity and last but not least the high reliability. The most important factor is coefficient of thermal conductivity that is influenced by voids area. That is the reason why attach voids evaluation is the most important factor of joints quality in power electronics.

Measurement of voids presence realized by X-Ray analyzation is quite proper and exact method in practice. Within this work we develop new method for automatic detection and location of power chips, which were soldered on DBC substrate, and presence of voids area in die attach solder joint. The method of chip location is provided by two dimension correlation applied on X-Ray images. It is very important voids in solder joint detected, because during soldering process lot of voids and defects in die attach can occur. Basic indicator of joints' quality is quantity and size of voids in die attach. Automatic detection of chip and voids in die attach is achieved by techniques of image processing like filtering, energetic normalization, thresholding and image enhancement (Fig 3.) [5]. Automatic method improving evaluation of voids area in die attach that is expressed by percentage from the whole area.



a) b)

Fig. 3. a) The X-Ray basig image of die attach and DBC substrate; b) detailed and binary image of die attach area

IV. FUTURE (WORK)

In the future work we will focus on design, simulation and fabrication of power module based on LTCC substrate with different structure of internal channels (spiral, meander, etc.).

Secondly our experiments will be oriented to develop new type of solder alloy used in power electronic which will be created by rapid cooling technology.

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Correlation between user experience in electronic entertainment and psychophysiological measurements

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***Abstract*—With the increase in popularity of electronic entertainment (EE), the demand of optimization of its individual element arose. Big studios producing products of EE (movies, video-games, music, etc.) are benefiting from any gathered feedback from their customers. Customer's reaction to individual parts of the video-game might be invaluable for future level-designers, in form of information about each single aspect/feature targeted in the optimization process. In this paper, we present a study of individual checkpoints on the way of optimizing such EE products using artificial intelligence. We also present a way of using psychophysiological measurements of subjects playing video-games or watching movies to optimize their general EE experience.**

***Keywords*—Electronic entertainment, Psychophysiological measurements, Heart rate, Video-games**

Fig. 1: What Happens When Video-Games Can Read Your Face [6]

I. Introduction

Psychophysiological measurements proved to be an objective, continuous, real-time, non-invasive precise way to assess the game experience. Although, for best results, it is needed to carefully control the experiment using the specialized equipment (both problems addressed in following sections).

Using the psychophysiological data, we should be able to find correlation between various features in tested domain and current phychophysiological state of the subject. Thus, giving the developer the information about how the subjects reacts to current segment in the domain. In the past, researchers were trying to determine the players experience through set states, such as boredom, using known emotional states instead of psychophysiological measurements [1]. For example, if the subject playing a video-game is getting bored (state determined by an exact combination of psychophysiological states) while walking in the long corridor with no enemies, the level-designer has an option to either add some enemies (if the story line allows it - [2]). Some of the another options are to change the current music played, even changing the shape of the corridor completely using a Procedurally Generated Content (PCG) algorithm [3]. This implies that video-games may definitely be considered as an emotional experience [4].

There are numerous psychophysiological measurements which may be useful for this research: Heart Rate (HR), Electro-dermal Activity - Skin Conductivity (EDA), Facial Electromyography (EMG), Electrocardiogram (ECG), etc. [5]. Although so far we have only used HR data. In the future, we are planning to gather information about subject's EDA and their individual emotional states using image recognition [6]. This opens another interesting course of research - finding a correlation between psychophysiological measurements and emotional states of the subjects. Fleming an Rickwood studied the difference between violent and non-violent video-games on children's arousal, aggressive and positive moods [7].

In our research, we plan to incorporate continuous HR data into similar demo as shown on Fig. 2. We will try to find a correlation between individual game events and responses of the subjects. Afterwards, we plan to use one the well-known artificial intelligence techniques to optimize user experience in specific domain.

II. Related Work

In the past the research of psychophysiological responses may have been focused on a different goal then optimization EE products - such as work of Ballard an Wiest in 1996, where they studied the effects of violent video-games on male's hostility and their cardiovascular responses [8]. Another interesting feature (while very easy to control during the game) is an amount of blood in the game. Barlett et. al. studied the effect of the amount of blood in a violent video-game on aggression, hostility and arousal of the players [9].

Of course, the domain with highest psychophysiological changes of subjects are horror movies and video-games. Dekker and Champion focused on said domain studying the effect of fearful experiences on the subjects [10].

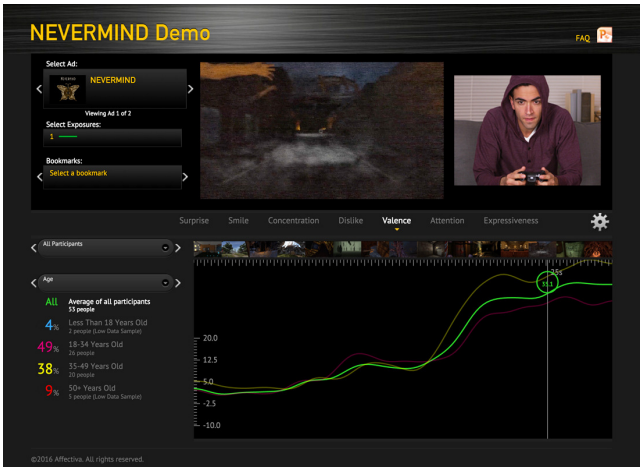

Fig. 2: Demo of Affectiva Software [13]

The experiments require fairly big number of subjects, since there are very different results throughout individuals as a players. Kallio et. al. determined up to 9 different types of gaming mentalities [11]. As stated in [12] by Tafalla, even subject's gender plays fairly important part in their psychophysiological responses during the experiment.

There is a fairly similar research done at MIT, studying player's responses to video-game in real-time, using the data gathered from subject's face (see Fig. 1) using image recognition techniques [13]. We expect this research's results to be very useful in conjunction with our data, hopefully even finding correlation between them.

III. Sensors

With the recent popularity increase of various wearable sensors, it becomes easier for developers to get valuable psychophysiological data as feedback from the customer during his EE experience. Up to recently, the most used way were simple questionnaires presented to the customers or effort to measure emotions of the subject using various image recognition techniques.

As previously stated, we have been using only HR data of the subject so far. Also only one subject has been tested during gameplay. For gathering the HR data series, we have been using the Fitbit Surge HR sensor[1]. After a brief survey of available wearable sensors, this one was chosen due to its ability to track HR during the whole day (instead of most available sensors which are tracking HR only during workout) and Fitbit's API provided for independent developers. The second sensor available for our research to gather HR data is Microsoft Band 2 which also meets said requirements[2].

For gathering EDA data (specifically Galvanic Skin Response - GSR) we are planning to use either non-commercial sensors connected to Arduino/Raspberry Pi or Shimmer3 GSR unit, which is considerably more expensive. After gathering enough GSR data, we are planning to compare it with HR data and find any possible correlation (indulging the research done in [14]).

Lastly, we will be using the facial features extracted from video stream of subject using Microsoft Kinect v2 sensor. Although Microsoft's SDK for Kinect only provides 3 basic emotional states of the subject, using image recognition we might be able to gather more specific information about subject's mood (such as [13]).

List of sensors which will be used in the research and their potential (desired) application:

1) Fitbit Surge HR for obtaining Heart Rate data.
2) Microsoft Kinect v2 for getting emotion data from face features.
3) EDA sensor for obtaining Galvanic Skin Response data real-time, to compare with HR

IV. Problem domains

Based on our extensive experience in the field, we have decided to try video-games as a starting domain of our research. Individual events in video-games are easy enough to keep track on, which is a major advantage when finding a correlation between them and subject's HR. We have chosen two games: Dota 2 (see section IV-A) and Hearthstone: Heroes of Warcraft (see section IV-B), both among the most popular games in their fields.

A. Dota 2

Dota 2 is a multi-player online battle arena (MOBA) game set in a three-dimensional (3D) graphical environment, presented from an oblique high-angle perspective. Two five-player teams compete in matches on an asymmetrical playing field. Each player commands one of 111 "Hero" characters, which feature unique abilities and styles of play. At the start of a match, all Heroes have an experience level of one: they level up, and become more powerful, by accumulating experience points through combat. Whenever a Hero gains a level, the player may unlock a new ability for them, or enhance their statistics.

Considering that Dota 2 as a multi-player game is played by two teams of 5 players, the possibility of another interesting research arises: Studying the effects of game events on each player within the team as well as whole-team impact. Having such data might open a possibility to simulate collaborative behavior of intelligent agents in a new way [15].

B. Hearthstone: Heroes of Warcraft

Hearthstone is a digital collectible card game that revolves around turn-based matches between two opponents, operated through Blizzard's Battle.net. Players can choose from a number of game modes, with each offering a slightly different experience.

Each Hearthstone match is a one-versus-one battle between two opponents. Gameplay in Hearthstone is turn-based, with players taking turns to play cards from their hand, casting spells, equipping weapons, or summoning 'minions' to do battle on their behalf. Unlike card games like Magic: The Gathering, the opposing player has no means to interactively interrupt or counter the current player's action during their turns, though may play cards on their turn that will create events that automatically respond to the other player's actions. Games may be between two players, or one human player and one computer-controlled opponent [16].

[1] https://www.fitbit.com/
[2] https://www.microsoft.com/microsoft-band/en-us

V. Experiments

As previously stated, we already did some elementary experiments in our research. We have tracked the subject playing 2 different video-games - Valve's Dota 2 and Blizzard's Hearthstone: Heroes of Warcraft (Hearthstone). The games were played in carefully controlled environment, where subject was not disturbed by any external events. These experiments already showed very different results emerging from the nature of the game itself. While Dota 2 as a Multi-player Online Battle Arena (MOBA) is more action-based game, Hearthstone is an turn-based card game.

Also, after a few sessions, we noticed the results vary slightly in each session. This might be caused by even minor changes in subject's current psychological or physiological state. Some of the factors affecting human involuntary neural system - thus the values of subject's HR are air temperature, body position, body size, medication use, even subject's satiation may take major part in the final outcome of the experiment. This again emphasize the importance of careful control over the experiments during our future research.

A. Dota 2

After 4 games of Dota 2, the subject showed an average 85.03 HR (see Fig. 4).

Resulting from the previous section, it has to be taken into consideration that recreating the same conditions for all experiments is near-to-impossible task. Especially when experiments are done with longer games, such as Dota 2, since it is difficult to play several games in a row at the same day.

After only a small amount of games played, we were already able to find some interesting patterns emerging from our experiments. It is obvious that HR of the player is rapidly decreasing while the player is dead (waiting for respawn). There are several spikes in the typical game of Dota 2, where the player is participating in so-called massfights (big encounter where most of the players are fighting enemy's team). In almost every game, there is also a significant spike in HR of player at the end of the game (see Fig. 3). This is caused due to most of the games ends with one last attempt of losing team to defend its base before conceding the victory to the enemy.

B. Hearthstone: Heroes of Warcraft

The subject played 3 sessions of Hearthstone games, one consisting of 4 games, other two of 2 games. Subject's average HR during the first two sessions was 76.97 (see Fig. 5). The third session showed average HR of 82,69 (see Fig. 6). Of course, while one Dota 2 game takes about 40 minutes to 1 hour on average, the typical Hearthstone game lasts for around 5-10 minutes. This is needed to be taken into account, since it is unlikely to preserve above-average HR for a long time during the game.

There are no obvious patterns visible from such low amount of experiments (compared to Dota 2), most likely caused by short nature of Hearthstone games. The results seem chaotic at first, but we are confident that after obtaining bigger dataset, some interesting patterns will be uncovered.

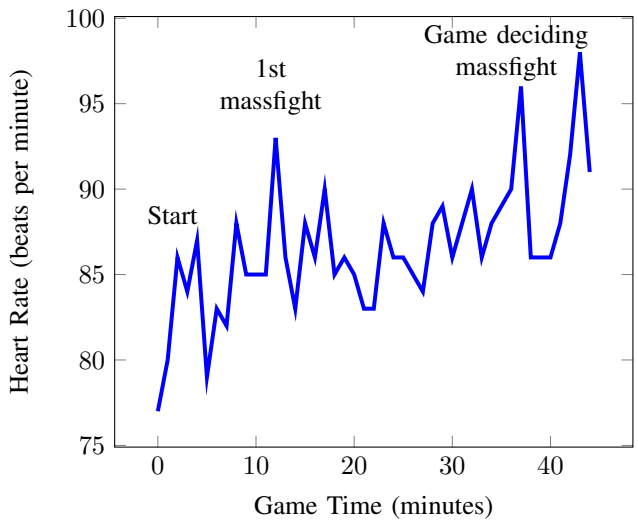

Fig. 3: Typical game of Dota 2 played by tested subject

Fig. 3 shows HR of subject during the game of Dota 2. Subject's HR increases significantly during massfights (big encounter where most of the players are fighting enemy's team), while decreases when the player is dead (waiting to respawn).

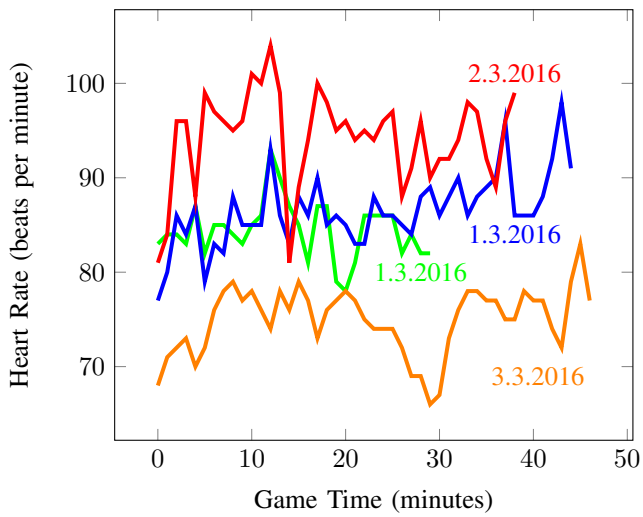

Fig. 4: 4 games of Dota 2 played by tested subject

Fig. 4 display similarities of subject's HR during 4 games of Dota 2, even though games were played in two different sessions. There are noticeable spikes of HR in several game stages, closely described in section VI.

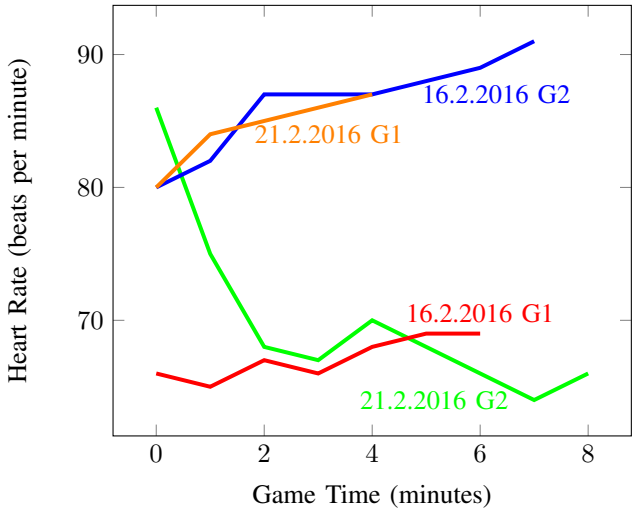

Fig. 5: Hearthstone: Heroes of Warcraft sessions 1+2

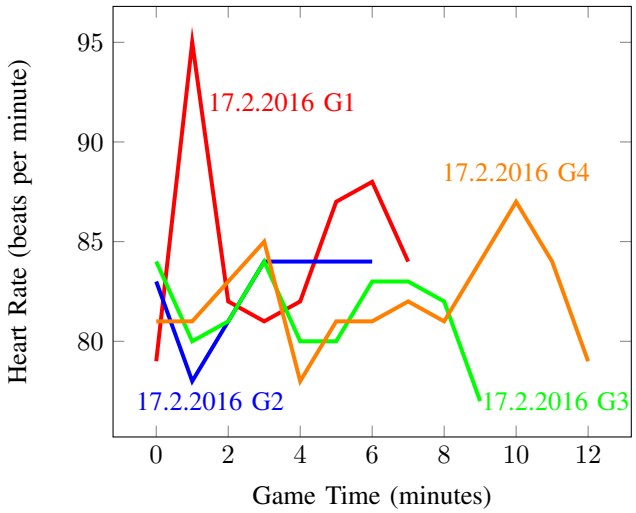

Fig. 6: Hearthstone: Heroes of Warcraft session 3

Both Fig. 5 and Fig. 6 show subject's HR during different Hearthstone games, played in different sessions. There are no obvious patterns to be seen due to low number of experiments done, this is to be changed in future research, more closely described in section VI.

VI. Conclusion and Future work

It has to be taken into consideration, that the domain has a major impact on the final data (even though we try to find a correlation). The data from both games are not easy to compare due to major difference in the game lengths.

After only a few games played by our subject, there are regular alteration in subject's HR. There are specific events which changed the HR whenever they occurred: start ot the game, first massfight, final (deciding) massfight. Also, the subject's HR decreased near to a minimum when waiting for their hero to respawn.

So far there are no particular HR-changing events found in Hearthstone. Nevertheless, this is likely to change after a higher number of experiments, even thought the game is less dynamic than Dota 2.

In future, we are also planning to run our experiments on one other genre: First Person Shooter (FPS) games, arguably the most dynamic genre of video-games. And finally, we are hoping to find differences between psychophysiological measurements of winning and losing players while understanding its effects on individual subjects.

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Covariance-based spectrum sensing

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***Abstract*—This paper presents a summary of the authors' recent research work in the area of single user and cooperative spectrum sensing based on the properties of the covariance matrix of the received signal. A brief overview of the state-of-the art literature showing the importance of the selected topic is provided. The major authors' contributions are presented.**

***Keywords*—Spectrum sensing, signal detection, cooperative sensing, sphericity test**

I. Introduction

The increased demand for spectrum usage in the recent years poses high requirements on the efficiency of spectrum utilization. Licensed parts of the spectrum are usually not utilized in an efficient way by the primary (licensed) users (PUs). One way of increasing the efficiency of spectrum utilization is to enable so called secondary spectrum access by secondary (unlicensed) users (SUs) to access spectrum holes (i.e. unused parts of the licensed parts of the spectrum), while avoiding to cause interference to the PUs. In order to exploit the spectrum holes, SUs must have timely and accurate information about their availability. The two most discussed approaches for providing this information to the SUs are *geolocation databases* [1] and *spectrum sensing* [2]. This paper presents a short summary of the authors' recent research work focused on spectrum sensing.

II. Initial status

The basic principle of spectrum sensing can be described as process, in which SU analyzes its radio environment, creates a test statistics from the received signal and based on this statistics, decides between two hypotheses: *PU transmitting* or *PU idle*. This process can be performed either locally by a single SU (single-user spectrum sensing) or by exchanging local sensing data in across a network of SU nodes (cooperative spectrum sensing).

A. Problem formulation

Let us consider the general model for Q-users cooperative spectrum sensing in the presence of P primary users. Let us denote $\mathcal{H}_0$ as the hypothesis of primary signal being absent and $\mathcal{H}_1$ as the hypothesis of primary signal being present in the signal received by the secondary users. The signal received by i-th secondary user can be then expressed as:

$$\mathcal{H}_0 \quad : \quad \mathbf{x}_i = \mathbf{n}, \tag{1}$$

$$\mathcal{H}_1 \quad : \quad \mathbf{x}_i = \mathbf{H}_i\mathbf{s} + \mathbf{n}, \tag{2}$$

where $\mathbf{x}_i \in \mathbb{C}_i^K$ is the data vector received by the i-th user, K_i is the number of the receiving antennas of the i-th user. The matrix $\mathbf{H}_i \in \mathbf{C}^{K_i \times P}$ contains the coefficients of the channel between the P primary users and the i-th secondary user. The $P \times 1$ vector $\mathbf{s}$ denotes the signals transmitted by P primary users and finally the $K \times 1$ vector $\mathbf{n}$ is the complex Gaussian noise with zero mean and covariance matrix $\sigma^2\mathbf{I}_{K_i}$, where the scalar σ^2 is the noise power. By combining the received data vectors from all i secondary users we obtain the combined received data vector $\mathbf{X} \in \mathbb{C}^{\prod_{i=1}^{Q} K_i}$

$$\mathbf{X} = [\mathbf{x}_1^T, \mathbf{x}_2^T, \ldots, \mathbf{x}_Q^T]^T \tag{3}$$

The problem of signal detection (and spectrum sensing) is to find function (test statistics) $\mathcal{T}(\mathbf{X})$ and threshold ϵ such that following error probabilities are minimized

$$P_{fa} = P\{\mathcal{T}(\mathbf{X}) > \epsilon | \mathcal{H}_0\}, \tag{4}$$

$$P_m = P\{\mathcal{T}(\mathbf{X}) < \epsilon | \mathcal{H}_1\}. \tag{5}$$

The probability P_{fa} is the probability of false alarm, i.e. the probability of falsely detect the presence of primary signal under $\mathcal{H}_0$. Reversely, the probability P_m is the probability of missed detection, i.e. the probability of falsely reject $\mathcal{H}_1$ hypothesis. The test statistics can be e.g. energy of the received signal, ratio of the maximum-to-minimum eigenvalue of the covariance matrix of the received signal, or some other quantity, which clearly differentiate between $\mathcal{H}_0$ and $\mathcal{H}_1$. In order to calculate the optimal threshold ϵ that minimizes P_{fa} and P_m, or that at least provides some predefined value of P_{fa}, it is necessary for the probability distribution of the test statistics to be known or at least approximately known. Therefore, for the practical application in signal detection in spectrum sensing, it is crucial to design test statistics with the reasonable level of distinction between the $\mathcal{H}_0$ and $\mathcal{H}_1$ hypotheses, provided that the designed test statistics have mathematically tractable probability distribution.

B. Covariance-based spectrum sensing

While there are several signal detection and spectrum sensing methods based on various characteristics of the received signal (e.g. energy-based detection [5], cyclostationary detection [6] or matched-filter detection), the author focuses on so called covariance-based detection [7], [8], which with its blind (i.e. no a priori information about the PU signal are required) nature provides outstanding signal detection performance in various scenarios.

Most of the publications in the area of covariance-based spectrum sensing focus on spectrum sensing performed just by single SU (i.e., $Q = 1$). For such case, several covariance-based test statistics have been proposed, i.e. maximum-to-minimum eigenvalue ratio [9], test statistics in the form of ratio of maximum eigenvalue to the geometric mean of the eigenvalues of the covariance matrix [7] or so called sphericity test [10] (ratio of the trace of the covariance matrix to its determinant). The author focuses mainly on the analysis of sphericity test in his research about covariance-based spectrum sensing. Although this methods is relatively well studied, it still lacks more precise and mathematically tractable description in terms of the probability distribution of its test statistics.

The generalization of the single user sphericity test is a very suitable candidate method also for cooperative detection ($Q > 1$). This generalization is denoted as multisample sphericity test and it was analyzed from the statistical point of view e.g. in [11]. This method has not been applied in spectrum sensing yet and thus it creates a lot of space for a scientific contribution in the area of cooperative spectrum sensing.

III. Results and publications

The most important results from the previous year of the authors' PhD. studies is the publication of a paper [12] in the Journal of Networks and Systems Management, a highly impacted CC journal. This paper tackles the problem of competition between the primary users in the process of dynamic spectrum allocation in spectrum trading. In the scenario under investigation, primary users compete between each other with the goal of selling as much spectrum resources to the secondary users as possible in order to maximize their revenue. It was shown that when the system is under/overutilized, the price competition and demand sensitivity as a major economic impact do not play a key role in the decision process of the SUs. Instead, the physical location of the SUs in the range of the PUs is of greater importance. Thus the resulting prices for the spectrum portions are uncorrelated in under/overutilized network. In contrary, if the network utilization is between $50 - 85\%$, the economic principles start to apply and strictly determine the market behaviour. Within that network utilization range, the price sensitivity of the SUs causes successful connections to the non-closest PUs, suppressing the effect of distance as the major physical factor considered in this paper. This research was made with the cooperation with the team from the Department of Finance at the Faculty of Economy, TUKE.

The author spent 10 months (from December 2014 to September 2015) at the Victoria University of Wellington (VUW) as a visiting PhD. student via Erasmus-Mundus THELXINOE exchange program, in which Technical University of Košice participates.

The activities carried out during the authors' research mobility and the subsequent results can be summarized as following:

- The area of the covariance-based spectrum sensing has been thoroughly studies and the key publications in this area were identified.
- An extended approximation of the probability distribution of the test statistics for the sphericity test based on Chi-squared distribution was proposed. Another approximation of the probability distribution of the test statistics for the sphericity test based on the series of derivatives of the normal distribution was proposed. These approximations are more accurate than the ones proposed in the state-of-the are literature and thus provide better performance of the spectrum sensing mechanism.
- A novel method for cooperative spectrum sensing based on multisample sphericity test was proposed and analyzed. The performance of the proposed method seems to be better than the existing methods for cooperative spectrum sensing. The detailed performance results are still being evaluated.

These results are being prepared and planned for publication at international conferences and in a highly impacted journal in the cooperation with researchers from VUW.

IV. Future research

In the future, the author is planning to focus on further analysis of the proposed cooperative spectrum sensing method. Special attention will be posed to the effects of quantization of the test statistics and its influence on the spectrum sensing performance. Also the author is working on the detection method based on a statistical method denoted as *meta-analysis* in the cooperation with the colleagues from VUW.

Acknowledgment

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Current State of Control and Modeling of Complex Systems Using Fuzzy Cognitive Maps

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***Abstract*—In this paper we present a current state of our research in the area of intelligent control and modeling of complex systems. We focus on recent progress in solving this research task with an implementation of a new multi-purpose Fuzzy Cognitive Maps library and accompanying graphical user interface. In the last section of the paper we outline our plans for further work in which we will make the proposed library available on cloud via web API and use it to apply the Three-Term Relation Neuro-Fuzzy Cognitive Maps methodology to modeling and control of selected complex systems, specifically the multi-agent robot system and the small turbojet engine.**

***Keywords*—fuzzy cognitive maps, modeling, control, complex systems,**

I. Introduction

The main objective of our research as stated by the title of my future PhD thesis is the "Utilization of means of computational intelligence in situational control of complex systems". We have chosen the Fuzzy Cognitive Maps (FCM) as the selected intelligent method because of its universal properties which suitably combine the approximation capabilities of neural networks and readability of rule-based fuzzy systems.

II. Initial State of Research

In the previous period we focused on finding a solution to several drawbacks [1] related to the vanilla FCM, which are tied to its capabilities to model dynamic nonlinear relations within complex systems.

In order to tackle these problems, we proposed a novel Term Relation Neuro-Fuzzy Cognitive Maps (TTR NFCM) methodology [3] which enhances the conventional FCM by two new features. The first addresses the dynamics of concept relations by inclusion of trends in the concept update formula using the Three-Term Relations (TTR), which are inspired by control engineering methods, namely the PID controllers. The second main feature is the replacement of simple linear weights between concepts by small nonlinear feed-forward neural networks or multilayer perceptrons (MLPs).

In order to evaluate this method and to tackle the problems and deficiencies of existing tools which are available for FCM modeling, we proposed a new general multi-purpose library [4] which is currently being implemented.

III. Current State of Research

In our recent work we dealt with the implementation of the proposed library [4] along with a compatible graphical user interface. We also successfully deployed the library for simple computations and modeling within the Matlab environment.

A. Implementation of Multi-Purpose FCM Library

We proposed the FCM library (see Fig. 1) with the simplicity of model prototyping in mind. The library is also designed to supports various methods for relation expression (e.g. the TTR-NFCM) and in the future it will also provide built-in learning mechanisms to adjust the FCM parameters.

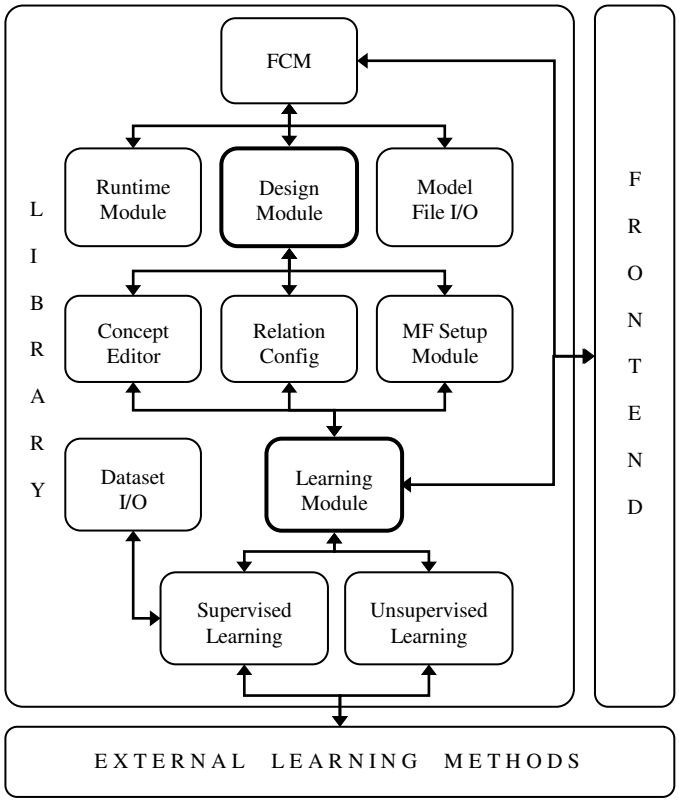

Fig. 1. A system diagram of the proposed FCM library[4].

After a careful consideration of several aspects related to the library implementation [4], we decided to develop it as a shared dynamic library (DLL) using the .NET framework,

which is well integrated within modern versions of Windows OS. This way it can be easily incorporated into various programs within several programing languages and environments, such as Python, Matlab, Simulink, WPF, etc.

Among the functions which the library offers, we can count the following:

- add, remove, connect, disconnect concepts,
- change concept relations (weights),
- list concept names, rename concepts,
- get and set concept activation value,
- set concept fuzzification function,
- save and load the map.

The library has already successfully undergone a preliminary tests within the Matlab environment and is freely available to download at [5].

B. *Implementation of Graphical User Interface*

Along with the library we also developed a graphical user interface (see Fig. 2) based on Windows Forms with help of Microsoft Automatic Graph Layout (MSAGL) library [6]. The MSAGL provides a support for online user interaction with the designed FCM and also allows to render the updates of the concept activation values in the real-time during the map simulation. The GUI wraps all the functions provided by the FCM library mentioned in the previous section of this paper.

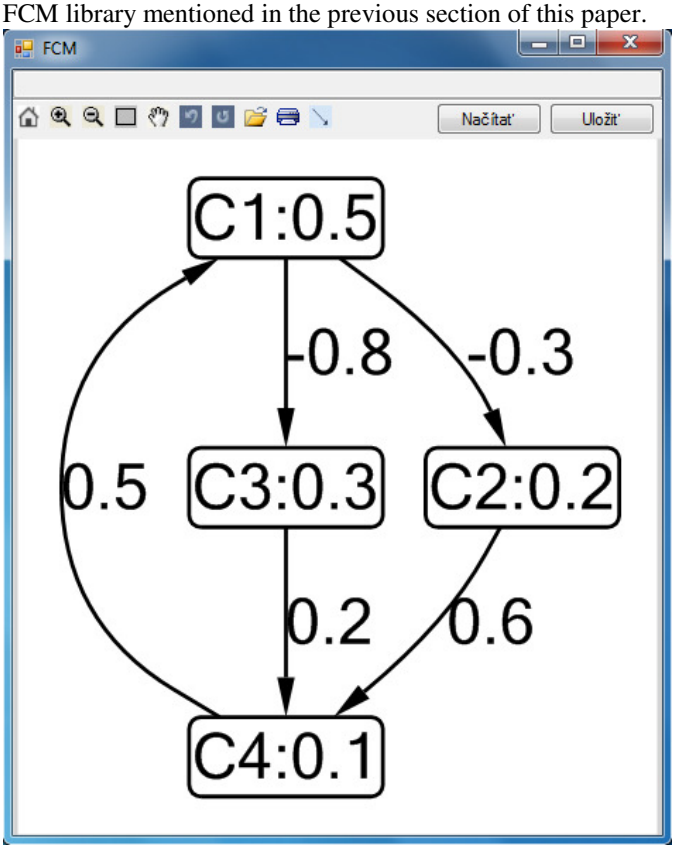

Fig. 2. Current state of FCM graphical user unterface.

IV. Future Work

Our current goal is to finish the library implementation and complete the learning module which will support the adaptation of the map using evolutionary and population based optimization and also the supervised learning using the backpropagation of error method.

Consequently we will proceed with the exposure of the library FCM engine running on cloud via API, which will provide access to all the functions of the library as stated in the end of the section III.A of this paper.

After that, in accordance to the objectives of my future PhD thesis [7], we will use the library to specific control-related tasks in the area of multi-agent robot systems and also to create an experimental model of the ISTC-21V engine (see Fig. 3) using the proposed TTR NFCM method.

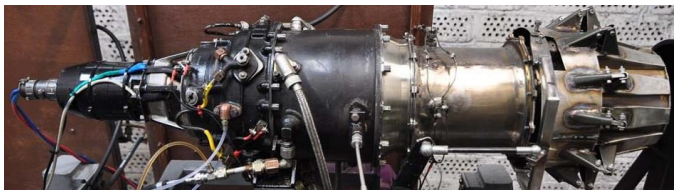

Fig. 3. Small turbojet engine ISTC-21V [8].

After the method is successfully applied and evaluated for the purpose of system modeling, we will proceed with a design and implementation of an FCM controller for the ISTC-21V engine. Our goal is to simplify and outperform the existing control system (which currently consists of several different control algorithms) with a single unified approach.

Acknowledgment

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Cyber-Physical Systems, Modelling Framework and Application into Distributed Control Systems

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***Abstract*—This paper introduces cyber-physical systems (CPS), their applications and challenges in the real environment, as well as characteristic features. One of the defining characteristic of the CPS is the hybrid description and the most general hybrid modelling via discrete hybrid automata (DHA) is presented. Subsequently an example of hydraulic CPS is written in the form of DHA and set into distributed control system (DCS) in the possibilities of DCAI, FEEI, TUKE. Study and enrichment of the CPS research field is the content of my dissertation thesis *Hybrid Models of Cyber Systems and their Application into Distributed Control Systems*. Moreover, DCS, which can be considered as CPS, is compared with DCS implemented at CERN, as it is also part of my dissertation thesis.**

***Keywords*—cyber-physical system, embedded system, hybrid system, discrete hybrid automata, distributed control system.**

I. Introduction

Cyber-physical systems refer to the tight integration of computational and physical resources [1], [2]. Research advancement in the area of CPS will surely transform our world with systems that are more precise (robotic surgery, nanotechnologies), work in dangerous and inaccessible environments (fire-fighting, autonomous systems for search and rescue), respond more quickly (autonomous collision avoidance), provide distributive coordination (automated traffic control), are highly efficient and augment human capabilities (assistive technologies, health-care monitoring) [3]. From this point of view many research challenges emerge: CPS composition, security, safety and robustness of CPS, architecture of CPS, sensor and mobile networks, control and hybrid systems, model-based development and verification of CPS, etc. [4].

Dealing with the challenges that CPS provide is a crucial part of my dissertation thesis, precisely, model-based development and verification of CPS.

Next topic in my dissertation thesis is the implementation of CPS into distributed control systems (DCS). DCS are large scaled and complex systems composed of layers from the lowest, which is represented by real processes and dynamical systems, up to the coordination/management layer.

II. Cyber-physical systems

Cyber-physical systems perfectly integrate computation with physical processes and provide abstractions, modelling, design and analysis techniques for the integrated whole. CPS require computing and networking technologies to embrace not merely information, but also the physical dynamics, see

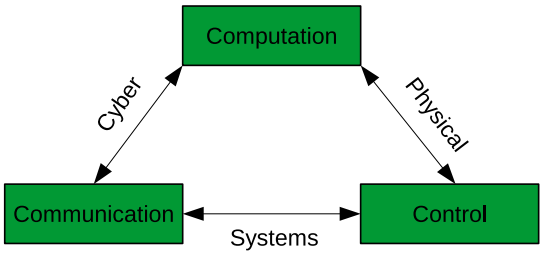

Fig. 1. Overview of a cyber-physical systems [7]

Fig.1. The interactions among control, computing, network and physical systems require new design technologies [5].

Embedded computers and networks monitor, evaluate and control physical processes based on a feedback control, where physical processes affect computational process and vice versa. An overlap occurs among embedded systems and CPS, as well as real-time systems as illustrated in Fig. 2.

We can comprehend CPS from two aspects. From the perspective of composition, it is composed of embedded system and network components. From the perspective of method, it uses a feedback mechanism to control the physical environment [6].

Defining characteristics of CPS are [5]:

- *cyber-capability in every physical device and resource constraints* - software is implemented in every embedded system and system resources are constrained as well, e.g.

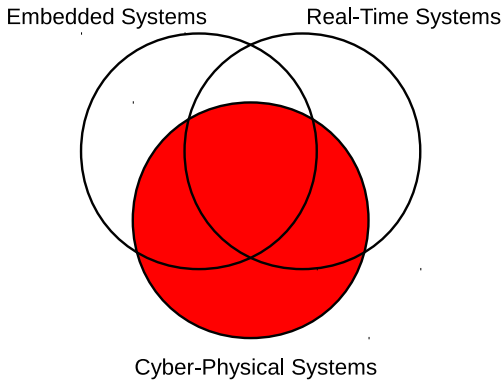

Fig. 2. Overlap between cyber-physical systems, embedded systems and real-time systems [8]

network bandwidth, computation resources,
- *close integration* - physical processes are deeply integrated with the computational processes,
- *extreme scales and networked* - CPS contain many wireless technologies e.g. - GSM, blue-tooth, wi-fi, which allows creation of CPS of vast levels and are considered as distributed systems,
- *complex spatial and temporal scales* - different subsystems of CPS have different time and space requirements,
- *dynamical reconfiguration/reorganization* - CPS require adaptive characteristics because of their size and complexity,
- *high degrees of automation and closed-loop control* - CPS take advantage of easy manipulation and from control, which is realized by feedback control,
- *operation must be dependable and certified in some cases* - this is one of the most important characteristic of CPS, as CPS are complex and spacious, it is needed that the system is secured and reliable.

III. Hybrid dynamical systems

Dynamical system (DS) describes an evolution of a state over time [9]. DS can be influenced by input signals, which can be represented by control signal or disturbance. DS can also have output signals, which might be measured or regulated. Such DS are called control systems. Based on the type of their state, DS can be classified into:

1) *continuous* - if the state of a DS evolves in Euclidean space $\Re^n$, $n \geq 1$,
2) *discrete* - if the state of a DS evolves in the range of a finite set $\{q_1, \ldots, q_n\}$,
3) *hybrid* - combination of a continuous and discrete system.

Based on time, DS can be classified into:

1) *continuous time* - $t \in \Re$ and evolution of the state is described by a differential equation,
2) *discrete time* - a set of time is a subset of integers $k \in N$ and evolution of the state is described by a difference equation,
3) *hybrid time* - evolution of a DS is over continuous time but discrete events(instantaneous jumps) occur.

CPS belong to a hybrid systems category with the hybrid time. The most significant representations of the hybrid systems are:

- discrete hybrid automata (DHA) [10]
- piece-wise affine (PWA) systems [11]
- mixed-logical dynamical (MLD) systems [12]
- switching control [13]

DHA is the most general description of the hybrid systems, where if the discrete part preserves its state then the continuous part of DS evolves according to difference equations assigned to that discrete state [14]. When an event occurs and fulfil required conditions, which lead to change of the discrete state, event causes change in the continuous part as well [14]. Modelling of DHA is composed of four parts:

- switched affine systems (SAS)
- event generator (EG)
- finite state machines (FSM)
- mode selector (MS),

which are depicted on Fig.3. These parts of the DHA are defined as:

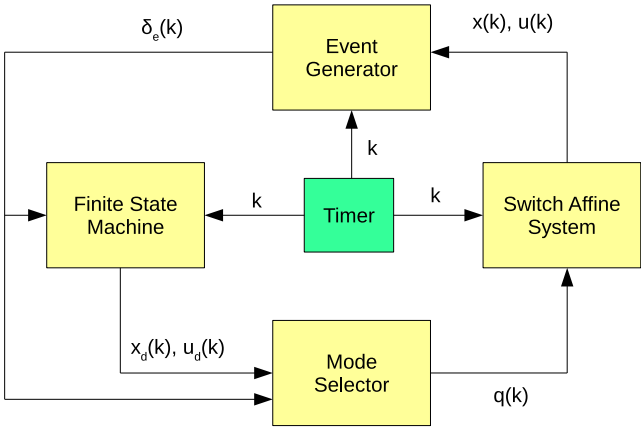

Fig. 3. The DHA framework for modelling CPS

- switched affine systems - describe the continuous part of the hybrid system, which is defined as follows:

$$\begin{cases} x(k+1) = A_q x(k) + B_q u(k) + f_q \\ y(k) = C_q x(k) + D_q u(k) + g_q \end{cases}, \tag{1}$$

where $x(k)$ - state of the system, $y(k)$ - system output, $u(k)$ - system input and $\{A_q, B_q, C_q, D_q\}$ is a set of matrices and vectors $\{f_q, g_q\}$ represent nonlinear vectors for discrete state q of the system.
- event generator - provides a generation of a specific event based on the fulfilment of boundary conditions. Mathematical description of EG:

$$\delta_e(k) = f_h(x(k), u(k), k) \tag{2}$$

$f_h : \Re^n \times \Re^m \times N_{\geq 0} \rightarrow E \subseteq \{0,1\}^{n_e}$
- finite state machines - represent the discrete part of the hybrid systems, which can be described as follows:

$$x_d(k+1) = f_d(x_d(k), u_d(k), \delta_e(k)) \tag{3}$$

$x_d(k+1) \in X_d \subseteq \{0,1\}^{n_d}$, $x_d(k)$ - discrete state vector, $u_d(k)$ - discrete input, $\delta_e(k)$ - output of EG
- mode selector - defines the continuous part of DS in the frame of SAS. Output signal is defined in the form:

$$q(k) = f_m(x_d(k), u_d(k), \delta_e(k)) \tag{4}$$

IV. Example of CPS description in the DHA frame

Consider a hydraulic dynamical system stated in [15], [16]. Structure is shown on Fig. 4. The input to the system represents the inflow $q_0(t)$. Dynamics of this system is dependent on the height of a liquid in the second tank. If the height $h_2(t)$ is lower than the height h, in which the liquid level in the second tank runs over the the height of the bottom of the first tank, the dynamics evolves according to the physical laws for the two tank hydraulic DS without interaction (5), however if the height $h_2(t)$ is above the height h, the dynamics of the system is described as the two tanks hydraulic system with interaction (6).

Mode $q = 1$

$$\begin{aligned} \Delta h_1(t+T) &= \left(1 - \frac{k_1 T}{F_1^s}\right) \Delta h_1(t) + \frac{\Delta q_0(t) T}{F_1^s} \\ \Delta h_2(t+T) &= \frac{k_1 T}{F_2} \Delta h_1(t) + \left(1 - \frac{k_2 T}{F_2}\right) \Delta h_2(t) \end{aligned} \tag{5}$$

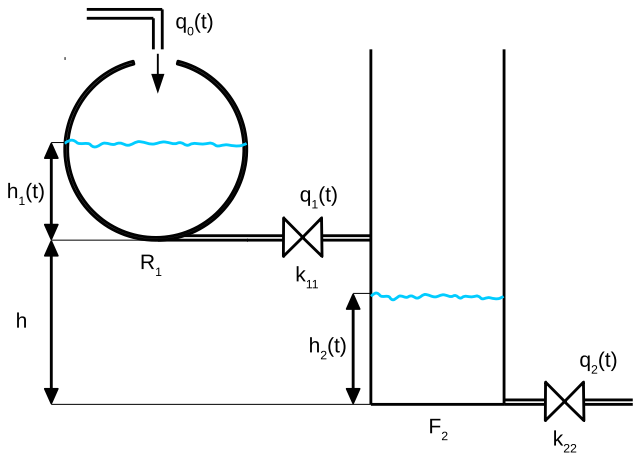

Fig. 4. The system of coupled tanks

Mode $q = 2$

$$\Delta h_1(t+T) = \left(1 - \frac{k_1}{\frac{F_1^s}{T}}\right)\Delta h_1(t) + \frac{k_1}{\frac{F_1^s}{T}}\Delta h_2(t) + \frac{\Delta q_0(t)}{\frac{F_1^s}{T}}$$

$$\Delta h_2(t+T) = \frac{k_1}{\frac{F_1^s}{T}}\Delta h_1(t) - \left(\frac{k_1}{\frac{F_2}{T}} + \frac{k_2}{\frac{F_2}{T}} - 1\right)\Delta h_2(t) \tag{6}$$

Parameters of this system are : F_1^s - cross-sectional area of the first tank in the steady state, F_2 - cross-sectional area of the second tank, k_1, k_2 - modified flow resistances constants, T - sample rate.

These two mods of the dynamics of the stated system represent FSM, to each of these mods is assigned a set of discrete difference equations in the SAS frame. Fulfilment of the condition $h_2(t) = h$ triggers EG and consequently MS selects the dynamics of the system, which is determined by EG.

V. Distributed control system

DCS are composed of many different systems (together forming CPS [17]), which determine different approaches to their modelling and control. Hybrid modelling and resultant control of such systems are the main topics of my dissertation thesis *Hybrid Models of Cyber Systems and their Application into Distributed Control Systems*. DCS itself can be represented as CPS, however distinct systems comprising DCS can also represent simpler CPS. Considering this representation of CPS, DCS provides a very good framework to study and implementation of many different modelling and control techniques. Such a DCS infrastructure is realized at DCAI FEEI Center of Modern Control Techniques and Industrial Informatics and is composed of 5 levels, as depicted on Fig. 7 [18].

Techonological level is situated at the lowest level and is represented by real models, actuators and sensors. From the variety of real models, the most important models for my dissertation thesis are under-actuated mechanical systems and hydraulic dynamical systems stated in the section IV. As an example of the under-actuated system can be considered Multipurpose workplace of nondestructive diagnostics with linear drive, whose part is a classical single inverted pendulum model, Fig. 5 [19].

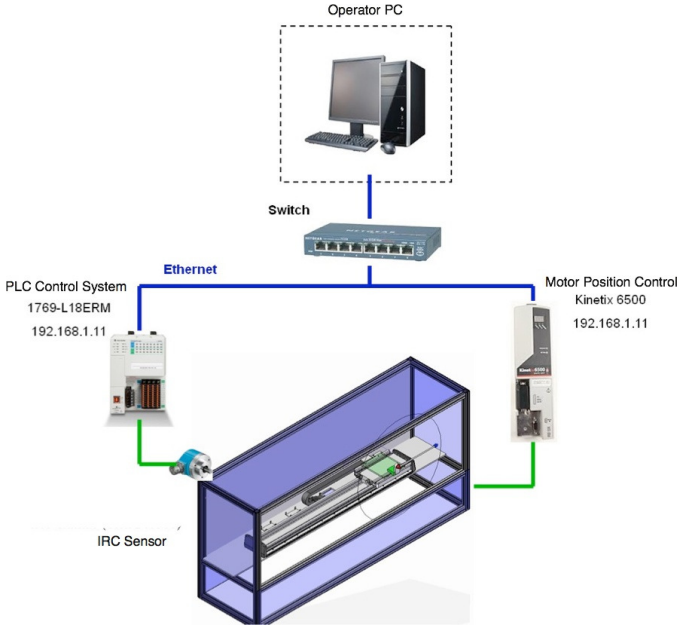

Fig. 5. Multipurpose workplace of nondestructive diagnostics with linear drive [18]

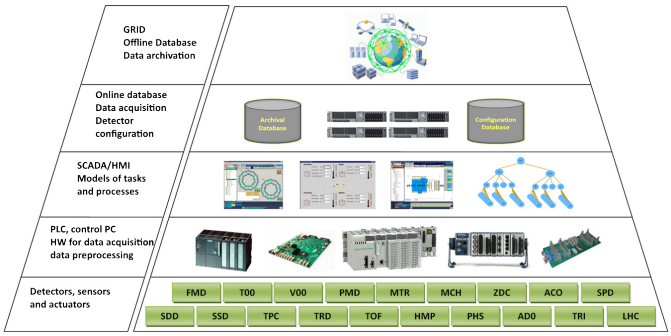

Fig. 6. DCS of ALICE detector control system

Directly above the zero-level of DCS appears *Technological level of control and regulation*, which is denoted as the first level of DCS. Hardware realization of this level is made with the help of programmable logic controllers (PLC) and technological PC′s onto which are connected model sensors and actuators from the first level. In the context of the mentioned models, classical inverted pendulum is controlled by PLC and hydraulic systems by technological PC.

The second level of DCS is represented by *SCADA/HMI* technologies and simulation models of the zero-level real models. SCADA/HMI ensures data acquisition, collection and archivation as well as supervisory control of the systems from lower levels of DCS. Simulation models included in this level serve for simulation purposes, control design and verification of algorithms [19]. My dissertation thesis is situated mainly into these three levels of DCS.

The level above SCADA/HMI is *Information level of control* which includes relational databases, ERP/MRP and MES systems. At the top of DCS is *Management control level* based on multidimensional databases and OLAP technology [20].

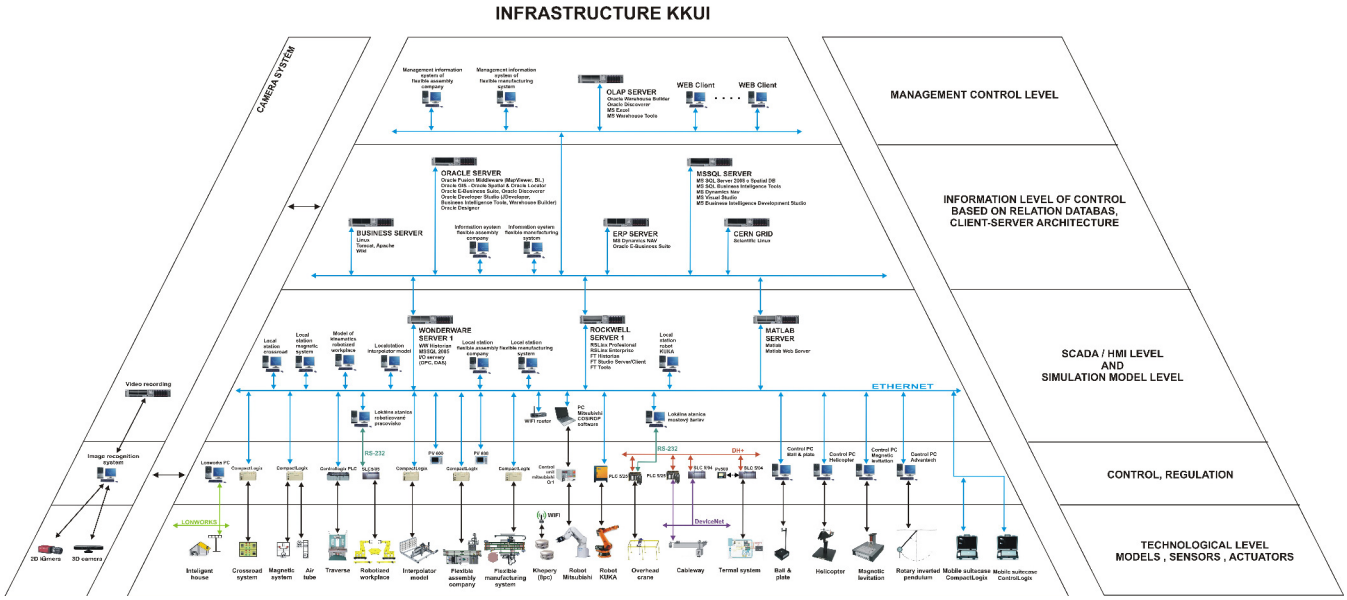

Fig. 7. Distributed control system (DCS) pyramidal model implemented at the Department of Cybernetics and Artificial Intelligence

VI. Conclusion

This paper provides a basic notion of a cyber-physical systems, their specifications and challenges they pose. One of the biggest challenges is to model such a cyber-physical system. Mathematical modelling of CPS is mainly done with the help of hybrid systems framework. This modelling framework can be used to implement CPS into distributed control systems architecture. Such a DCS architecture is also used at CERN, see Fig. 6, where information and experience from our own architecture can be utilized. Moreover, finite-state machines are used to model processes in CERN, which are part of the most general form of hybrid systems - hybrid automata. The author is also a member of Alice Collaboration in CERN Alice experiment and it is one of the main topics of his dissertation thesis.

CPS offer a huge research space and only further research will show us which applications and consequences in real life we can expect.

Acknowledgment

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Data acquisition and SOA gateway

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***Abstract*— This work deals with industrial data acquisition, remote control and related problems. Intention of this work is to focus on solution with own architecture, services and created algorithms. The architecture uses Serviced Oriented Architecture (SOA) and algorithms inspired from machine learning. Results of this work will improve remote control with help of contextual behavior of gateway and integration of operational and informational technologies in industry.**

***Keywords*— SCADA, CPS, SOA, remote control.**

I. Introduction

Industrial IT is emerging vary fast and new revolution approaches appear in automation and control. New approaches have significant importance in devices, which are supposed to work fast, together and effectively. A lot of devices has direct network connectivity or use gateway (mediator) to transfer data [1]. Data are used for analytics, prediction and control of the plant. In the meaning of SOA, data are collected and offered via services to another IT services inside or outside plant. Same like OPC UA. These services improve interoperability and flexibility inside hierarchical ICS (Information and Control System). Improving point of SOA appeared in moving selected ICS services into cloud and benefit from better interoperability and reliability. SOA and cloud brought a lot of space for work, mainly in data transfer and data management.

According to research and commercial publications, I summarized problems, which are aimed at industry, remote control and data acquisition [2]. The most popular problems are: improvement of interactive interoperability with devices, device management, interconnection with technological layer and its unification, better quality of monitoring, data consistency and analytics. Another type of problem is diagnostic over embedded systems and security/connectivity issues [3],[4]. I selected these problems:

1. how to improve collecting, integrating industrial data,
2. how to decrease energy consumption and network overload with such big amount of sensors and actuators,
3. Unified and non-fixed connection to technological layer.

Mentioned selected problems are connected with SCADA (Supervisory Control and Data Acquisition) system and remote control [1]. This work deals with solution for distributed sensor network and data acquisition based on SOA.

This paper consists of short state of the art, known facts, solved tasks, results and work expectation in the future.

II. Initial Status

I divided initial states of selected problems for this year into:

1. Trend of ICS is to use integration of Operational and Information technologies. Therefore, I am concentrating on designing gateway/mediator, which will improve this integration [5].

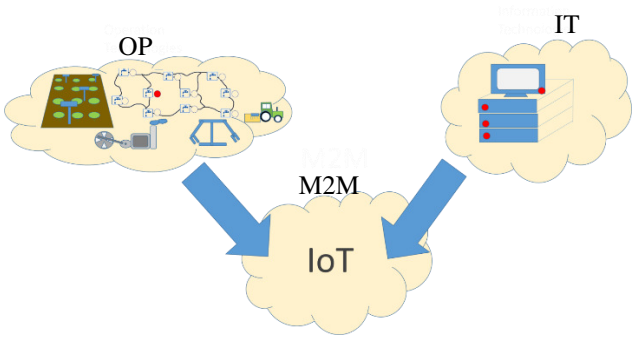

Figure 1 Integration of OT and IT

2. Today, there can be sensor and actuators implemented without wiring into large distributed systems. Therefore, battery plays a key role in many cases and systems are supposed to solve the power consumption problems and effectively do data acquisition. There exists algorithms like WiseMAC or TRMA, which can help to save battery and offer good connectivity. But their workload is scheduled and some important measurements might be missed or inaccurate. Therefore, we made event-based solution, which is based on information detection, which is mentioned in the [3], [4].
3. There is still increasing amount of end devices in distributed system. There exists solution, which benefits from the cloud and services to aggregate, store and process data. But still, there appears places for communication and connectivity improvements in the industry. Communication with physical devices is important to for good functionality of all ICS. Therefore, I focused on sensor network and SCADA gateway/mediator [5].

III. Solved Tasks in Previous Year

Compared to the selected problems and results from previous year, I focused on:

A. CPS-s (Cyber-physical systems) interactive topic – M2M communication with interactive communication topic.
B. Gateway – inner representation of gateway (represented by CPS).

A. CPS interactive topic

Sensors and actuators can be smart and have some network interface. These sensors and actuators can be connected with gateway or mediator. These gateway transfer data into services, which are implemented in the cloud. In other words, gateway creates an interface between sensor/actuator layer and services of ICS higher layers. The role of the gateway is data transmitting data or routing in regular case. I designed the M2M interactive topic communication to improve better understanding of information from technological layer in the large distributed sensor network. This communication creates interactive communication between end-device and ICS service. This type of communication helps to control and collect data from sensors without knowing the topology of sensor/actuator network. The word interactive means that end-devices are grouped into interactive communication topic according to their properties. Designed gateway method helped us to create an abstracted layer of end-devices network, which is described in [8].

Gateway is based on data mining techniques to manage data. I used k-means clustering after analyzing some data mining techniques. The k-means preference was its interactivity. We reached contribution in communication, where I used large network of sensor/actuators based on publish/subscribe method. Method uses a mapping table, which is dynamically change according to already connected nodes to the gateway. This table routes data between the end-devices or services. As a result, the gateway allows to translate messages from sensor/actuator network and services in the ICS. The amount of data or information is not reduced, but proposed and offered as a service with higher abstraction of context [8].

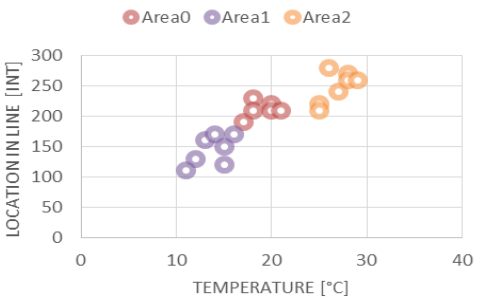

Figure 2 Graphical representation of grouped end-devices in monitoring system [8]

B. CPS interactive topic

I designed and partially implemented gateway. The gateway role is to integrate OT and IT, transfer data from sensor network to higher layer of ICS. The second goal is to create an abstract layer of monitored environment without losing any information nor data. Solution is based on SOA and interaction with cloud ICS services in the cloud. The gateway plays the key role in SCADA. Therefore, the designed gateway is peer-to-peer connected with other gateways to provide stable functionalities. Base principal view of gateway is in the Figure 3. More about realized parts and functionality is described in[5],[6],[7]. The finally goal is contextual behavior of the gateway and better representation of monitored environment without knowing network topology of sensor/actuator.

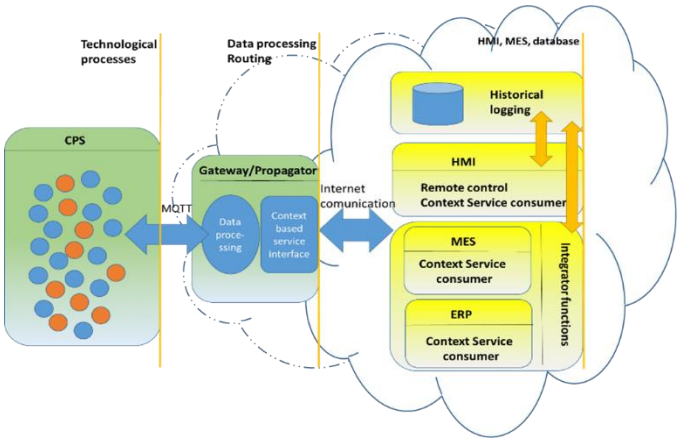

Figure 3 Symbolic schema of solution without cloud implementation

IV. Future work

I want to finish my gateway realization and implement designed context behavior into gateway. Next, I want to analyze results and find additional improvements.

V. Conclusion

Last year, I designed, implemented and tested interactive topic in M2M communication. According to requirements, I designed better inner representation SOA gateway and did further realization of gateway.

Acknowledgment

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Data visualization of abnormal behavior in smart homes environment

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***Abstract*— Goal of this paper is to describe processes related to evaluation of unusual activities carried out in smart home appliances with the help of self-organizing maps (SOM) or individual model views. Evaluation of activities was achieved by calculation, which is dependent on the models views, and by SOM that is learned from standard activities. The system is controlled through a simple graphical user interface that was proposed.**

***Keywords*—Unusual activity, self-organizing map (SOM), models views, graph, evaluation, appliance**

I. Introduction

Automatic starting of appliances, switching on and off the indoor or outdoor lights, security system in a household and analyzing state changes in application (mobile phone or web application) is a vision of the future intelligent household. Research is currently not focusing only on development of absolutely new technologies but rather it is focusing on improvement of these intelligent households and making them more intelligent and able to learn resident's behavior, adapting and operating in an active way. This paper is dealing with evaluation of completed activities in the intelligent household, where these activities are categorized as standard or nonstandard activities based on their behavior. Designed system is able to find length and type of nonstandard situation which will be evaluated from historical data and based on actual condition. The system can be used for energy saving, taking care of user's health and also as a security system. Sensors allow for collecting different types of activities that are completed by appliances, for example switching on the outside lights, opening the doors and the windows. Number of activities can be also visualized using graphs. Key factor driving the research in the area of smart households is especially to improve the running of household, make possible saving energy and knowing the household for user. The system gives to the user the feeling of certainty and safety after the install.

II. Theoretical background

When an unusual activity is found out, system will map unusual activity behavior into one of the following behavior types [1]:

A. Unusual activity

Unusual activity is identified as the non-standard. If output from algorithm is less than 0.5 and it means that the activity was carried out in an unusual time or a it's duration was unusual. Unusual activity becomes each activity, which was evaluated as non-standard.

B. Unusual long activity

It is the activity with the unusually long duration. It can occur, if the appliance is switched on too long when compared to standard duration.

C. Unusual Short activity

As unusual short activity is considered an activity that takes an unusually short time. However, this condition can occur at any time. An unusually short duration of activities can occur, if the appliance is switched off before accomplishing its purpose, thus, it fails.

D. Missing activity

This type of activities includes activities that may occur in the case of expectation for specific activity by the user or the appliance at a specific time with a specific duration, but the user was absent or appliance did not switch on, so activity was not performed.

III. Proposal for the view

Views are divided into several categories: yearly, monthly, weekly and daily views according to the time scale. Based on the views we can accurately detect, respectively capture the special situation which can also call user's attention to the serious activities. However, it is necessary to compare the different views among themselves because not every captured unusual condition in one view will be presented as non-standard in other views. Consequently, it is necessary to define a certain tolerance that will recognize when an activity becomes non-standard activity and by contrast, when the percentage is so small that the activity can be ignored, and there is no need to give attention to it. Tolerance expressed as a percentage will be multiplied by a coefficient, that will be strict for each appliance. It ensures that not all appliances will have the same evaluation, because user gives other coefficient to each appliance. This technology is the first proposal for the new detection of non-standard activities. New formula for calculating the likelihood of unusual activity is designed for

reliable evaluation. Types of Views: daily view, weekly view, monthly view, yearly view, normal view (Fig.1).

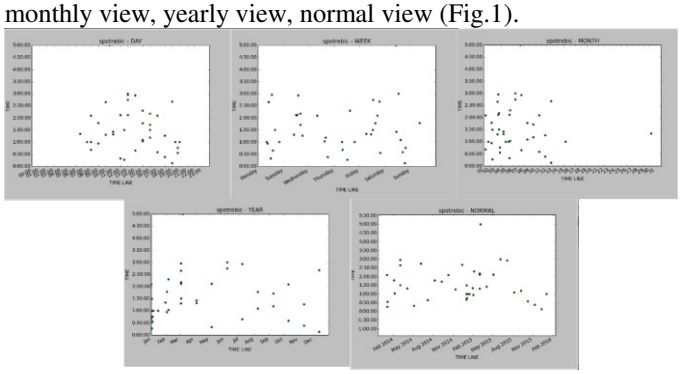

Fig. 1. Appliance views of standard situations

IV. SOLUTION

The purpose was to design a system that would be used to visualize the data and then evaluate such data consisting of the two parameters from the database. One parameter indicates beginning of any activity completed by specific appliance in the household and the second parameter indicates the duration of the activity. These activities will be portrayed in 2D chart [3]. It will be a system to evaluate an activity depending on previous activities and evaluate them either as standard or nonstandard. The system will be able to show activity in different views, including different time frequencies. Thereby making the system more transparent and more convenient to use. All data will be stored in a database where every appliance will have a record of its activities. All of these functions are controlled by a simple and intuitive graphical user interface, which is included in the system design. The realization of this system will therefore be necessary to propose several algorithms, databases, features a graphical user interface to enable the system to operate most reliable and accurate.

A. Solution system for the evaluation of non-standard activities

System is implemented in the Python scripting language with appropriate library. The self-organizing map [4] algorithm was taken from [5], which is programmed in Python, so there was no need to rewrite functions. Python programming language allows the rendering of 2D activities in the graph in which the X-axis is drawn in the format of a time axis in each individual point of view and the Y-axis shows the duration of the format [hh:mm:ss]. Various activities, whether standard or non-standard will be plotted as points on a graph.

B. Manual and automatic data evaluation

Self-organizing maps are maps that will ensure evaluation of the specific activities of the appliance. Source code and algorithm ensuring the creation of SOM [2], learn SOM and evaluate the activity was taken from [5], where the author has made the scripts available to the public. After downloading the source code written in Python, the script will be extended to other functions and methods to enable the script to suit the conditions of the system and subsequently worked properly as required. There are two recognized types of evaluation activities of the appliance: manual evaluation activities in a smart home, Automatic (Real-time) evaluation activities in a smart home.

C. System's output

After completion algorithm system provides output (Fig.2) in text format, which is shown below. Output offered the coordinates activity of 2D graph, the type of activity and possible evaluation activity for the non-standard provide more detailed character activity.

```
(X, Y : 35.375, 11.55)UNUSUAL ACTIVITY
Result: 0:23397998778872, isUnusual:True,
isUnusualLong:False, isUnusualShort:True,
isMissing:True)
```

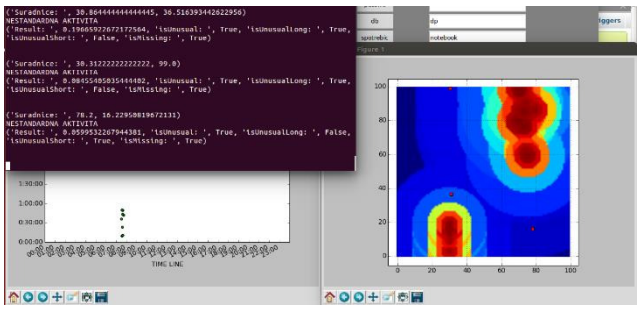

Fig. 2. System's output

V. CONCLUSION

Purpose of this work was to create system absorbing nonstandard situations that happen in the intelligent household. By using system, the user can immediately respond to the nonstandard situations, according to the importance of activity. The system allows learn data of standard situations and then evaluation another activity depending on individual models of view. After evaluation, the system gives to the user the results about each activity written in database of appliance in shape text output where the character is given to the each activity. The system can also serve as an information broker, when the user is interested in duration length of activities of each appliance used to models views.

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Design and implementation of recommendation algorithm based on process mining methods

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***Abstract*— In this contribution we present an innovative idea of using process mining methods for recommendation. Creating a process model which is based on event log analysis aims to identify the real behavior of process and enables its deep analysis and optimization. From the business perspective, process model derived from e-shop event logs enables to get more complex view to purchased products and support inbound marketing activities for increasing the profit. From the process mining perspective, deriving a process model could provide new opportunities in the area of recommendations techniques. The aim of this paper is to present an innovative approach of process mining for recommendation purposes. We provide evidence of suitability of our approach by means of experiments comparing classic recommendation methods and our new designed process mining method.**

***Keywords*— event logs, process mining, process model, recommendations**

I. Introduction

The ability to transform data into valuable information leads to significant improvements in management and decision making. Information systems daily log a large amount of events from real life. A lot of executed activities and events are mediated by some enterprise information system or other kind of software application, where they are recorded and kept. This enables to monitor and subsequently coordinate and simplify all behavior processes [1]. Events are used to characterize the dynamic behavior of a process in terms of identifiable, instantaneous actions, or decision making upon the next activity that will be performed. However, it is not only important to know how the processes were launched or how particular activities interacted. It is also important to know, how can be this information utilized in the future. This paper deals with ability to transform data obtained from information system (in this case it is an e-shop providing sport accessory and clothes) to valuable knowledge and using this knowledge in area of product recommendations. Our goal is to design and implement recommendation models based on process mining techniques which could provide better recommendation results as classic recommendation algorithms based of collaborative filtering. Designed methods will be verified on real data and results will be compared with traditional methods by AUC curve metric.

II. The State Of The Art

Process mining is a young research discipline which connects the area of Data mining, Business Process Management, Machine learning and Statistics. The key document entitled Process Mining Manifesto (created by the IEEE Task Force on Process Mining) aims to promote the topic of process mining and was published in October 2011. Since then, several significant documents in fields of process mining area were published, e.g. papers dealing with process model discovery or papers describing the particular methods and algorithms of process mining, written by Aalst, Weijters, Maruster [1], Weijters, Ribeiro [2] or Medeiros, Weijters, Aalst [3]. Nowadays authors in their key papers describe event logs analysis from different perspectives, e.g. *organizational perspective*, described in Jin, Wang a Wen [4], *time perspective* mentioned in Jagadeesh, Chandra, Bose and Aalst [5] and *a case perspective* specified in Dudok and Brand [6]. However, current trends in process mining area are more and more focused on event log analysis, which results could be implemented in real time systems for the purpose of prediction, detection of variances or process optimization. On the other side, there is a different scientific area of recommender systems. Current approaches to develop recommendations, current trends and the most used methods and their applications are described in detail in publications of authors Jannach et al. [7] and Ricci et al. [8]. Based on main process mining techniques and well-known recommendation algorithms we have designed a new recommendation method based on process model behavior which will be described in next part of this paper.

III. Designed Solution

A. Design of non-deterministic Process Model

In the first phase of our research, we were focused on creating non-deterministic process model of customer behavior in monitored e-shop. As a starting point, we used knowledge and experience about process mining methods based on our previous research described in [9], [10], [11] and [12]. In our case, the process is a set of activities which customer realize from starting browsing the e-shop to final purchase confirmation. Each purchase is one process instance. Data file consists of 1 817 400 activities describing more than 440 000 customer purchases. For the purpose of process design, the main three attributes are analyzed: Customer ID, Product ID and Purchase Date. After first data cleansing and

transformation, we have analyzed associations between product purchases which is important to know because of finding related products and also seemingly non related products. We have created transition matrix and the process model by using Fuzzy-miner algorithm [12]. The main goal was to find model, which covers real purchase process and will be simple, precise, appropriate and reasonably complex. After several iterations, we have found a suitable process model that covers 10% of main activities which represent more than 75% of all purchases in the monitored e-shop.

B. Design and Implementation of Recommendation Method

After creating suitable process model, our ambition was to design and implement product recommendation method based on this process model which could provide better recommendation results as main recommendation techniques. After first orientation on classic recommendation techniques described in [13], [14] and [15] we have focused on designing main method of recommendations reflecting product associations included in transition matrix. We have also designed rank functionality, which assigns rank to each product based on its timestamp (delta between last purchase date and the current purchase date). This rank functionality takes into consideration also link aging. We have also created three modifications of this method and we have obtained results of recommendations which we have compared with results obtained by classic methods of recommendations by AUC curve metric. Designed methods are named: *All purchases, Last purchases, Top rank 3* and *Top rank 5*. Following table describes the results of compared methods on two different data files.

Tab.1 AUC results

METHOD	AUC: file 1	AUC: file 2
All purchases	***0.536***	***0.593***
Last purchases	*0.515*	*0.529*
Top rank 3	*0.520*	*0.520*
Top rank 5	*0.526*	*0.561*
WRMF	0.464	0.475
Item k-NN (k = 20)	0.361	0.385
Item k-NN (k= 20 w)	0.411	0.454
Item k-NN (k = 50)	0.345	0.370
Item k-NN (k= 50 w)	0.487	0.519
Item k-NN (k = 80)	0.302	0.335
Item k-NN (k= 80 w)	0.513	0.543

File 1 describes purchase process in winter season and file 2 describes similar process in summer season. As it is described in Tab.1, in case of *file 1,* results of AUC curve are better for all designed methods than results of AUC curve based on classic recommendation algorithms. In case of *file 2,* results of AUC curve provide better values for three of the four designed methods compared with classic recommendation algorithm results. Based on these results we can state that designed solution is successful and could be applied in practice in given e-shop.

IV. Conclusion

This paper describes a new approach to recommendation based on suitable process model. Designed solution was verified on real data. Since obtained results of recommendation methods have met our expectations, we can summarize our research as successful and suitable for further development and implementations in practice.

Acknowledgment

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Design of Methodology to support Decision Making in the Field of Data Analysis

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***Abstract*—This paper describes the results of my work in recent years during my postgraduate studies with emphasis on my last year´s results. The paper consists of introduction to the problem, my motivation and design of solution. Unfortunately, results are not the part of this report, because I work these days on their interpretation. Since I am in the last year of my study, further plans of my research will be described very shortly. List of publications from previous year is also part of this paper.**

***Keywords*—Methodology, Decisions Support, Data Analysis, Data Tools, Data Platform, Business Intelligence.**

I. Introduction

Amount of data available to the various organizations is rapidly increasing. Actually, data volume is not only one problem. Very important fact is that data is from different devices and also have different formats and lifetimes. There are terabytes of records – absolutely useless for any mining technique or obtaining of a relevant knowledge. On the other hand, only a few megabytes of csv files can be useful for the mining a really good knowledge to increase company profit. The field of data analysis is not confined to the commercial sector only. There are also applications in the science and research and the market is growing just because of the quantity of products and analytical tools is growing too. All of these platform, environments and tools aim to be the most versatile for any company. The market offers a variety of solutions from simple an open sources analytical platforms to the most complex. Moreover, it is now a huge demand for applications in the cloud. These are all factors that complicate the selection of appropriate analytical environment for organizations disposing own data. Another big problem is fact that the organizations actually have no idea what to do with their data. They even do not know what parameters are crucial for their decision. So, this is ultimately complicates the selection of an appropriate analytical environment for data analysis.

These are all reasons why it is necessary to consider a methodology to support the right decisions in the IT area. Organizations having a data just cannot lose months of testing different applications and platforms only for the purpose of finding best solutions. This is the main point of my work and research. The purpose is to design a methodology or decision support system to obtain a reduction time for all types of organizations looking for suitable alternatives of their data analysis. In other words – I try to identify key criteria for choosing suitable analytical platform. This is related to the next points of research [1][2][3]:

1. Mapping the current state
2. Design of mathematical models and algorithms
3. Identification of parameters (criteria)
4. Design of Data Analysis taxonomy
5. Verification of methodology

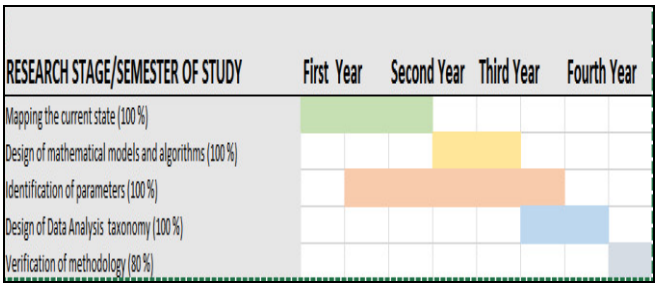

Fig. 1. Progress of Research Stages

II. RESEARCH STAGES

A. *Mapping the current state*

This phase includes the study of current trends in data analysis. That term conceals tools, platform, development environments, integrated information systems supporting Big Data processing, Business Intelligence as well as statistical tools for data-mining. Mapping the current state seems to be very important because just the categorization of these environments will be output of the proposed decision system. To be proposed methodology the most universal, as the output has to offer organizations the full range of analytical tools - from simple open source applications to complex analytical platforms and cloud services related to data analysis. In addition, this area is teetering on the edge between the various scientific and business objectives [2].

B. *Design of mathematical models and algorithms*

I designed three mathematical models as a basis for methodology. A very important thing to realize that all our models operate with input parameters of individual choice (proposed analytical platforms). In essence, the selection

criteria for the organization are parameters. If the organization has a priority in SQL relational database – one of the input parameters is just a SQL database. Second model was used for purpose of verification in a number of real companies in Slovakia. Algorithm is performed in the following points:

1. Defining the criteria on the basis of scientific and business articles.
2. Assigning weights to the following criteria based on the occurrence of set of articles.
3. Selection of user´s criteria with the sum of weights not bigger than 40 % of the total.
4. Browsing all alternative and calculating final score for each alternative.
5. Determination of winning alternative.

C. *Identification of parameters*

Identification of parameters is also important part of the entire methodology. It is not very easy to design a mathematical model working with *n* parameters, but identification of relevant criteria for choosing a good analytical platform is more complex. This task is the result of a comprehensive analysis of current trends and the current state of the art. It is the most demanding phase from the terms of time.

There are several ways to identify criteria entering into my methodology. One option is to talk with experts and people who deal with this issue. We could use a questionnaire for this purpose, but it is not very practical solution because every expert would have to identify criteria and give them weights (due to the second and third model). Therefore, we decided for an experimental and also bit risky way. Criteria will be identified from set a scientific and commercial articles. Our decision follows from fact that the authors of these papers are ultimately also experts of people who are dealing with this topic. Each time when an attribute describing some technology appears, this attribute will be recorded as an input parameter – criterion for selection. This will yield *n* input parameters and also we are able to give them weights what is more interesting. We get 31 criteria after last iteration of identification. The biggest weight reached a criterion – integration with relation database systems. Next one is a tracking historical data using OLAP. There are also significant criteria for example – processing in real-time, batch processing data, working with XML, support and integration of programming languages, integration with Hadoop, reporting, internal ETL mechanisms and very interesting criterion is necessary of programming knowledge[2][4][5][6][7].

D. *Design of Data Analysis taxonomy*

I suppose, it is very important to focus on taxonomy in area of data analysis. There are a huge amount of different data analysis tools, approaches, algorithms, methods, platforms and so on. This is reason, why clear categorization is necessary. I purposed 8 big groups which are actually offered outputs of my methodology. Every group has some smaller subset, but upper layer of designed taxonomy contains these categories:

1. Business Intelligence Modules
2. Data Visualizations Tools
3. Stream Analytics
4. Content Analytics
5. Business Discovery
6. Process Mining Tools
7. Data Mining Tools
8. Statistical Tools

E. *Verification of methodology*

Purposed methodology was verified by use cases. All companies are from Slovakia and data is from various domains such as industry, finance, monitoring IT systems and manufacturing. Unfortunately, evaluation the results is not part of this report as not all data are processed.

III. CONCLUSION AND FUTURE WORK

In next few days, I plan to finish evaluation the results and also writing of dissertation. I am also writing the last paper into the journal with impact factor 2.313 – Deicsion Support Systems.

ACKNOWLEDGMENT

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Design, development and implementation of ASIC structures in UWB applications

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***Abstract*—Main topic of this article is introduce to advanced UWB systems based on high performance analog Application Specific Integrated Circuits (ASIC). Moreover letter deals with design flow of the ASIC circuits, simulations, and implementation into the Ultra-WideBand (UWB) systems. Specially attention is given to describe main parts of the UWB M-sequence transceiver and receivers as well. Finally are described user-specific circuits as differential and low noise amplifier, A/D converter and wide-band modulator implemented in UWB systems than a base parts or extensions and advanced design software tools used for design and developing of ASIC circuits.**

***Keywords*—UWB, Ultra-wideband, ASIC, Application Specific Integrated Circuits**

I. Introduction

The goal of this article is to give an overview of the Ultra-wide band (UWB) systems and modified variations based on application of the specific integrated circuits developed and tested specially for wideband sensing applications based on M-sequence sensors [1]. These systems are able to use in situations where in first place is a human live i.e. disaster like earthquake [2]. Were developed applications which are detect and localize a person or several persons trough the wall and detect breathing or heart beat where the UWB radar system can be deployed [3],[4],[5]. Or another application may be ground penetrating radar and crack detection in tunnels, mines localization in minefield, in archaeological research, etc. [6]. Modified UWB systems are also used for time domain reflectometry (TDR) non-destructive techniques for obtaining parameters of liquid materials for example milch (lactose), salinity, moisture of solid materials e.g. grain, or special applications like measuring of reflection coefficient S11 using of a standard two channel M-sequence based reflectometer [7], [8]. Anyway UWB M-sequence systems represents an interesting innovative sensing tool with a large area of applications. The goal of these methods is to gain informations about devices or materials under tests (DUT, MUT) in near areas of interest [9].

What exactly mean M-sequence? M-sequence represents concept of binary pseudo noise codes (PN- codes) generated from digital high-speed shift register included into transceiver. Shift register is developed as ASIC as well and more about this is described in section II. PN- codes provide best conditions for large suppression of random interferences while protecting the sensor electronics and the test DUT from strong electric fields. This is especially important, since one often deals with very near field measurements involving e.g. biologic tissue. Furthermore, it also enables monolithic integrated RF-circuits manufactured in a low-cost semiconductor technology.

II. Basics of functionality of the UWB sensor

Basicly the UWB M-sequence sensor system consist of one stimulus signal radio frequency (RF) transmitter and two wide-band receivers [10]. For special application may be used more or less receiving channels e.g. UWB TDR technigues - one receive channel with directional coupler or 3D capturing of moving persons - four receiving channels. Fig.1 represents basic block schematic diagram of the analogue part of the UWB sensor head [11].

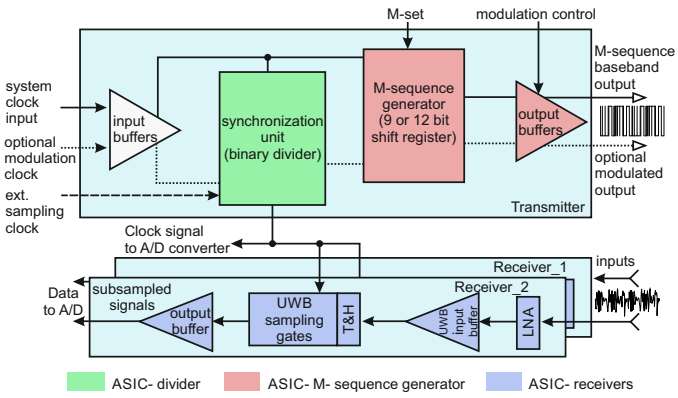

Fig. 1. Simplified block schematic diagram of UWB sensor head

In order to use the system in wide range of applications, is able to use clock generators from several MHz up to 10 GHz and more. A single tone RF generator (master clock) pushes a digital shift register. If this shift registers disposes of appropriate feedbacks, it provides the M-Sequence Maximum Length Binary Sequence (MLBS) at its output. This signal serves as a test signal. It is periodic stimulus. The usable bandwidth, in order to avoid the aliasing, is $\leq$ fc/2, where fc is the master RF-clock rate. On the receiver side, the signal of interest is captured by a track and hold (T&H) circuit operating in an under sampling mode so that low cost ADCs and acquisition memories can be applied.The sampling unit works in the T&H mode, whereas the actual sampling gate is embedded between a low-noise preamplifier (LNA) and an output buffer of high input impedance.

The significant RF components of the system, the M-Sequence Generator, the binary divider and the T&H circuit are manufactured in low cost, high performance SiGe BiCMOS HBT Semiconductor technology [12].

A. UWB M-sequence transceiver

The concept of linear M-sequence stimulus signal generator [3] consist of a network of nine or twelve digital microcells (flip-flops type D) with two feedback outputs. It should be observed that outputs mus be even number when it will be linear generator. Currently has been released a new version of 15th order M-sequence generator that included 15 flip-flops. Generated pseudo noise (PN) stimulus is the periodically repeated signal with whose period equal to $2^N - 1$ elements. Where N is number of microcels used into stimulus generator. This means that for N = 9 or 12 flip-flops the duration of the stimulus signal will be 511 or 4095 elements per one period. In next this structure also comprises output buffers circuits for amplifying transmitted signal (marked with red color in Fig.1). Fig.2 shows basic schematic diagram of 9th order stimulus generator used in UWB systems most often.

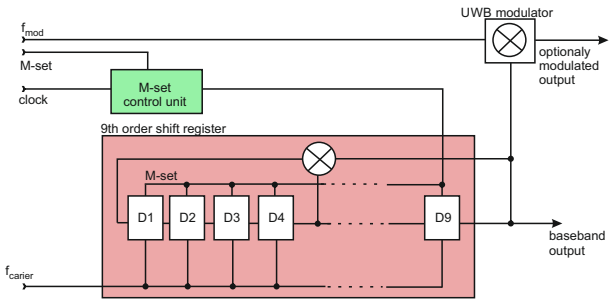

Fig. 2. Block schematic of 9th order M-sequence generator without input and output buffers

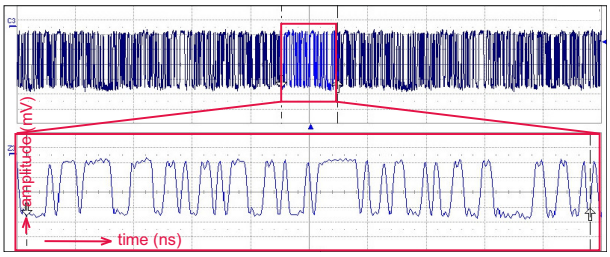

Fig. 3. Output signal from M-sequence generator in time domain at fc=5 GHz and 0dBm output power

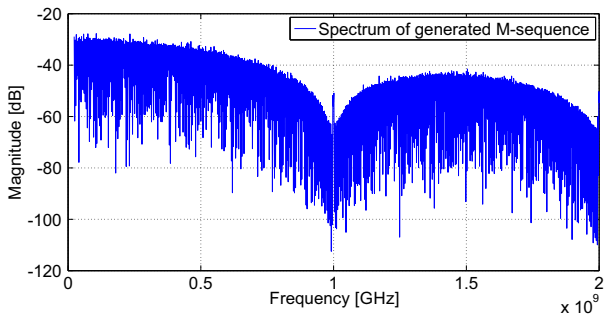

Fig. 4. Spectrum of the M-sequence stimulus signal

Using a modern measured devices is able to draw a very fast signals like our M-sequence generated in wide range of UWB band. Fig.3 shows a shape of output M-sequence captured in time domain at 5 GHz frequency of clock generator. Zoomed area represents a very short time period around 20 ns of generated signal. Next in Fig.4 is shown a spectrum of transmitted M-sequence stimulus in this case on 1 GHz of carrier frequency. Performance level of transmitted stimulus is around -30 and less up to -45 dBm. These values of power are very small and oncoming to the noise values (around -70dBm). Therefore UWB radar systems can be called like the noise radars [10], [13]. Ultra-wide bandwidth gives high range resolution and the range ambiguity is suppressed as a result of the pseudo-random waveform.

B. UWB M-sequence receiver

The UWB receiver [3] chains act as broadband sampling unit, which provide the measurement signals at a lower rate (typically 20-100 M samples/s) for subsequent digitalisation and data processing with commercially available low-cost components of A/D converter. The sampling unit works in the track and hold mode (T&H), whereas the actual sampling gate is embedded between a low-noise preamplifier (LNA) and an output buffer of high input impedance (Fig.1). The low noise amplifier (LNA) [14] is a common emitter differential amplifier operate in Class A with miller capacitance neutralisation. Key parameters of the LNA are 50/100 Q single-ended/differential input impedance; 12 dB gain; noise figure better than 6 dB; and operational frequency band from 100 MHz to 18 GHz. The T&H stage is based on switched emitter followers which drive the charge storage capacitors. Thus, the T&H network represents a time variable capacitive load of the LNA leading to transient spikes while switching.

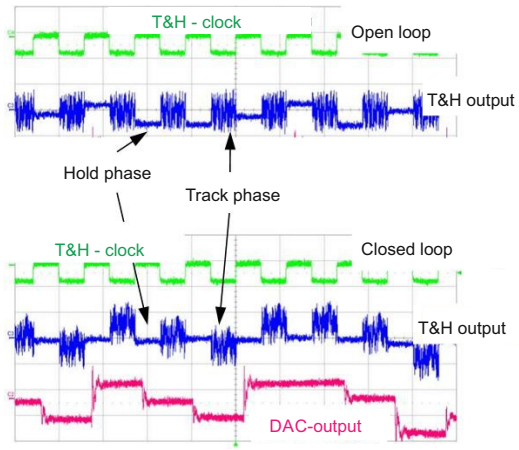

Fig. 5. Principle of T&H circuits- time courses at the output

Due the subsampling mode, the voltage droop of the charge storage capacitor during hold phase is an essential parameter of the T&H core, which calls for very low leakages in the switch, in the hold capacitor and mainly the input impedance of the output buffer. The achieved droop rate of the T&H circuit is better than 10 % FS/ms (FS-full scale). The output buffer represents a differential amplifier with emitter degeneration and a cutoff frequency of about 3 GHz. It serves as an ADC driver and provides a differential voltage swing of 1 V at the 1 dB compression point. Fig.5 shows an example of the output signals of the T&H circuit. The constant voltage during the hold phase must be captured by the ADC. In the open loop example (above), we can observe that the hold voltage jumps from sample to sample. Hence, the ADC must be able to convert voltages within a large range.

C. Binary clock divider and synchronization unit

Binary clock divider and synchronization unit [3] is also next very necessary part of UWB sensors systems. Circuits of the synchronization unit are responsible to provide a stable clock signal for receiving of the stimulus M-sequence signal, preprocessing and conversion for A/D converter.

III. Designed ASIC structures

In this section is described current state of analogue ASIC circuits based on 0.35μm SiGe BiCMOS technology process [12] which have been developed in our Department of electronic and multimedia communications (KEMT). They are additive or base parts of UWB systems.

A. Differential amplifiers implemented in ASIC structures

Differential amplifiers are used to amplify analog as well as digital signals, and can be used in various implementations in order to provide an output from the amplifier in response to differential inputs. This basic circuits element almost of all analog integrated circuits (ICs) is often used as a building block or sub-circuit in high quality operational amplifiers, linear and nonlinear signal processing circuits, and even in the certain logic gates as well as digital interfacing circuits. A very useful feature of differential amplifiers is rejects the input signals that have a common phase such as induced noise. Presented differential amplifier [15] was designed, developed and tested on KEMT. Example of fabricated chip of differential amplifier in cascade connection with pair of LNA amplifiers is shown in Fig.6. Fig.6 also shown micro-photograph of chip design and testing nano probes for power supply and RF signals connections. All of the measurements were realized on nano probe station.

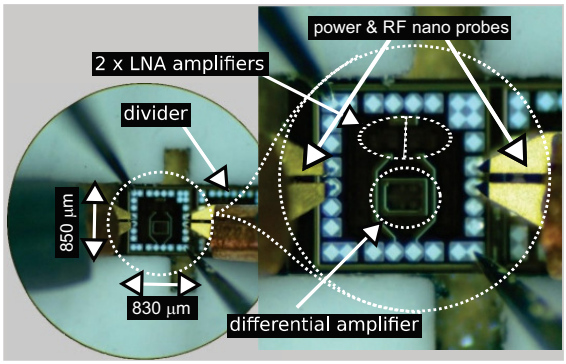

Fig. 6. Photo of the measured silicone wafer caught on a nano probe station [15]

The results from the simulation and from the measurements of the differential amplifier under test are presented in [15] and [16]. That is not everything. Further were developed and currently updated new concepts of wide-band LNA's, de-modulators and 5-bit A/D converter [17] in S35D4M5 technology.

IV. Technological process used for design and development the ASIC circuits

When looking at the currently available semiconductor technologies and their roadmaps, the implementation in the SiGe BiCMOS branch seems to provide the best balance between performance and costs.

AMS 0.35μm SiGe BiCMOS (S35D4M5) process [18] is designed to support advanced RF design with highest performance and lowest process complexity. High speed SiGe heterojunction bipolar transistor (HBT) transistors with lowest noise figures enable designs for operating frequencies up to 7 GHz with current consumptions significant lower than comparable designs based on conventional CMOS RF processes. The S35 is fully modular to ams 0.35μm mixed signal CMOS, enabling designers to reuse the entire IP from their existing CMOS-library.

The 0.35μm SiGe BiCMOS S35D4M5 technology (supported by austriamicrosystems manufacturer) is based on the proven 0.35μm mixed signal CMOS process and includes an additional high performance analog oriented SiGe HBT transistor module. This advanced RF process offers high speed HBT transistors with excellent analog performance such as high maximal frequency and low noise as well as complementary MOS transistors with the option of 5V input/output CMOS transistors. Accurately modeled high linear precision capacitors are available as Poly1 and Poly2 or Metal2 and Metal3 versions (Fig.7). The modular integration of linear resistors, high quality varactors and spiral inductors realized on thick Metal 4 layer makes this process ideally suitable for a wide range of high performance RF applications up to 20 Gb/s i.e.:

- GSM systems
- Bluetooth
- Transmitters and Transceivers for the industrial, scientific and medical (ISM) radio bands (868 MHz, 915 MHz, 2.4 GHz, 5.6 GHz)
- GPS, Glonass
- Wireless LAN up to 5.6 GHz, etc.

Key Features of S35D4M5 technology:

- 0.35μm gates of MOS transistors
- 0.40μm emitters of bipolar transistor
- 3.3V supply voltage for CMOS
- 5.5V supply voltage for peripherals
- Four metallic layers Met1, Met2, Met3 and thick Met4.

Properties of the S35D4M5 technology process make it suitable for exploitation and development in UWB systems works in very high frequencies and ultra high frequencies up to 10 GHz and ultra wide band as well.

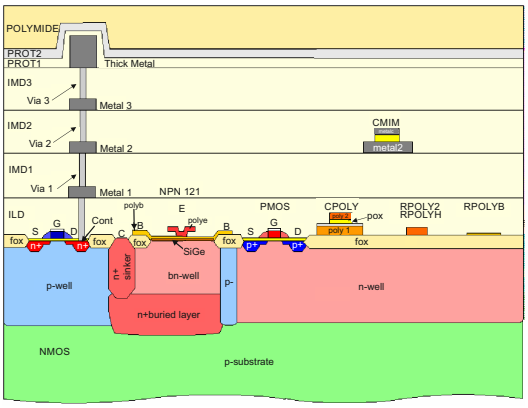

Fig. 7. Wafer cross section

Fig. 7 represents cross section of all parts and layers witch ones are available from manufacturer of S35D4M5 process.

A. Design flow of ASIC circuit with using a modern design tools

IC studio design environment integrates all of Mentor Graphics ASIC design tools into a seamless flow that enables designers to quickly and accurately conceptualize, capture, simulate, layout, and verify the most challenging of custom, analog, RF, and mixed-signal designs. Prominent design capture tools in the ICstudio environment include Design Architect-IC, a powerful schematic capture, netlisting, and simulation control cockpit, and IC Station, layout editor and chip assembly tool. These capture tools integrate tightly with best in class Calibre [19] verification platform and Eldo [20] and advance simulation tools to provide a cohesive front to back ASIC design flow. IC studio also provides robust data management and revision control capabilities to facilitate collaborative IC design.

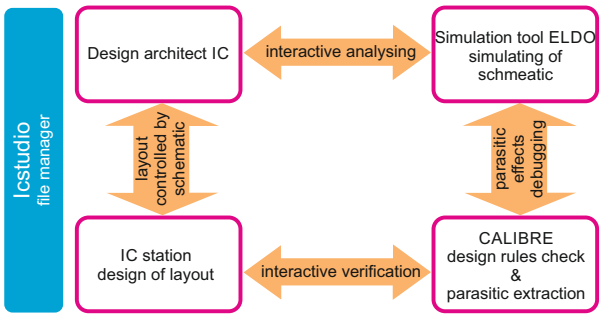

Fig. 8. Development environment for IC design based on Mentor Graphic software

Fig.8 represent base structure of environment for design of application-specific integrated circuit - IC studio in which we can be seen a interconnection between all software tools for design of schematic, layout and simulation tools.

V. Conclusion

The theoretical knowledge of the base structure of UWB M-sequence radar systems has been described. In particular base functionality of transceiver, receiver, synchronization unit and selected ASICs has been presented. Design of application-specific integrated circuits is interesting way how to expand obtained knowledge in area of complex electronic systems. I would to continue working on design and development of ASIC circuits in our department of electronic and multimedia communications and make them desirable for next generations of UWB applications. I think that a new variety of the electronic systems like this have the potential to develop innovative solutions, especially for use in modern industry, from agriculture to health. UWB systems are a perspective tools for solving a lot of problems in a wide spectrum within the meaning of wide area of interest.

Acknowledgment

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Development in Detection and Fault Estimation in Fault Tolerant Control Systems

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***Abstract*—Development in solving of research tasks is shortly described in this paper. Majority of the tasks were focused on topic of fault estimation, that provides elegant and effective solution to relevant set of solved problems. Task of virtual actuator design for P and PI structures in combination with H_∞ approach was also solved. Interesting results obtained in development of fault detection methodology based on unitary transfer function matrices are briefly described.**

***Keywords*—fault detection, fault estimation, fault tolerant control, unitary system**

I. Introduction

Any real system is under influence of disturbances that degrade its performance or components of the system. It is possible to design a system that is robust to influence of disturbances for a price of decreased performance, or it is possible to partially shield the system while increasing its cost and cost of maintenance. There is still a possibility that the disturbances influencing the system will be severe and cause a fault. Fault in a system changes its functionality to the point that the system is unable to perform in desired way and can lead to a failure, that is permanent inability of the system to perform. However, different approach based on principles of Active fault tolerant control systems (AFTCS) assumes that the controlled system with its controller is not passive towards the disturbances but is able to actively detect the fault, identify it and perform remedial actions, that are able to decrease or even nullify influence of the fault, or prevent the development of a fault into a failure. Obviously, such ideas were present in development of large number of systems even before. Valuable systems used hardware redundancy or had robust design. Approach of AFTCS provide different and complementing point of view able to provide better performance and/or decrease the necessity of hardware redundancy [1].

More theoretical than practical division of tasks in development of AFTCS consists of fault detection, isolation and identification, although it is possible to find a completely different nomenclature describing the same content. The task of fault detection is practically simple, however it should be able to provide sufficient information for further identification of a fault and that is not a trivial task. Fault estimation approach skips the fault identification step and assumes the existence of a specific fault. Estimated value of a fault provides also means for immediate remedial action and thus providing good performance while maintaining simple control structure.

II. Initial status

Fault detection using LQ control properties was already investigated and well described [2]. It does provide fast fault detection however it seems that obtained residual functions do not provide useful information for next stages.

Virtual actuators are increasingly better developed. This approach provides fault accommodation with satisfactory results, however assumes a perfect fault detection and identification.

Fault estimation is interesting approach that circumvents theoretical division of tackled problem. Less conservative approach to this problem was described in [3] and provided basis for additional work.

Interesting approach for fault detection using observer [4] provided inspiration in development of a different fault detection method, that could provide relevant results usable in next stages of fault tolerant control.

III. Description of solved tasks

Several mathematical equations are described in following part of the paper. It is assumed that reader is familiar with common notation. Vectors are denoted by bold small letters, matrices by bold capital letters. It is assumed that all the vectors and matrices are of appropriate sizes. Symbol $*$ denotes transposed element of a matrix.

A. H_∞ approach to virtual actuators design

This approach employs H_∞ principle to achieve better performance in case of presence of noise in the system [5]. H_∞ guarantee the best robustness to a time-delay in fault detection and isolation. Design for P and PI structures is described in form of conditions formulated as linear matrix inequalities. Better treatment of this topic can be found in [6].

B. Fault detection with unitary transfer function matrices

Solved problem was to find and unitary representation of the fault residual filter for the system described by equations

$$\dot{\boldsymbol{q}}(t) = \boldsymbol{A}\boldsymbol{q}(t) + \boldsymbol{B}\boldsymbol{u}(t) + \boldsymbol{F}\boldsymbol{f}(t) + \boldsymbol{E}\boldsymbol{d}(t), \tag{1}$$

$$\boldsymbol{y}(t) = \boldsymbol{C}\boldsymbol{q}(t), \tag{2}$$

with the square transfer function matrix of unknown fault input and the residuals. System is unitary if transfer function $\boldsymbol{G}_f(s)$ has all singular values equal. It is shown with more detail in

[7] that for system (1), (2) and prescribed scalar s_0 there is matrix $\boldsymbol{L}$ such that transfer function matrix takes form

$$\boldsymbol{G}_f(s) = \boldsymbol{G}_\Delta(s)\boldsymbol{G}_{f\Delta}(s) \tag{3}$$

where

$$\boldsymbol{G}_{f\Delta}(s) = \boldsymbol{C}(s\boldsymbol{I}_n - (\boldsymbol{A} - \boldsymbol{L}^o\boldsymbol{C}))^{-1} = \frac{\boldsymbol{V}}{s + s_o}, \tag{4}$$

$$\boldsymbol{G}_\Delta(s) = \boldsymbol{I}_m + \boldsymbol{C}(s\boldsymbol{I}_n - \boldsymbol{A})^{-1}\boldsymbol{M}, \tag{5}$$

$$\boldsymbol{L}^o = \begin{bmatrix} s_o\boldsymbol{I}_m + \boldsymbol{A}_{o11} \\ \boldsymbol{A}_{o21} \end{bmatrix}\boldsymbol{V}^{-1}; \quad \boldsymbol{A}_o = \boldsymbol{T}\boldsymbol{A}\boldsymbol{T}^{-1} = \begin{bmatrix} \boldsymbol{A}_{o11} & \boldsymbol{A}_{o12} \\ \boldsymbol{A}_{o21} & \boldsymbol{A}_{o22} \end{bmatrix} \tag{6}$$

$$\boldsymbol{M} = \boldsymbol{T}^{-1}\boldsymbol{L}^o, \quad \boldsymbol{T} = \begin{bmatrix} \boldsymbol{V}^{-1}\boldsymbol{C} \\ \boldsymbol{F}^\perp \end{bmatrix}, \quad \boldsymbol{V} = \boldsymbol{C}\boldsymbol{F}, \tag{7}$$

$\boldsymbol{F}^\perp$ is the left orthogonal complement to $\boldsymbol{F}$. The proposed method is not applicable for every system, if eigenvalues of $\boldsymbol{A}_{o22}$ are unstable, it is impossible to design a stable observer. Then, there is a possibility to design observer with singular values almost equal, however it would be preferable to overcome this problem using different approach. Interesting property of such an unitary observer is that generally it is possible to see directional properties in generated residual signals. This could possibly lead to development of residual generator applicable with combination of other methodologies that requires more precise information about the occurred fault.

C. Adaptive observer based actuator faults estimation

The method exploits the state space observer principle in adaptive scheme to estimate actuator fault. System that is described by equations (1), (2) with state observer

$$\dot{\boldsymbol{q}}_e(t) = \boldsymbol{A}\boldsymbol{q}_e(t) + \boldsymbol{B}\boldsymbol{u}(t) + \boldsymbol{F}\boldsymbol{f}(t) + \boldsymbol{J}(\boldsymbol{y}(t) - \boldsymbol{y}_e(t)), \tag{8}$$

and the fault estimation updating law is in form

$$\dot{\boldsymbol{f}}_e(t) = \boldsymbol{G}\boldsymbol{H}^T\boldsymbol{e}_y(t), \tag{9}$$

where $\boldsymbol{H}$ is computed gain matrix and $\boldsymbol{G}$ is learning weight matrix to be set interactively. The task is to find a observer gain matrix $\boldsymbol{J}$ and matrix $\boldsymbol{H}$, or better said obtain sufficient condition in form of linear matrix inequalities that can be solved using methods of convex optimization, thus providing with correct values of matrices $\boldsymbol{J}$, $\boldsymbol{H}$ for given system (1), (2) and arbitrary parameter $\boldsymbol{G}$.

Simple design conditions are existence of positive definite matrix $\boldsymbol{P}$ and matrices $\boldsymbol{H}$, $\boldsymbol{Y}$ such that conditions

$$\boldsymbol{P} = \boldsymbol{P}^T > 0, \tag{10}$$

$$\boldsymbol{P}\boldsymbol{A} + \boldsymbol{A}^T\boldsymbol{P} - \boldsymbol{Y}\boldsymbol{C} - \boldsymbol{C}^T\boldsymbol{Y}^T < 0, \tag{11}$$

$$\boldsymbol{P}\boldsymbol{F} = \boldsymbol{C}^T\boldsymbol{H}, \tag{12}$$

hold, then observer gain matrix is given by

$$\boldsymbol{J} = \boldsymbol{P}^{-1}\boldsymbol{Y} \tag{13}$$

and fault estimation updating law as in (9).

For enhanced design conditions it is necessary to add matrix $\boldsymbol{Q}$, identity matrix $\boldsymbol{I}$, scalar γ and scalar tuning parameter δ such that conditions

$$\boldsymbol{P} = \boldsymbol{P}^T, \qquad \gamma > 0, \tag{14}$$

$$\begin{bmatrix} \boldsymbol{Q}^T\boldsymbol{A} + \boldsymbol{A}^T\boldsymbol{Q} - \boldsymbol{C}^T(\boldsymbol{Y}^T + \boldsymbol{Y} - \boldsymbol{I})\boldsymbol{C} & * & * \\ \boldsymbol{P} - \boldsymbol{Q} + \delta\boldsymbol{Q}^T\boldsymbol{A} - \delta\boldsymbol{Y}\boldsymbol{C} & -\boldsymbol{\delta}(\boldsymbol{Q} + \boldsymbol{Q}^T) & * \\ \boldsymbol{0} & \delta\boldsymbol{F}^T\boldsymbol{Q} & -\gamma\boldsymbol{I}_s \end{bmatrix} < 0, \tag{15}$$

$$\boldsymbol{C}^T\boldsymbol{H} = \boldsymbol{Q}\boldsymbol{E} \tag{16}$$

hold, then observer gain matrix is given by (13) and fault estimation updating law, again, as in (9). Tuning parameter δ adds a possibility to adjust behaviour of the observer.

Proof and complete description of both sets of conditions together with illustrative example can be found in [8]. Development of fault estimation for discrete-time systems was presented in [9].

IV. Next steps

Fault detection employing observer such that fault transfer function of the system is unitary opens different view at this task. Next steps in development of this approach will be focused on directional properties of residual functions. In best case scenario it could allow to use set of observers with fault estimation and real-time determination of the occurring fault.

Control reconfiguration in case when simple subtraction of estimated fault is not possible is a problem that should be tackled, but question is, whether it is possible to unite fault estimation and reconfiguration into single approach or it is necessary to use these methods as separate black boxes. Fault estimation of actuator faults is now well described and understood. Next tasks to tackle will consists of estimation of different class of faults and dealing with possibility of multiple distinct faults.

Acknowledgment

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Dielectric Spectroscopy of New Insulating Liquids in Transformers

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***Abstract*—This paper deals with my knowledge, experience and results, which I collected during last year on PhD. study. This paper deals with nanofluids, especially magnetic nanofluids which could be replacement for conventional insulating/cooling liquids as mineral oils. Monitoring of condition during thermal ageing of nanofluids might be by measuring as with conventional liquids, for this case the dielectric relaxation spectroscopy was used. The next development in my work for next period is described in last part.**

***Keywords*—transformer, insulating liquids, magnetic nanofluid, dielectric spectroscopy, cellulose**

I. Introduction

Developing of insulation liquid systems is accelerated from year to year. Mineral oil is mainly used in power transformers. The using mineral oil is limited by petroleum reserves and it has non-environmentally effects at leakage. In the world the number of transformer insulation systems that are filled with an alternative liquids, not based on petroleum, have increasing trend. Silicone and natural oils or liquefied gases are located in this "alternative" area. However, the requirements for higher quality and quantity of electric power bring (yet) only one solution for developing the transformers, namely: the increase of tank and cooling surface.[1] - [3]

Second important part of transformer insulation system is Kraft paper and pressboard, products from cellulose. These two parts of insulation system are dependent each other and it has influence on lifetime of device. The degradation of cellulose products has different rate for each fluid. Therefore, monitoring and knowing of specific phenomena are required.[4]

Since 1990's, researchers and engineers developed possible substitution for conventional thermal/insulation liquids composed of nanoparticles dispersed in these conventional liquids - nanofluids. Motivation for works of many researchers is in development of stable suspension without settle and with excellent thermal and the insulation properties. One of solution for improvement cooling/insulating properties in transformer is substitution of the used mineral oil by nanofluid based on previous oil, or using new liquids which are environmentally friendly and have electrical, chemical properties similar as mineral oil. [5]

II. Composition of nanofluids

Nanofluids, containing low volume of nanoparticles, can be one solution of problem of big sized power transformers. Nanoparticles used in nanofluids have been made of various materials, such as oxide ceramics (Al_2O_3, CuO), nitride ceramics (AlN, SiN), carbide ceramics (SiC, TiC), metals (Cu, Ag, Au), semiconductors (TiO_2, SiC), carbon nanotubes, and composite materials such as alloyed nanoparticles $Al_{70}Cu_{30}$ or nanoparticle core–polymer shell composites. Liquids used in transformers have a role in case of nanofluid as a carrier liquid. An important part of these liquids is surfactant - the surface active compound, which has been added in order to disperse nanoparticles. Surfactant consists of long chain molecules with polar and non-polar part. Polar part is attracted by nanoparticle and non-polar by fluid.[5]

Nanofluid consisting of magnetite particles Fe3O4 is called the magnetic nanofluid (MNF) with its specific properties described in [6] and [7]. Oleic acid is mainly used surfactant in this case of MNF.

One of important tasks in area of liquid dielectrics is monitoring of electrical, chemical a. o. properties and their changes with degradation degree. Spectroscopy of conventional liquids is today on considerably high level, but important questions in case MNF are: Is it necessary development of new spectroscopy method for MNF? How can the fluid affect cellulose products under chemical, electrical and thermal stress?

III. Solved/unsolved tasks of last year

During the last decade some of my colleagues from department started several works, which were based on monitoring dielectric properties and their changes with increasing thermal degradation for mineral oils, synthetic and natural esters and in MNF [7].

Understanding of polarization processes in dielectrics, measurement methods and knowledge from area of well-known dielectric spectroscopy in insulating liquids were a good stepping stone for identification changes in MNF. [6]

Important aspect for spectroscopy of the MNF is measuring of parameter, which could be good reflection for changes inflicted thermal, chemical, electrical ageing. In my case it has been observed by frequency domain relaxation spectroscopy:

before and after thermal degradation the parts of complex permittivity were measured and calculated.

The thermal dependence of polarization and dielectric spectroscopy in frequency domain was measured in ZCU Pilsen during my Erasmus mobility. We measured 4 samples: mineral oil, synthetic ester and one-layer magnetic nanofluid based on mineral oil and double-layer magnetic nanofluid based on synthetic ester. Samples were measured in frequency range from 0.5 Hz to 1 MHz and temperature range from 213,15K to 373,15K. Results are processed and article will be ready in the coming months. During evaluation of results the polarization phenomena were observed. The differences in polarization phenomenon of MNF and its carrier fluid are shown in Fig. 1.

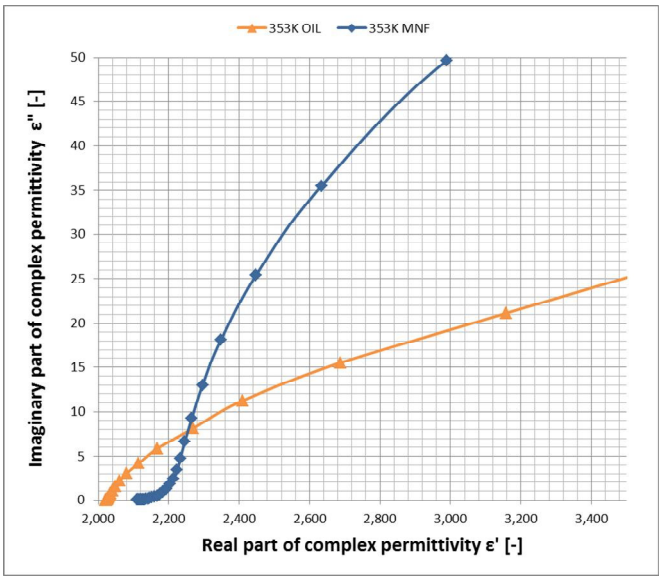

Fig. 1 Cole-Cole plot of MNF and carrier fluid (mineral oil) at 353K

These behaviors of polarization in liquids show the high contribution of the conductivity polarization in MNF. Unfortunately, the frequency range of spectrometer NOVOCONTROL was too narrow and there cannot be visible the phenomenon of relaxation polarization.

In the other experiment we observed polarizations in pressboard immersed in MNF and mineral oil with/without presence of cooper wire, which simulated part of winding and it had function of catalyst for aging. The aging was executed at temperature 353,17K, measuring every 150 hours reaching up to 500 hours. Subsequently changing measurement every 200 hours to 1000 hours, when stability of colloidal suspension was broken.

Another part of my work is coordinate diploma students with my supervisor on their works. We work on experiments about polarization in solid XLPE materials used in HV cables and thermal stress of these cables with subsequent of the time domain dielectric spectroscopy.

IV. Next steps

In [7] only MF was thermal stressed, but in real transformers the insulation system is composed of liquid, paper and pressboard. In my next work, the cellulose part will be subjected to precise analysis with thermal stress and also with mechanical stress where will be monitored the abrasivity of MNF. Since the few months the measurement of dielectric properties in frequency range from mHz to GHz is possible in our department. However, we don't have fixture for liquid samples usable in higher frequency range (2 MHz - GHz). Next aim of my dissertation work will improvement of spectroscopy methods and expansion of data set of MF and search further advantages or disadvantages these new composite materials.

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Effect of TCSC device on distance relay operation

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Abstract— **The increase in the line complexity, configuration and the power transmitted has introduced a number of problems in relation to distance protection. Distance relays are widely used as the main protection for transmission lines around the world. They operate based on impedance measurement at the relaying point, which is affected by several factors including the fault location, pre-fault condition (loading condition), short circuit levels, arc fault resistance and presence of FACTS devices on a transmission line. In this paper, discussion is made on the basic needs of protective systems, the various schemes of protection and the importance of distance protection in power system.**

Keywords **— FACTS devices, distance relays, faults, transmission lines.**

I. Introduction

In recent years the application of FACTS devices in power systems has increased to enhance the operational capacity of transmission lines. This has been achieved by pushing transmission lines to operate closer to their thermal and stability limits [1].

Protection is one of the most important areas of the power system operation, where the impact of FACTS devices is considerable and therefore it is essential to be studied. In this context, distance relay is very much prone to mal-operation as its impedance measurement is largely affected by the presence of FACTS devices and their operational strategies. Effects of these devices compounded with the impacts of previously mentioned factors could severely affect the apparent impedance measured at the relaying point and cause mal-operation of distance relays, in the form of over-reaching or under-reaching the fault point. Therefore, in the presence of FACTS devices, the conventional relay characteristics, such as Mho and quadrilateral, may not be suitable under some fault conditions. Impacts of FACTS devices on the measured apparent impedance at the relaying point are more complicated than the previously mentioned factors, since apart from their parameters, their installation points on transmission lines can also affect the measured apparent impedance [1]-[3].

II. General overview of issues

One of the most important FACTS devices which is connected to system in series is Thyristor Controlled Series Capacitor (TCSC) that is used to increase the overall capability of power transmission in a power long transmission line. Disadvantage of it is that although its usage will improve the power transmission capability and Stability on system, it may result i non-coordinated trip operation of circuit-breakers connected to main power system [4].

TCSC mounted on Fig. 1. (Left) is a type of series FACTS compensators. It consists of a capacitance (C) connected in parallel with an inductance (L) controlled by a valve mounted in anti-parallel thyristors conventional (T1 and T2) and controlled by an extinction angle (α). Using TCSC is possible to increase the transfer capability of existing power transmission systems together with the use of other benefits [5].

If we want solve only steady state (published in Elektroenergetika journal, 2015) we can simplify our model of TCSC, considering that ω is a constant representing the parallel connection unchanging capacitance XC and variable inductance XTCR (α), or susceptance BC and BTCR (α). After further simplification, we could replace the entire controller only element with XTCSC (α) respectively BTCSC (α), Fig. 1 (Right).

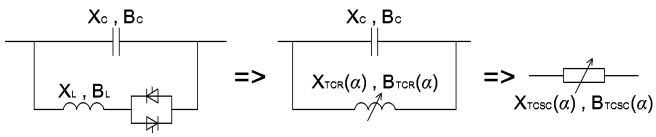

Fig. 1. Structures of simplified TCSC model

If we want to examine what will happen in power system when short-circuit or other dynamic state will occur we need to consider management of extinction angle (α) using controller, presented at Fig.2.

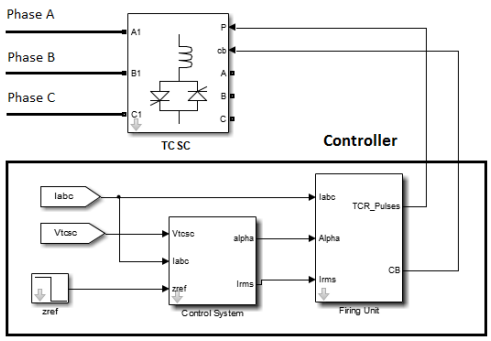

Fig. 2. Structures of dynamic TCSC model

It is well documented in the literature that the introduction of FACTS devices into power systems has a great influence on their dynamics. As power system dynamics changes, many sub-systems are affected, including the protective systems. Therefore, it is essential to study effects

of FACTS devices on the protective systems, especially distance protection [6].

III. Research Activities

At the beginning of my research I have dealt with theoretical study of operations and settings of digital distance protection (Distance Relay - DR). This study consisted from understanding of several different parts but mainly from operation and relation the internal logic of these devices.

Subsequently I continued my research by creating a functional model of DR in program Matlab / Simulink. In this program was designed the whole internal logic of protection which has been progressively improved and entered into the final version end of last year. This part was published in Elektroenergetika journal (Vol.7, No1 (2014)) and others. There is always space for next upgrades and further ideas to improve the model, which I gradually add to the model. Given that Simulink provides variability is not a problem to deliver any calculation

Next steps in extending the DR model lead to wider implementation of fault loop impedance calculation for different types, configurations (double line circuit, infeed) and operation modes (in service, maintance...) of the network which was published in a conference (Current Problems of Maintenance of Electrical Equipment and Management, 2015) and Acta Electrotechnica and Informatica journal, 2015.

In the past MHO tripping characteristics were most frequently used but these characteristic did not provide sufficient comfort settings.

In my research I worked with modern quadrilateral characteristic (composed of lines), which have variability settings, thereby providing opportunity for future adaptation and changes, which can occur by the addition of new device (in my case it will be TCSC device) to the existing power system.

My research was completed with last simulation which include above mentioned parts working together with TCSC device into one network. In this network, TCSC device was configured in various modes together with the impact of failures at different locations via one block (distance relay block).

IV. Results of Research

My research led to the creation of model (in Matlab, called subsystem) of distance relay, where the user only connects necessary measured values for calculate and sets the parameters and operation of the network (mentioned below) in user interface. This unit could be set according to the configuration of the power system in which will be implemented.

The block is fully functional and includes all the necessary parts for its operation. This block contains four tabs where the user can set the following:

- Parameters and operation of network
- Calculation of faults
- Characteristic
- TCSC

Using the above tabs, user can set line parameters (the symmetrical components of line impedance) or operation of network (protection of single or double line). After that we must choose the type of fault-loop calculation (cosine-phase comparator or amplitude comparator). The next step is to set parameters of tripping characteristics according to user needs.

This tab also includes the elimination of changing the reach of protection based on the thyristors angle and the ability to enable graphical representation of impedance. The last tab deals with the settings of various modes of TCSC device. After adjusting all the parameters we performed a lot of simulations for different network and various modes of TCSC.

More results of individual simulations and internally protection calculations are presented in my dissertation thesis with the same name as the title of the article.

According to the publication, I know that TCSC device have a significant impact on DR and therefore my final steps led to description and elimination of the impact of TCSC device on quadrilateral characteristic. This description would allow quicker and easier setting of distance relay parameters, if TCSC device will be fitted for the first time to the existing network.

V. Conclusion

In the presence TCSC device in power transmission systems, the conventional distance characteristic are greatly subjected to mal-operation in the form of over-reaching or under-reaching the fault point therefore these characteristic might not be utilized satisfactorily.

Since the distance relay are the most common used protection HV and EHV networks, therefore they should be given to more attention.

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Electrical Drive with Switched Reluctance Motor

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***Abstract*—The paper presents overview of electrical drives with switched reluctance motor. The basic characteristic and principle of operation are described below. Also the paper includes control options and control methods for torque ripple minimization.**

***Keywords*—electrical drive, switched reluctance motor, torque ripple minimization**

I. Introduction

The principle of switched reluctance motor was invented in 1838, but could not be realized in full scale of power. Development of power electronics has allowed improvement of its properties, which makes it comparable to other electrical motors.[1]

Switched reluctance motors (SRM) are gaining more and more popularity among electrical drives. This is due to their simple construction characterized by no magnets and winding on the rotor. Therefore, SRM is low-cost alternative to commonly used motors like brushless DC and AC motors. Other benefits are possibility of using SRM for a wide range of speeds and ability to resist to high temperatures. Among disadvantages belong torque ripple, which is caused by sequentially switching of phase windings. Such excitation also produces radial force on the rotor, leading to substantial vibration and acoustic noise. Partial reduction of the torque ripple can be achieved by editing the construction or by use of advanced control methods.[2][3] In Fig. 1 is shown torque ripple reduction tree.

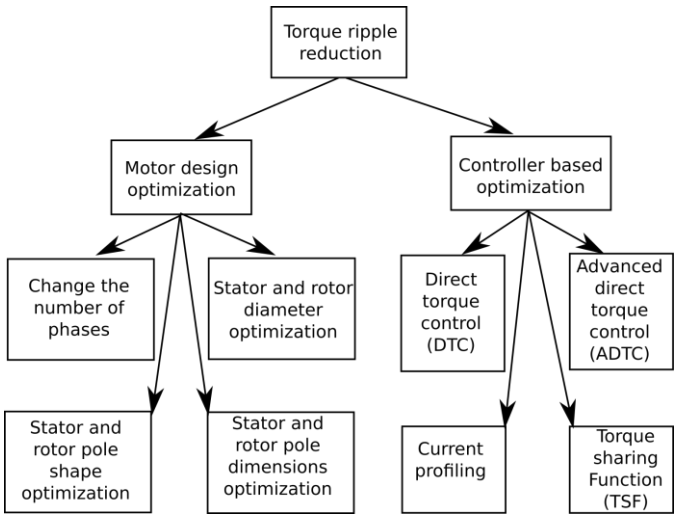

Fig. 1 Torque ripple reduction tree

II. Overview of Published Solutions

This paper is inspired by a few publications. The general overview provides section about SRM from [1], which includes basic terms of construction, mathematical model and introduce to control of SRM. It is thesis, which deals with issue of construction and modelling of SRM. The issue of construction and modelling SRM was presented in thesis [6][7].

Important part of electrical drives with SRM is control. Nowadays, engineers work on minimization of torque ripple which is caused by sequential phase switching. Complex information about control of SRM is referred in publications [4][8][9]. The control of SRM requires precise knowledge of rotor position. This signal allows gaining positioning sensor or method for sensorless control. The properties of sensorless control were published in papers [11][3].

While the price of electrical machines is rising, the price of electronic components is decreasing. Therefore, converters for SRM drives exist as separate section. The topology of basic and new converters was published in [12][13]. Comprehensive research of all parts of SRM drives is submitted in [5].

Some works like [14] that study the behavior of the SRM in case of switched reluctance generator, for example using SR generator in wind energy [15][17].

In present, SRM is researched also as drive for electric vehicles.[19][20] This confirms versatile use of SRM. At the 2013 Geneva Motor Show, Land Rover unveiled a range of seven electric research vehicles powered by SRM.[18]

III. Principle of Operation

The principle of operation is established on change of reluctance of magnetic circuit, when rotor generates torque to finish turning in aligned position. In Fig. 2 is shown construction of 3-phase SRM with number of poles $2p_1/2p_2$= 6/4 and rotor is in aligned position with phase A. While two rotor poles are aligned with the two stator poles, another set of rotor poles is out of alignment with respect to a different set of stator poles. The rotor will shift to a position where reluctance has minimal value and thus the inductance of the excited winding has maximal value. The number of poles on the SRM's stator is usually unequal to the number of the rotor poles to avoid the possibility of the rotor being in a state when it cannot produce initial torque, which occurs when all the rotor poles are aligned with the stator poles.[4] The rotor is rotated by sequential switching of the currents into the stator windings.

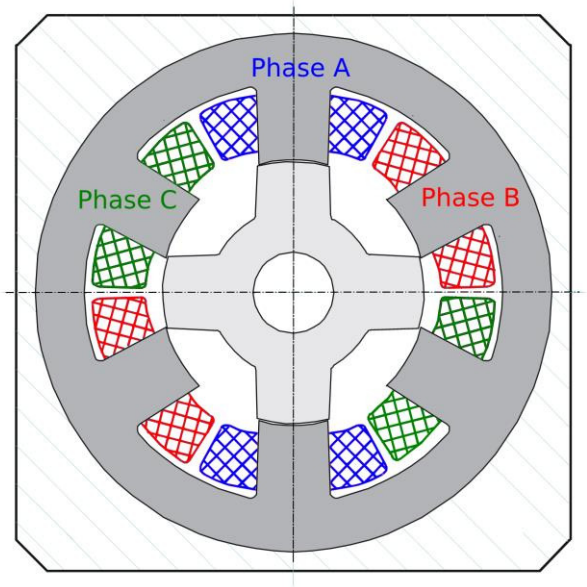

Fig. 2 Construction of 3-phase 6/4 SRM

In Fig. 3 is shown inductance dependent on rotor position. If rotor and stator poles of phase A are overlapped, then we can talk about aligned position of phase A. If phase is excited in this position, the motor generates no torque and inductance is maximal. In aligned position motor has minimal reluctance, because path of magnetic flow is shortest. If rotor is situated in position, where rotor pole is between stator poles, we can talk about unaligned position. In this position path of magnetic flow is the longest and inductance is minimal. SRM produces torque if it is situated between aligned and unaligned position. This effect is used by controlling SRM. An interesting feature of motor is that direction of motor rotation is independent on direction of the current, but is important timing of the current impulse, which depends on rotor position.

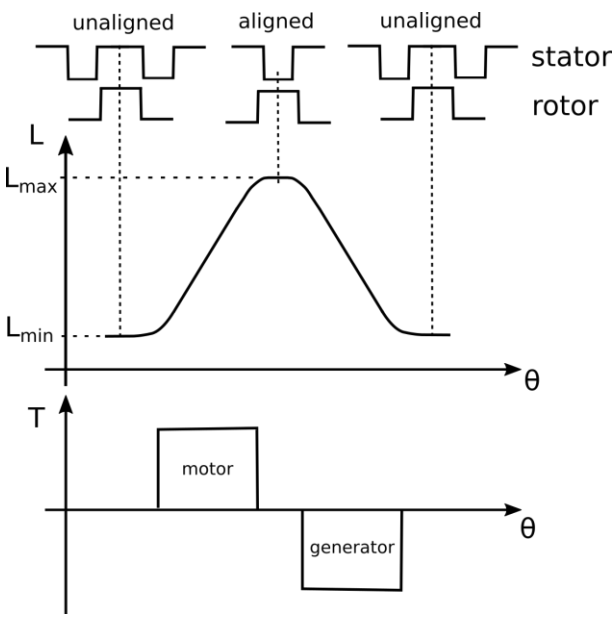

Fig. 3 Inductance dependent on rotor position

IV. SRM CONTROL METHODS

The motor is controlled by algorithm which sequentially excites phase winding to create torque in rotor. When phases are switched, the torque is rippled and appears as vibration and acoustic noise. Those vibrations can be possibly reduced by editing of construction and with advanced torque control methods. Few methods of SRM torque control are introduced in this section.

A. *Hysteresis current control*

This method is based on the main principle of the SRM: SRM produces positive torque if the current flows in the phase and inductance has rising slope. On the contrary, if the current flows in time when winding inductance has falling slope, SRM produces negative (braking) torque. The actual value of the current is keeping by the hysteresis current regulator so as current is equal to desired value of current $\pm\Delta I$. In pursuance of this condition are switched the power semiconductor switches in asymmetric converter.

The asymmetric converter consists of two power transistor and two diodes for each phase winding. If both transistors are switched, then current flows in the winding and voltage is equal to $+U_{DC}$ (State 1). If one of the switches is turned off, then inductance causes the current flows still through the winding, but voltage is equal to zero (State 0). If both of the transistors are turned off, then on the excited phase is connected negative voltage $-U_{DC}$ through the diodes until the current is not zero (State -1). Three states of asymmetric converter for phase A are shown in Fig. 4. [4][5]

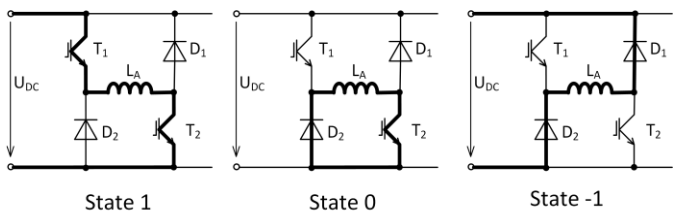

Fig. 4 States of asymmetric converter

B. *Current profile strategy*

As the torque is dependent on the phase currents and rotor position, it is evident to control the phase current profile through wave shaping technique for reducing the torque ripple. Current profiling method requires to know characteristics of SRM i.e., torque dependence on current and rotor position. The optimized current overlap during the commutation (a trapezoidal current profiling) can be obtained by identifying a central commutation point where the values of incoming and outgoing phases are equal. The total time taken for computation and conduction of test is very high. [21]

C. *Direct torque control (DTC)*

Conventional DTC method is based on control torque during the phase commutation. The phase commutation is divided to 3 regions and is needed to know which phases are incoming and outgoing. The boundaries of regions depend on the geometry construction of SRM. The phase commutation and region dividing is shown in Fig. 5. Output torque is regulated by conditions in the hysteresis regulator. Those conditions are described in TABLE I. States of incoming (outgoing) phases are denoted in Fig. 4, when each phase can have three states. In fig. is shown feedback regulation diagram of SRM by DTC method. Currents of SRM are measured and used to computation of estimated torque. [4]

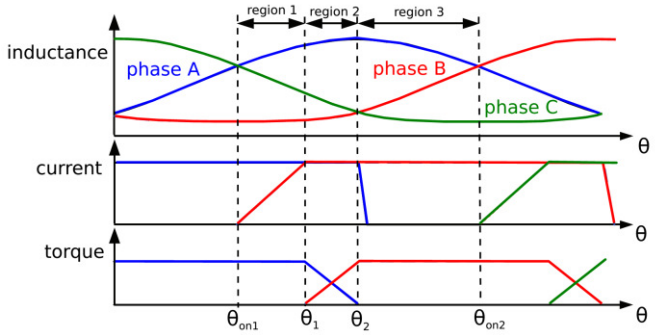

Fig. 5 DTC method – boundaries of regions

TABLE I
DTC SWITCHING RULES

Region	Condition	State	
	ΔT	Incoming	Outgoing
Region 1	>0	1	0
	>ΔE	1	1
	<0	1	0
	< -ΔE	1	-1
Region 2	>0	0	0
	>ΔE	1	1
	<0	1	0
	< -ΔE	0	-1
Region 3	>0	0	-1
	>ΔE	1	-1
	<0	0	-1
	< -ΔE	-1	-1

D. *Advanced direct torque control (ADTC)*

ADTC combines the conventional DTC with the PWM method. The duty ratio of the phase switch is regulated according to the torque error and simple control conditions of the DTC. Therefore, the sampling time of the control can be extended, which allows implementation on low cost microcontrollers. The regulation diagram for DTC and ADTC method is shown in Fig. 6.[16]

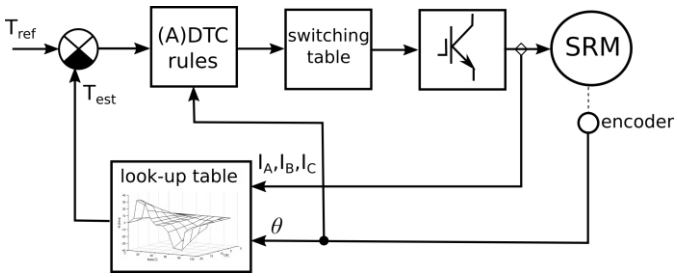

Fig. 6 Regulation diagram of DTC and ADTC

The ADTC method can adjust the average phase voltage to control a variety of phase currents in one sampling time, which can extend the sampling time and obtain smaller torque ripple than the conventional DTC. However, the PWM generator is added, and the switching frequency of the ADTC is double that of DTC's with uniform sampling time in the worst case. So the switching loss and EMC noise are increased in the ADTC method.

E. *Torque sharing control*

The next powerful method to reduce torque ripple is torque sharing function (TSF) method. The TSF method uses the pre-measured non-linear torque characteristic, and simply divided torque sharing curve is used for constant torque generation.[4]

According to the torque sharing curve used the traditional TSFs can be classified as linear or nonlinear TSFs. The nonlinear TSFs further can be divided into cosine, exponential and asymmetric TSFs.[17] In Fig. 7 are shown linear and cosine TSFs which are dependent on phases inductance. In general, the torque sharing function in a rotor period is defined as:

$$f_{TSF(k)}(\theta)=\begin{cases}0, & \theta<\theta_{on(k)}\\ f_{up}, & \theta_{on(k)}<\theta<\theta_{off(k-1)}\\ T_{ref}, & \theta_{off(k-1)}<\theta<\theta_{on(k+1)}\\ f_{down}, & \theta_{on(k+1)}<\theta<\theta_{off(k)}\\ 0, & \theta_{off(k)}<\theta<\theta_{on(k)}\end{cases} \quad (1)$$

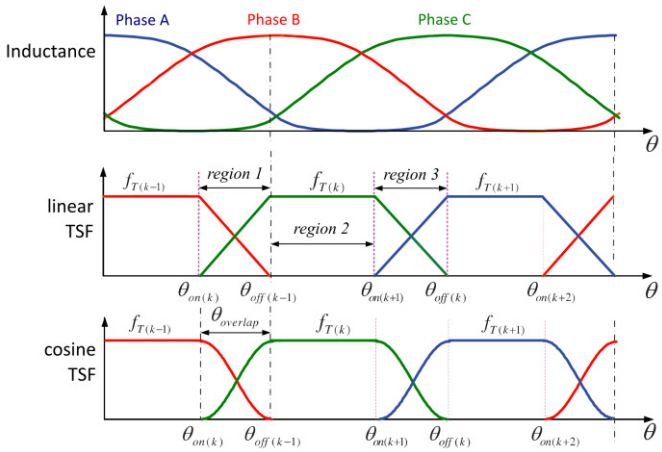

Fig. 7 Torque sharing functions

Three-phase torque commands are changed to current command for each phase according to rotor position. Therefore, TSF control method belongs among indirect torque control method. Each phase current is regulated separately and for current control can be used hysteresis regulator. The regulation diagram is shown in Fig. 8.

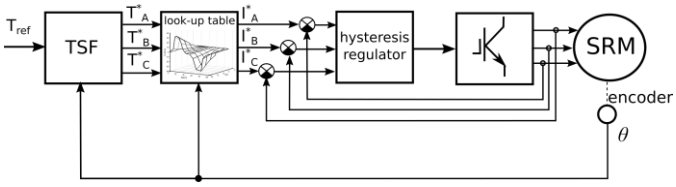

Fig. 8 Control diagram for the TSF method

V. CONCLUSION

The switched reluctance motor belongs to the electrical machine with simple construction, when rotor is basically a piece of steel (and laminations) shaped to form salient poles. Its biggest disadvantage is ripple of produced torque which is possible to reduce by editing the construction or by use of suitable control method. As a result of its inherent simplicity, the SRM promises a reliable and a low-cost variable-speed drive and will undoubtedly take the place of many drives now using the cage induction, PM and DC machines in the short future.

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Embedded cryptographic primitives with improved side-channel attack resistance

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***Abstract*—In this paper, we provide a brief review of the results of our research in the recent year. Two main topics are described in this work - defending McEliece public-key cryptosystem and a new countermeasure against side-channel attacks based on m-of-n coding. We provide basic information about principles of new methods of countermeasure against side-channel attacks in embedded devices. Furthermore, we present results achieved in the field regarding the two discussed topics.**

***Keywords*—Differential power analysis, embedded devices, m-of-n coding, McEliece cryptosystem, countermeasure.**

I. Introduction

Security of embedded devices gets more importance in modern world than ever before. The Internet of Things (IoT) appears to be having a major influence on how microcontroller (MCU) technology develops. Low-cost ultra low-power MCUs will be used mainly as edge devices in IoT [1], [2]. There are several alternatives for MCU development in this segment but low cost MCUs based on 8-bit (mainly new 8051-compatible cores with embedded RF connectivity) and 32-bit cores (ARM Cortex M0+ based) will compete in this segment for longer time. These MCUs contain relatively large program Flash memories (typically at least 64 kB). However, many of these MCUs still lack specialized peripherals, e.g. true random number generators (TRNGs) or cryptographic coprocessors required for security enhancement. Efficient protection of these embedded devices has to be added by software developers.

Security of electronic devices strongly depends on hardware or software implementations. These embedded devices exposed to adversary attacks are the most vulnerable. MCUs in the edge devices are the most critical ones. Differential power analysis (DPA) [3] as a subgroup of side-channel attacks (SCA) posses critical threat to the embedded devices security. Countermeasures against DPA attacks can be based on masking [4], [5], hiding [6] and shuffling [7]. Almost all of the commonly used countermeasures require TRNGs. Our paper proposes a straightforward method of hiding based on balancing of the power consumption in typical low-cost MCUs without TRNG where the majority of other countermeasures are not possible to implement.

II. Attacking and defending McEliece cryptosystem

In this section, we present an efficient countermeasure against side-channel attacks on the McEliece public-key cryptosystem. Firstly, we deploy two correlation power analysis attacks based on a chosen ciphertext attack targeting the cryptosystem. We demonstrate that a part of a private key - a permutation matrix can be recovered using the attacks. We show that a revelation of the permutation matrix possess a critical threat to the cryptosystem. We attack two software implementations of a secure bit permutation. The cryptosystem and its variations are implemented on a 32-bit ARM-based microcontroller. We provide details and results of the attacks using power consumption measurements of the hardware (Fig. 1).

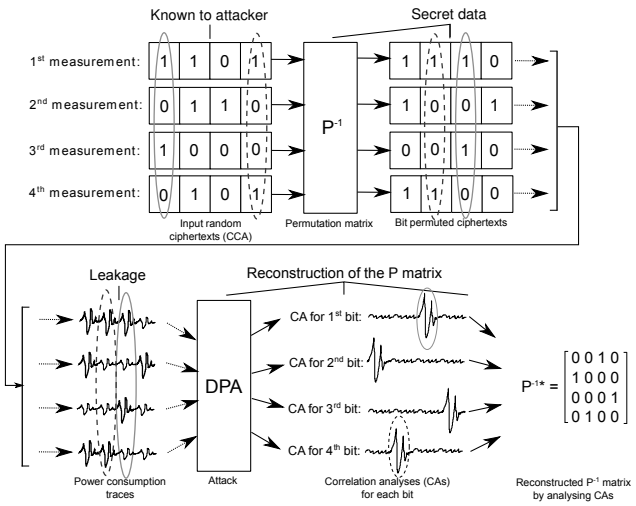

Fig. 1: Main steps of the CPA attack on the secure bit permutation. We input random ciphertexts while the permutation matrix $\mathcal{P}^{-1}$ remains the same. We measure a leakage from the permutation itself (the attack on [8]) or from the syndrome computation (the attack on [9]).

We present an outline of a novel efficient countermeasure against the attacks. The countermeasure (which is a derivate of a masking technique) uses properties of the McEliece cryptosystem in order to reduce a complexity of the technique. Our new method does not require a large amount of random bits and it reduces computational time compared to the regular masking technique. These properties can be profitable for low-cost constrained and embedded devices (Fig. 2).

III. Countermeasure against side-channel attacks based on m-of-n coding

In this section we present a new method of countermeasure against the DPA attack [10]. We use randomly assigned general

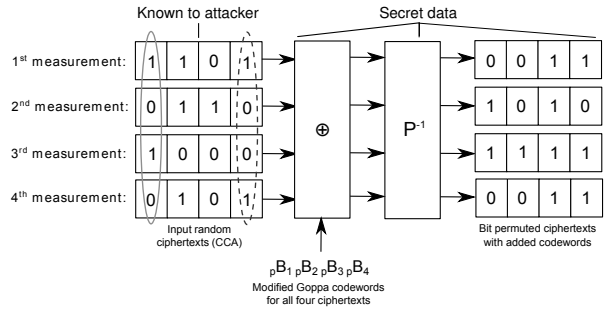

Fig. 2: Secure bit permutation with the proposed countermeasure. Modified Goppa codes are added to ciphertexts as masks before the permutation. During and after the permutation, an adversary is unable to find patterns (gray and dashed ellipses) in permuted ciphertexts with added Goppa codewords.

constant-weight codes (m-of-n codes) for every intermediate value in a secure embedded device (Tab. I). In an ideal hardware, the equal Hamming weight of data ensures balanced power consumption for any values in the device and thus it complicates the DPA attack.

TABLE I: Different constant-weight codes with decimal and binary equivalents. Note that 2-of-5 coding has 10 codewords in total and two codewords are not used.

Decimal	Binary	One-hot	Balanced	2-of-5
0	000	00000001	000111	00011
1	001	00000010	001110	00101
2	010	00000100	010101	01001
3	011	00001000	011100	10001
4	100	00010000	100011	00110
5	101	00100000	101010	01010
6	110	01000000	110001	10010
7	111	10000000	111000	01100

We demonstrate the method on a table based AES cipher and we propose several implementation tricks to reduce the size of tables to 24 kB/12 kB that are acceptable for some practical MCU implementations. We evaluate the performance of proposed method in terms of speed, memory usage and we test possible side-channel leakages (Fig. 3) on an ARM Cortex-M3 MCU implementation.

IV. Conclusion

In this paper, we outlined the main results of our research in the recent year. We presented the secure implementation of McEliece cryptosystem and the secure implementation of byte-oriented ciphers. In the future, we will focus on publication of our yet unpublished results, on writing of the PhD dissertation and on a successful defense of the dissertation.

Acknowledgment

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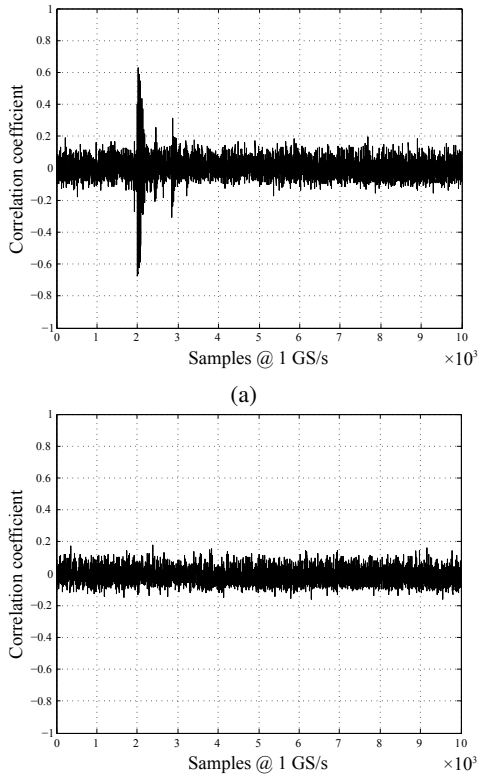

Fig. 3: DPA attacks with Hamming weight model on the straightforward table implementation of AES byte substitution (a) and the implementation using m-of-n coding (b). Significant correlation coefficient peaks that can be distinguished from the surrounding noise indicate a successful attack using Hamming weight model.

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Emotion Recognition from Speech Signal

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***Abstract*—Emotions in speech are very good indicator of human state of mind. To have machines understand humans, and their inner conditions, is in focus of science for decades. Following this path, this article is dedicated to emotion recognition from speech signal, and to speaker recognition from expressive speech. For that purpose, three different databases of emotional speech were used. In preprocessing of the speech material, different speech features, containing emotional information, were extracted. Extracted features were then mapped to i-vectors, vectors of fixed length of low dimension. As a scoring method of used recognition system, Mahalanobis distance metric was applied and accuracy of recognition system was calculated for speech emotion recognition, and for emotional speaker recognition as well.**

***Keywords*—emotions, i-vector, speaker recognition, database of emotional speech.**

I. Introduction

Human ideas, intentions and states of mind are interposed throughout the speech. Human speech is complex signal, in which explicit information of what was spoken, and very important implicit information of how it was spoken are contained. Understanding the ultimate relevance of spoken text message is tightly connected to the very implicit channel of human communication. In general, multimodal speech information such as emotional background of speech, facial gestures, and body language specify the real meaning of what has speaker said, and may help to determine why he/she had said it that way.

For purposes of this article only emotional information hidden in speech signal are important. According recent technological boom the automatic speech recognition (ASR) doesn`t consider linguistic meaning of the speech only. The emotional background of speech signal became very important in this scientific field as well. Those complementary information of speech can be, alongside the ASR, exploited in different application. For example, in medicine for neurological [1] and psychological disorders and diseases diagnostics, in forensics and safety monitoring, in entertainment industry, marketing, automatic tutoring and many others [2].

II. Initial Status

The first roots of speech recognition may be dated back to the 30s of last century. In 1960 at the Stanford University the first speech recognition system was used. In 80s of the last century the ASR mayor advance was made mostly on technical level. Nowadays considerable focus is on emotion recognition from human speech, and that is the scope of this article as well.

After the study of theoretical background of emotional recognition and initial experiments [4][5][6][7] the synopsis of dissertation thesis was specified:

1. The application of methods for creation and annotation of database of emotional speech.
2. The application of methods for selection of emotional characteristics from expressive speech, which would include information on F0 and its local and global changes as well.
3. The application of new methods of feature vectors selection, synthesis and reduction.
4. Analysis of emotional information in speech signal in process of speaker recognition suitable for forensics applications.

III. Solved Tasks in The Previous Year

Tasks which are summarized in the following section were solved in the last year of postgraduate study.

A. Creation and preparation of databases of emotional speech

For purposes of speech emotion recognition, and speaker recognition from expressive speech three databases were used.

The first one, for speech emotion recognition, was Electromagnetic Articulography database (EMA DB) [3]. This database (one male and two female speakers without professional theatrical training; duration aprox. 1 hour), in English language, contained appropriate amount of short time speech samples for speech emotion recognition, in four basic emotional states (neutral, happy, sad, angry), and was used without any adaptation.

For the speaker recognition from expressive speech two databases, one in English language, other in Slovak language, were used.

The first one of them was obtained by adapting emotional recordings of emotional prosody database [8] (duration aprox. 8 hours). The obtained database contains emotional recordings of eight professional actors (five women, three men) in emotions of neutral, happiness, anger, contempt, sadness, pride, elevation, etc. In experiments only emotional recordings of neutral, happiness, anger, contempt and sadness were used. The original database was manually labeled, then processed in Transcriber [9], and finally cut by proprietary software into

the form suitable for intended experiments.

The second database, used for the speaker recognition, was created from audio sessions, which were captured from free FTA DVB-T transmission using PCI digital capture card. Emotional utterances of different speakers were extracted from those sessions. All of the emotional utterances were manually labeled, processed in Transcriber and cut into separate emotional utterances of individual speakers with duration from 5 to 6 seconds. The emotional evaluation was provided on the whole sentences or segments of the sentences so that the explicit meaning of the utterance was captured in recording. Emotional range of recorded utterances covers mostly emotions of neutral state and interest as well as negative emotions (anger, aggressiveness, etc.).

This database (duration aprox. 3 hours), in Slovak language, consists of emotional utterances of 11 subjects (six women, five men), all of them without proper theatrical training. In experiments of this article only emotions of neutral, interest and surprise were used.

B. Extraction of acoustic features

In process of feature extraction from emotional utterances of mentioned databases, different number of different acoustic features were extracted. Namely MFCC (Mel-frequency Cepstral Coefficients), LPC (Linear Prediction Coefficients), LPCC (Linear Prediction Cepstral Coefficients), PLP (Perceptual Linear Prediction), LFPC (Log-frequency Power Coefficients) coefficients in amount of 12, 14, 16, 19 and 22 coefficients per frame. To the static coefficients, delta and acceleration, and the third regression coefficients respectively, were added. The impact of number of static coefficients and added time derivates on recognition rate was then observed.

Alongside the cepstral coefficients, the F0 was extracted from emotional utterances as well, and different static coefficients and F0 were concatenated.

C. Application of reduction method and feature vector combination

To reduce the dimension of extracted features vectors from emotional utterances a state of the art i-vector principle was applied [10]. To find out the best performance of the recognition system, the dimension of the i-vectors was experimentally set to 10, 15, and 20 respectively and results were compared. GMM with 32, 64 and 128 mixtures was used in process of speaker and emotional modeling.

IV. Results

According the parametrical setting of the experiment the best result (over 80%) were obtained, in both, the speech emotion recognition and speaker recognition, while adding the third regression coefficient to static coefficient and first and second time derivates (Fig. 1). Concerning the i-vector dimension, the best result were retrieved, while setting the dimension of i-vector to 10 and modeling the speaker/emotional model with 32GMM (Fig. 1). While increasing the i-vector dimension and numbers of GMM the recognition rate drops. In case of speech emotional recognition mostly LFPC insured the best recognition rate as illustrated in Fig. 1, possibly because of their ability to retain fundamental frequency information better than MFCC and so. In speaker recognition it was 22LPCC, 22LPC and 22 LFPC as can be seen in Fig. 2. Decreasing the number of static coefficients in feature extraction lead to lower recognition performance. Obviously smaller number of static coefficients extracted in front end processing doesn`t contain enough descriptive information for such recognition tasks.

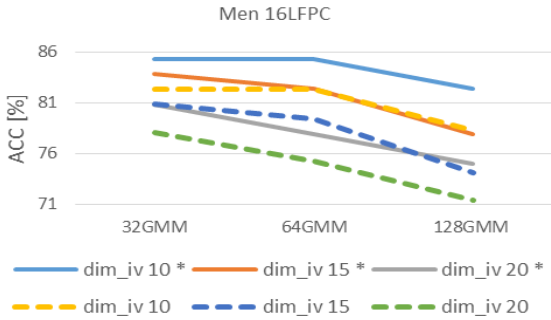

Fig. 1 The impact of adding the third regression coefficients (marked with *) to the static and time derivates, and i-vector dimension effect in speech emotion recognition.

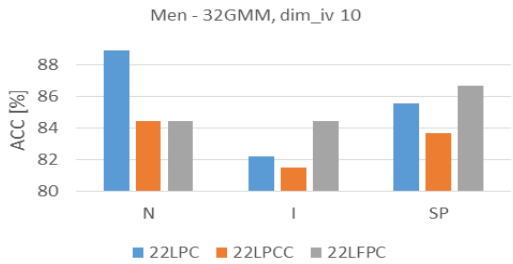

Fig. 2 The best recognition rate in speaker recognition from expressive speech on Slovak dataset. TVM iterations = 10. N – neutral emotional state, I – interest, SP- surprise.

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Equivalent Consumption Minimization Strategy for Parallel Hybrid Vehicle

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***Abstract*— This paper presents an equivalent consumption minimization strategy (ECMS) simulated by QSS model of a parallel hybrid electric vehicle. Simulated fuel consumption results of HEV were compared with a combustion engine vehicle.**

***Keywords*—ECMS, parallel hybrid, QSS toolbox.**

I. Introduction

Trends nowadays are forcing vehicle producers to innovate the drivetrain of standard vehicles. One of the popular approaches to meet emission regulations is to equip drivetrain with internal combustion engine (ICE) with electric motor (EM). Vehicles with at least two sources of energy (implicitly not only ICE and EM) are called hybrid electric vehicles (HEV).

Hybrid propulsion system provides several advantages. EM provides maximum torque from zero rpm, high efficiency, may be overloaded and is also capable of energy recuperation. ICE disposes of high torque in high rpm and offer wide driving range. Maximizing advantages of HEV require good energy management.

Main task of the energy management is to meet driver power demands and to achieve better fuel economy and greenhouse gases (GHG) emission.

This paper is devoted to equivalent consumption minimization strategy (ECMS) of the parallel hybrid vehicle.

ECMS is easy to implement, but does not guarantee global optimality.

II. Vehicle model

Two different approaches to the HEV modeling can be adopted: the backward (quasistatic - QSS) and the forward-facing modeling with respect to the physical causality principles.

QSS approach reverses the usual cause-and-effect relationships of dynamic systems. Instead of calculating speeds from given forces, based upon given speeds (at discrete time), QSS calculates accelerations and then determinates necessary forces. As a result, effects in QSS are mean speed, acceleration and driving force caused by prescribed speed at certain time. Moreover, the high performance CPU is not necessary for QSS simulation. On the other hand, QSS is not suitable for capturing of dynamic phenomena, because it assumes the capability of the drivetrain to meet power demands [1].

Table 1 Modeled vehicle parameters

Vehicle parameters	**Unit**
Total vehicle mass (+ electric propulsion components)	750 kg (+ 250 kg)
Cross section	2 m^2
Drag coefficient	0.22
Rolling friction coefficient	0.008
ICE parameters	**Unit**
Displacement	0.708 l
Max. power	46 kW
EM parameters	**Unit**
Max. torque	70 Nm
RPM	5700 s^{-1}

III. ECMS – Equivalent Consumption minimization strategy

The main principle of ECMS is controlling of the power flow from the ICE and the EM to minimize vehicle fuel consumption and engine GHG emissions. The main concept of ECMS supposes that the battery energy consumption is considered as ICE fuel consumption. Thanks to this assumption, only one variable has to be considered [2].

Objective of the real-time ECMS is to reduce the global criterion to an instantaneous optimization problem, introducing a cost function dependent only on the system variables at the current time. Thanks to equivalent consumption assumption, local criterion can be formulated as in (1), where $P_{ICE}(t)$, $P_{EM}(t)$, $P_{req}(t)$, $\dot{m}_{ICE}$, $\dot{m}_{EM,eq}$ is ICE and EM power, required power, ICE consumption mass and equivalent EM consumption mass, respectively. To calculate EM fuel consumption, equivalence factor is needed. Equivalence factor considers energy paths from the fuel to the electric energy storage [3].

$$J_t = \dot{m}_{ICE}\left(P_{ICE}(t)\right) + \dot{m}_{EM,eq}\left(P_{EM}(t)\right)$$
$$\left\{P_{ICE}^{opt}(t), P_{EM}^{opt}(t)\right\} = \arg_{\{P_{ICE}(t), P_{EM}(t)\}} \min J_t \text{ if } P_{req}(t) \geq 0 \quad (1)$$
$$\left\{P_{ICE}^{opt}(t) = 0, P_{EM}^{opt}(t) = P_{req}(t)\right\} \quad \text{if } P_{req}(t) < 0$$

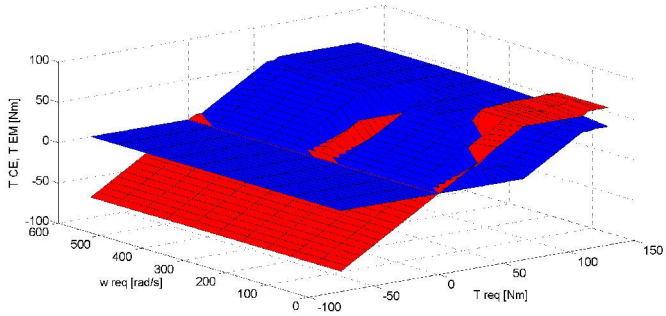

Figure 1 Torque required from CE (blue) and EM (red) depending on total torque required and engine speed.

Equivalent fuel consumption can be calculated as:

$$\dot{m}_{EM,eq} = \gamma \cdot s_{dis} \frac{1}{\eta_{EM}(P_{EM})\eta_{EM}(P_{EM})} \frac{P_{EM}}{H_{LHV}} + (1-\gamma) s_{chg} \eta_{EM}(P_{EM})\eta_{EM}(P_{EM}) \frac{P_{EM}}{H_{LHV}} \quad (2)$$

where η_{EM}, H_{LHV} represents EM efficiency and CE lower heating value. γ can be calculated as:

$$\gamma = \frac{1 + sign(P_{EM})}{2} \quad (3)$$

s_{chg} and s_{dis} represents equivalence factor during charging or discharging. These factors are variable, depending on driving cycle and they are not optimal for various driving conditions. Due to this, ECMS does not guarantee battery state of charge (SOC) sustainability in real-time applications.

IV. Realization

ECMS control in modeled HEV by QSS is represented by look-up table. The table is created by the algorithm on Figure 2. Input values for that algorithm are 3-D ICE fuel consumption map (fuel mass in kg/s in depending of engine speeds and torques), EM efficiency map (efficiency in depending of EM speeds and torques) and minimum and maximum speeds and torques of ICE and EM (limiting all possible operational states).

Computation of $\dot{m}_{EM,eq}$ is realized iteratively with the chosen step of T_{EM} and ω_{EM} where is made an assumption that EM efficiency is equal to battery efficiency. After that, *Control* matrix is calculated. Variable m represents all possible torques demanded by gearbox. Maximum torque T_{max} is sum of maximal EM torque and ICE torque. Negative torque is provided only by EM. Variable n stands for speed iterations. If positive torque is demanded, algorithm is testing different torque split combinations. Optimal power split is obtained by argmin function applied on J_t vector. Control matrix is shown on Figure 1, where w_req and T_req represents required speed and total torque. Z axis represents torques from EM and CE at given driving conditions (w_req, T_req).

V. Conclusion

ECMS proposed in this paper was compared with QSS model of vehicle without electric propulsion part. The parameters of vehicle are in Table 1. HEV disposes the same parameters and higher weight.

ICE vehicle fuel consumption is 3,457 litres/100 km in accordance to NEDC driving cycle. HEV fuel consumption varies with the different s_{dis}, s_{chg} parameters. Best results were achieved when s_{dis}=3.9 and s_{chg}=1. SOC at the end of the test

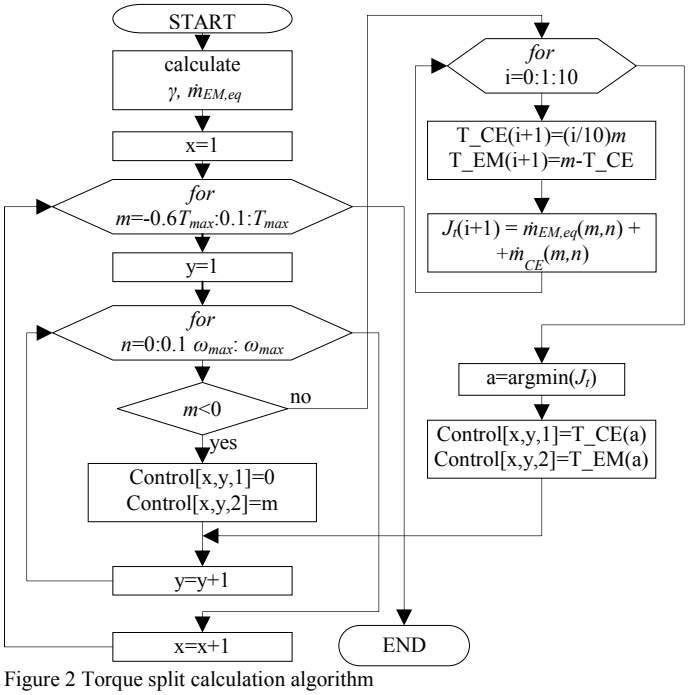

Figure 2 Torque split calculation algorithm

Table 2 Comparison of ICE vehicle and HEV consumption

Cycle	ICE Vehicle [l/100km]	HEV [l/100km]	Improvement [%]
NEDC	3,363	1,751	47,9
EUDC	3.566	1.696	52.4
FTP-75	4.029	3.684	8.6
FTP-Highway	2.949	2.212	25
130 kph	5.306	5.449	-2.7
50 kph	2.559	2.786	-8.9

cycle was almost at the same level as at the beginning (+1%).

Total fuel consumption of hybrid vehicle was 1,751 litres/100 km. Table 2 shows results during other test cycles.

Hybridization of vehicle propulsion system with suitable energy management is able to improve fuel consumption during dynamic driving significantly. On the other hand, during stable operation at constant speed there is opposite trend, which is caused by constant torque delivered primarily by ICE.

There are many ways how to improve ECMS real-time performance. One of them may be adding SOC sustainability criterion into the current algorithm. This may be achieved by real-time computation of equivalence factors, depending on the future driving conditions achieved by GPS.

My future work should be focused on the other control strategies for HEV and their optimization for usage in small vehicles propelled by different sources.

Acknowledgment

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Evaluation of Parameters for Tracking Objects in Multi-Camera Systems

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***Abstract*—Presented research is focused on the analysis, comparison and design of streaming, detection and tracking technologies and their mutual interconnection in the multi-camera environment. Principal interest is the design of a tracking system with capability of detecting the objects in a real-time across multiple moving cameras. Another feature to be introduced is the ability to stream video from the most relevant source. The metric that allows rating of each visual source contained within the system is outlined and is following the analysis of prior researches from this area of interest, while taking into account the specific characteristics and requirements of multi-camera systems with moving cameras.**

***Keywords*—Multi-camera systems, Object tracking in video, Streaming technologies.**

I. Introduction

According to a study [1], ninety percent of the data transmitted via the Internet should be in the form of video in 2015. This prediction is not completely true, even though the proportion of the transmitted video content rapidly increases. People are using video to communicate, share their experiences or learn. Watching conferences, presentations and lectures is becoming more and more popular, and viewers are becoming more demanding and more critical to the quality of picture and sound, or level of interactivity with presenters.

Production team that provides this broadcasting must have a lot of members and must work with the amount of equipment. They must be constantly on the alert, operate with devices, searching for the best shots, cutting them into a live streaming or to record. During longer events this kind of work is very difficult and exhausting. Therefore, a lot of researches are trying to replace the automated or semi-automated multi-camera systems requiring only minimal or even no control and operation.

Thus, the aim of this paper is to analyze the fields, which would provide a theoretical basis for the system design that solves these problems. The work deals with the analysis of streaming technologies that are used in the transmission of video and audio. Another part is devoted to the basic problems of computer vision and methodologies for the identification of objects in the image, also the analysis of object classification methods in video is carried out. The concept of multi-camera systems is defined and unsolved or inadequately solved problems in this field are specified.

II. Initial Status of Research Task

Topic of object tracking in multi-camera system covers many commercial solutions. However, these do not solve any problem or create new problems.

Existing solutions can include tracking the objects in static multi-camera systems. Such system typically requires a common viewing angle for multiple cameras and hence the object that is being tracked is never lost. However, in this type of solution is required a larger number of cameras.

Another solution is the dynamic turning cameras based on the prediction of movement of the reference object or on predefined mapping sound source to a specific location of the object. The first of these solutions introduces a problem that it is applicable only in situations in which the reference object is carried out – this includes simple and easily predictable movements. In the second solution, one have to manually map camera images, even before a shot is taken.

In terms of research, the work [2] is related, author proposes a metric to select the best shot from multi-camera system. The metric is composed of objective parameters and subjective inputs from live streaming audience.

III. Partial Results

The main scope of this work is the analysis of technologies which are useful in process of object tracking in multi-camera systems.

A. *Streaming technologies*

The first part of analysis is focused on the processing of video streaming and is divided into several sections. The introduction defines the concept of streaming and analyzes video codecs. This part includes Theora, VP8 [3], H.264/AVC [4], H.265/HEVC [5] codecs and comparison between H.264 and H.265 [6]. The second sections is aimed on video file containers (FLV, MP4, OGG and WebM) and the last part is describing streaming protocols (RTP, RTSP, RTMP HLS) and live media encoders (FFMPEG, FMLE).

B. *Preprocessing of frames*

Once the image is processed, and necessary also sent, the object detection can start. However, better process sequence is for image to be preprocessed and prepared for the next phase.

In this part of work the analysis is focused on technologies

such as thresholding [7], morphological operations [8] (erosion, dilatation, opening, closing), picture filters [8] (box filter, Gaussian filter, median filter), histogram of colors, reverse projection of histogram and moments of pictures.

C. Object detection

The next step after preprocessing of frames is object detection. In this research three methods for detecting objects are presented. The first is optical flow which is suitable for environments containing the moving camera and static object [9].

Another method (better for situation with static camera and moving object) described in study is called background modeling [9]. This method is divided to recursive (image differentiation, mom-linear predictive filter) and non-recursive techniques (Kalman's filter [10], Mixture of Gaussian Distributions [11]). The last method, background subtraction [9], is described in process steps – preprocessing, background modeling, foreground detection and data validation.

D. Object classification and tracking

In this part the four types of object classification are described [12]. Classification based on color of the object is the simplest one but it has the lowest percentage of finding an object [13]. On the other side, texture-based classification is the best for object detection but process resources for this method is the highest. Better solution could be combination of color-based classification and two other – based on shape and movement of the object [14].

Object tracking is the last step in this process. Analysis is focused on tracking algorithms with regarding on Tracking-Learning-Detection (TLD) algorithm. The libraries utilized in object tracking (OpenCV, FastCV) are presented and the vector of parameters (P^t), which TLD algorithm sent as output, is defined (Fig. 1).

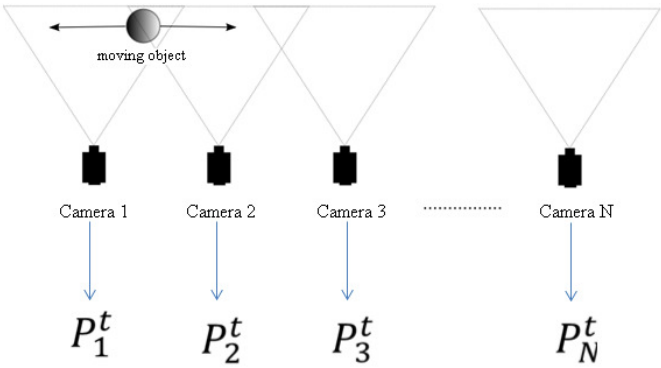

Fig. 1 Cameras sending vector of parameters

E. Multi-camera system and metric proposal

The final part of this research is focused on definition of multi-camera systems, parameters of these systems and last but not least, the proposal of metric for tracking object in multi-camera environment.

The metric is based on output information from tracking algorithm and it is combined with audio tracks from microphone. The main idea of metric is to map one audio track to a particular object that is being tracked by one camera (Fig. 2).

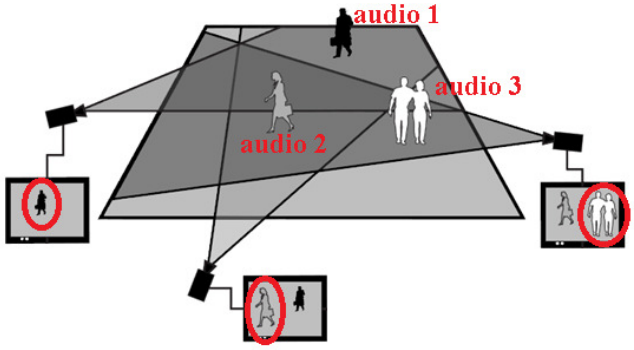

Fig. 2 Mapping audio sources to tracking objects

IV. Future Research

Based on this analysis the future research activities will be aimed on the specification of the optimization in design of multi-camera system while using methods that will be necessary for the solution that appears to be the most effective and optimal. Formal definition of the metric for evaluation of individual video sources in a multi-camera system is necessary, solution may be based on classification methods.

The correctness of the proposed mechanisms and design of solution will be experimentally verified. The aim is the proposal of a model solution for multi-camera system with the specific parameters. Model will implement elements of the automatic control for streaming while tracking more objects in multi-camera environments with moving cameras.

Acknowledgment

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Fault Diagnosis of a Selected Model Application within the Distributed Control System

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***Abstract*—This paper is presenting some activities of research area of the author's dissertation thesis Methods and Approaches Non-destructive Diagnosis of Dynamical Systems. A part of this article is focused on chosen fault diagnosis methods based on dynamic system model or on data obtained by vibration measuring system. In addition, selected model applications for fault diagnosis algorithms design and verification are also presented.**

***Keywords*—fault diagnosis, fault detection, vibration diagnosis, distributed control system**

I. Introduction

Fault diagnosis of dynamic systems is a very actual research area at present, because it is a very useful in increasing of more complex systems reliability and safety. The main goal of the fault diagnosis is the early detection and localization of incurred faults in dynamic system [1].

The fault diagnosis methods and algorithms can be divided into two main branches - to methods and algorithms based on dynamic system model and to methods based on measured data. Both branches can be furthermore divided into qualitative methods, such as finite state machines or statistical methods, or to quantitative methods, which selection is presented in this paper in more detail. Also, the results of fault diagnosis algorithms can be used for fault tolerant control [1], [2].

II. Previous analysis and achieved results in research field

Distributed Control System (DCS) implemented in DCAI FEEI, enables to solve many kinds of problems in area of modelling, control and fault diagnosis. A brief overview of used methods was presented in [3] where the main interest was dedicated to methods, which could be implemented into the technological level, control level or SCADA/HMI level of DCS implemented in DCAI.

In the previous year of study the author's research was oriented to modelling and control design of the selected model application and results are presented in [4], [5].

Very important for the further dissertation thesis research orientation is the selection of fault diagnosis methods, which can be used for the diagnosis of the actuators or sensors malfunction of selected model applications from the DCS of the DCAI.

Research field of fault diagnosis has been subject of research under goals of project Research and Development Operational Program for project: University Science Park Technicom for innovative applications with knowledge technology support.

III. Solved tasks and results

In the last year, the overview of suitable fault diagnosis methods and algorithms for model applications from the DCS of the DCAI was prepared. The overview of selected methods and algorithms of fault diagnosis is listed in the dissertation prospectus [6]. The Dissertation prospectus was oriented mainly to the group of quantitative fault diagnosis methods based on dynamic system model (model-based fault diagnosis methods), specifically on two methods - the first method uses states estimation for fault diagnosis and the second one is based on the parametric identification. Another subject of research was the quantitative method of fault diagnosis that use measured data, namely the vibration of specific dynamic system part. This method is based on measured data frequency analysis.

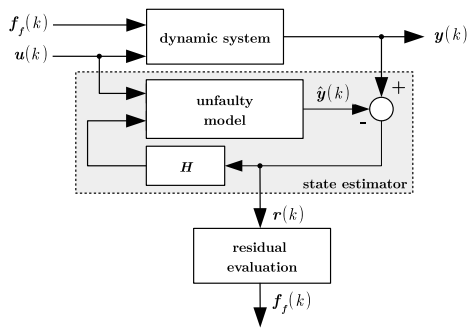

Fig. 1. General structure for fault detection with using state estimator

The first presented approach of the model-based fault diagnosis methods is based on the state estimators, which are used for fault diagnosis and this method comprise residuals $r(k)$ generation and residual evaluation (Fig. 1). Residuals are evaluated in order to detect, isolate and estimate the faults $f_f(k)$ magnitude. For fault isolation purposes, a bank of dedicated state estimators is used. Quick detection of faults and on-line implementation possibility is the main advantage of this method [2].

Another approach for model-based fault diagnosis is based on the system model parameters $\theta(k)$ identification. The occurrence of faults $f_f(k)$ in monitored dynamic system can be reflected by significant changes of model parameters $\theta(k)$. Residuum is generated by comparison of an actual identified parameters $\theta(k)$ and nominal parameters $\theta_{nom}(k)$ of monitored system. Process of faults diagnosis requires to use parametric classifiers. In the comparison with the estimator-

based fault diagnosis, this approach is quite slow [2]. On-line identification of the model parameters $\theta(k)$, based on recursive least squares method, is listed in [7].

Presented methods of fault diagnosis can be implemented to the *diagnosis system*, that is used for monitoring of system state. Depending on characteristics of monitoring system, *diagnosis system* can include fault diagnosis methods based on frequency analysis of measuring system vibration. This method uses for discrete Fourier transformation faults detection algorithms [8]. During the last year, author was involved in laboratory workplace creation for vibration measurement and analysis.

A part of author's dissertation prospectus [6] is focused to analysis of implementation possibilities of select control and fault diagnosis algorithms for selected model applications, which are a part of DCS of DCAI. For this purpose, two model applications from DCS of DCAI were chosen. The faults in selected model applications, which affect the controlled system cause sensors or actuators malfunctions, but not their total failure.

The first model application contains hydraulic system consisting of two cascade-connected cylindrical tanks (http://kyb.fei.tuke.sk/laben/modely/hyd.php). The model application of hydraulic system can be suitable for implementation and verification of the model-based fault diagnosis algorithms. Also, vibrations of the diaphragm pump can be measured and analysis for the detection of pump faults. Control and fault diagnosis algorithms for this model application can be realized directly by the PLC or indirectly, by a connected technological PC. This model application is used for design and verification of modelling methods and control algorithms, some achieved results are presented in [9].

The second model application is an intelligent positioning system and in general, it represents the concept of position control for an object moving on an adjustable plate (http://kyb.fei.tuke.sk/laben/modely/gnk.php). The model application of the intelligent positioning system can be use for the implementation of diagnosis algorithms of actuators (servo-motors) or sensor (camera) malfunctions. For this purpose can be use model-based fault diagnosis algorithms. The specific design solution of the model application enables implementation and verification of proposed control and fault diagnosis algorithms in various programming languages (C/C++/C#) or simulation tools (Matlab/Simulink).

Also, some activities and results in diagnosis research area of our workgroup within DCAI are presented in [10].

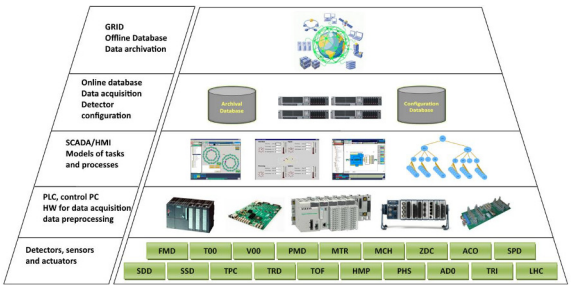

Fig. 2. Infrastructure of the ALICE Detector Control System

During the last year, part of the author research capabilities were focused on solving tasks in terms of the project *Upgrade of the ALICE Inner Tracking System*, related to cooperation of FEEI with European Nuclear Research Center in Geneva (CERN). For purpose of this project a workplace was created, what have a highly similar infrastructure like the ALICE Detector Control System, illustrated in Fig. 2. This workplace can use the data from sensors and actuators of the laboratory models of the DCAI like a substitution of the sensors and actuators of the ALICE Detector Control System. This workplace is used for verification of designed solutions of the project tasks in the FEEI conditions.

IV. Conclusion and Future Research

This paper briefly summarizes the author's research activities during the last year.

The following steps of author's research will be mainly focused on fault diagnosis algorithm design based on state estimators for residual generation and evaluation in order to detect, isolate and estimate faults magnitude. The results of estimator-based fault diagnosis algorithms can be use for fault tolerant control. Approaches to active fault tolerant control, mainly approaches based on predictive control, should be subject of the next year research. Also, algorithms of discrete Fourier transformation for vibration analysis can be designed. The designed fault diagnosis algorithms should be verified by the simulation and laboratory models of DCAI.

Acknowledgement

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Filtration technique based on complementarity of two ASR systems

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***Abstract*—An acoustic model is a necessary component of automatic speech recognition system, together with language model and dictionary. Acoustic models are trained on a large amount of speech recordings with transcriptions. Usually, hundreds of transcribed recordings are required. It is very time and resource consuming process to create manual transcriptions. Acoustic models may be obtained automatically with unsupervised acoustic model training. Unsupervised method for generating speech corpora for acoustic model training is presented in this paper.**

***Keywords*—Unsupervised acoustic modeling, automatic speech recognition, speech corpora**

I. Introduction

In the field of automatic speech recognition (ASR) are quality improvements still necessary. The better models are used in speech recognition systems, the better are speech recognition results (lower word error rate, abr. WER). This principle applies also for acoustic models. With the improvement of acoustic model better accuracy of the speech recognition system can be achieved. Usually, hundreds of hours of speech are required to train appropriate acoustic model while more speech data in the training process usually mean better acoustic model.

The speech data supplemented by the transcribed content together form a so-called annotated corpus. Corpus is required input to the acoustic model training process. The quality of the transcriptions in a corpus is influencing the quality of the resulting acoustic model. Those transcriptions are produced manually by people (trained annotators) and require 5 - 20 times more time than the recording itself. The other way around is to record the speech of reading a prepared text.

Recently, there have been proposed two methods for automatic or semi-automatic corpora building. Unsupervised or lightly-supervised methods use widely available audio content (Internet Pod-casts, Broadcast news, Lectures, etc.). In those methods, a bootstrap ASR system, whose acoustic model was trained on a small amount of manually transcribed speech recordings, is employed for generating the output hypotheses. Those ones are then processed in order to generate transcriptions. Lightly supervised method uses audio content for which are corresponding transcriptions available such as closed caption, audio-books, etc. In this method, the ASR system is used for selection of correctly transcribed parts in transcriptions and to time align them [1], [2].

The similar technique is used in the unsupervised method. It uses ASR system(s) to recognize untranscribed speech data, whose presumably correct hypotheses are selected with filtration technique [3], [4]. Filtration in this context means to remove presumably incorrect word from the hypotheses. In this paper, experiments with the unsupervised method for speech corpora generation will be proposed.

II. Unsupervised system for corpora generation

For preliminary experiments a dual unsupervised ASR system was designed. The system is based on two complementary ASR systems to obtain almost error free transcriptions. The systems flow diagram is shown in Fig. 1.

In all audio (or video) files are processed and recognized in both ASR systems in order to obtain transcription hypotheses.

Our ASR uses LVCSR recognition engine Julius based on triphone HMMs. Input speech is parametrized with standard MFCC feature vectors compound of 12 coefficient MFCC, log energy and delta and delta-delta coefficients. Left to right HMM has 5 states with heading and tailing non-emitting states. There are also models for the short pause, silence, noise and other non-speech events. More details about recognition system can be found in [5].

In the word-level recognition output of the ASR system are start and end timestamps for each word. It also contains posterior confidence measure for each word. Different constraints were examined to study the system's accuracy. Usually, unsupervised systems are set with constraints prior to the start, but it would require new recognition of a large amount of speech data each time when the constraints changes. The alignment is processed before filtration to avoid that. The alignment block does all word match and stores them in MySQL database with all known parameters about them. Parameters are start/end time offset and confidence score. Then all aligned hypotheses may be filtered with various constraint setup without the need to recognize all speech data again.

After alignment block goes filtration block. In the filtration step the hypotheses are taken from the database, which satisfy the criteria. Filtration has 4 adjustable parameters:

- maximum word's start or end time offset,
- minimum confidence score,
- minimum number of words in a row.

Only filtered hypotheses will pass to the corpus. Audio files are split according to timestamps, which were obtained from alignment/filtration.

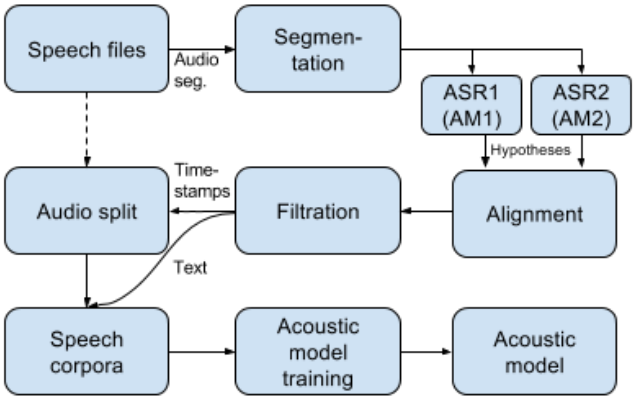

Fig. 1. Flow diagram of unsupervised systems which automatically generate speech corpus.

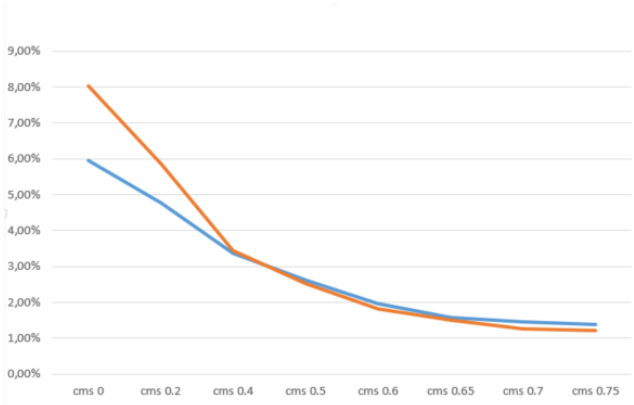

Fig. 2. WER (y-axis) values for different thresholds of confidence score (cms) (x-axis). Orange line shows WER values for phoneme and grapheme models, blue for two phoneme models trained on different training data sets.

III. Experiments

The system proposed in the previous chapter was used for experiments. Untranscribed audio data contain more than 330 hours of broadcast news in the Slovak language recorded from a commercial TV station from December 2014 till November 2015 containing 2 in-studio anchors and multiple reporters from exteriors with many interviewed guests. Audio recordings contained more than 272 hours of speech. Studio speech is clean but, on the other hand, the exterior speech often very noisy. It contains a lot of background noises, such as the wind, background sounds, speeches or music. For evaluation purposes a subset of 20 hours was manually transcribed by trained professionals. This subset was used in all experiments.

In the experiment it was complementarity of two ASR systems examined. Phonetic and Grapheme acoustic models trained on the same dataset were tested. Both models were trained on 680 hours of annotated speech from several corpora [6]. Filtration parameters were set as follows: A minimum number of words in a row - 4; Maximum word's start and end time offset - 20 ms, and thresholds for confidence measure (CMS) in range 0 - 0,75. Experimental results are shown in Fig. 2. The second experimental setup uses the same parameters, but acoustic models were different. Both acoustic models were phoneme (context-depenent phoneme) models trained on different subset of manually transcribed speech corpora. Each model compound the one half of the corpora.

As shown in Fig. 2 it is clear that system with two phoneme models trained on different sets of training data has better results compared to grapheme and phoneme models trained on the same set of training data. The WER degradation was noticed only when lower (or none) confidence threshold was used. Higher confidence increases accuracy in recognition hypotheses, but it also decreases the amount of obtained data. When confidence threshold was set to 0.75 value, then only 1,53% of original data was inserted into corpus. On the other hand, if the confidence threshold was set to 0 resulting over 50% of original data inserted into the corpus.

IV. Conclusion

The experimental results indicate that unsupervised system may be successfully used for automatic generation of speech data corpus, which will be later used for acoustic model training. If a large amount of untranscribed data is available, then a large amount of rejected hypotheses does not emerge a problem. The word-error-rate varies with different thresholds of confidence measure, with the best value of 1,39%. The relative reduction of WER between confidence threshold set to 0 and 0,75 is 23,27%. The amount of obtained data in the corpus was decreased by 36.61% relative. To use this system in production is crucial to set an appropriate threshold of confidence measure to have the right balance between WER and obtained amount of data.

From the results it is clear that the complementarity of two ASR systems can be also achieved by using different acoustic units (phonemes, graphemes) while the acoustic models are trained on all training data. With the presented combination of phoneme and grapheme acoustic models better WER levels can be achieved when high thresholds of confidence measure are set, compared to the case of phoneme acoustic models trained on split training data.

Acknowledgment

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Finite Control Set Model Predictive Control of Electrical Drives

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***Abstract* — The paper presents a brief introduction to finite control set model predictive control of electrical drives. Important assumptions and requirements are explained in detail and further steps in described predictive control are presented.**

***Keywords*—predictive control, electrical drives, power converter.**

I. Introduction

The computing power of today's electronic devices, processors and microcontrollers, has significantly increased since last decades. Now, there are computing units with clock rates up 4 GHz, which are yet available even for home applications and computer stations.

Except high computing rates, there is also a very common possibility to share computing tasks between two or more arithmetic units – processor cores. Whereas such a multicore techniques were common in ordinary computers, similar approach can be observed in low-cost microcontrollers, used in electronic devices, control units or power converters as well. Considering these possibilities, more complicated tasks requiring high sample rates can be successfully implemented, e.g. fuzzy control of the power converters [1] or recently very popular model predictive control (MPC). MPC uses mathematical model of the system to predict the system state for examined (admissible) control actions and then, using a control rule, the best action is chosen.

A special case of MPC is a finite control set model predictive control (FCS-MPC) introduced in [2] – [4], which is based on the fact of limited action possibilities (converter switching states) and computes prediction of every combination. Then, as in the conventional MPC, the best action is chosen by minimizing the control rule.

In this paper, an application of the finite control set model predictive control of electrical drives is described. The most important parts are explained in detail. Next, the hardware, which will be used for testing, is described. Finally, further steps are proposed.

II. Prediction - Mathematical Model

The prediction horizon for FCS-MPC is typically one-step forward. Using a larger prediction horizon is possible, but there is an exponential rising of computation time. For example, with one-step prediction of a simple 3-phase inverter, 7 predictions are needed. In the case of two-step prediction, 49 predictions are needed.

For the correct one-step prediction, a good discrete time model is needed. Additionally, in discrete state space equations, the future state is naturally given as $(k+1)^{th}$ sample. An overview of model creating possibilities and their suitability on predictive control can be found in [5]. Shortly, for correct prediction, the inputs should explicitly appear in every state equation, which they affect in continuous time model. Therefore, the Taylor series expansion is often used:

$$x_j(k+1) = x_j(k) + \sum_{l=1}^{N_j} \frac{T_S^l}{l!} \frac{d^l x_j}{dt^l}\bigg|_{t_k} \qquad (1)$$

where x_j is the system state, T_s is the sampling time, N_j is the order of the last member of the expansion, k is the sampling step and j is the jth state of the system.

The truncation of the series is performed in the way to fulfill aforementioned demand and depends on the order of the system (or subsystem). Considering electrical drives, the electrical subsystem is represented as a first order system. In this case, an input (voltage) explicitly appears in the current state equation using truncation of $N_j = 1$. If we consider the mechanical subsystem, the angular speed is derived as a second order system with the same inputs as electrical subsystem. Therefore, truncation of $N_j = 2$ is performed. Analogically, the position system is the third order system, meaning truncation of $N_j = 3$.

In the case of electrical drives, a machine load has high effect on machine states as well. Therefore, it is necessary to measure or to estimate the load torque. For this purpose, mostly Kalman filter with augmented state-space is used [6]. The advantage of the Kalman filter is its filtering and estimating capabilities at once.

III. The Cost Function

The cost function is an analytical expression of control demands and serves as a single controller for various system state variables at once.

If we consider electrical drives, typical control demands

can be summarized as:

- Precise position or speed reference tracking
- Limitation of maximal current
- Smooth behavior of electrical torque
- Fast disturbance rejection

Different cost functions for speed control of PMDC drive, according to mentioned demands have been explored and the results were published in [7]. Simulations of a position control of permanent magnet synchronous motor have been submitted for publication [8]. The cost function used in the mentioned position control of PMSM is defined as follows:

$$G = w_1\left(\phi_{ref} - \phi_{rj}\right)^2 + w_2\left(\omega_{ref} - \omega_{rj}\right)^2 + w_3\left(i_L + i_{B_\omega} + i_{dyn} - i_{qj}\right)^2 + w_4 i_{dj}^2 + f_{\lim}\left(i_{dj}, i_{qj}\right) \quad (2)$$

where ϕ_{ref}, ω_{ref}, i_{dyn} are the reference values for position, angular speed and dynamic current from ramp generator, w_i are the tunable weighting factors, ϕ_{rj}, ω_{rj}, i_{dj}, i_{qj} are the outputs of state predictors (angular position and speed and current components) for jth voltage vector as control action and function f_{lim} is the nonlinear function for current limiting.

The cost function, as it can be seen, is very simple to understand and does not require much of computing time. Moreover, as can be seen in [7], the very similar equation can be used in the PMDC control or other machines.

The cost function is computed for every admissible action in every sample. The control action with minimal cost function is applied.

The position of the cost function in the control structure applied on PMSM, as it was described so far, is depicted in Fig. 1.

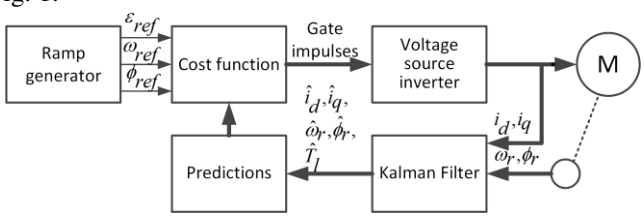

Fig. 1. Block diagram of FCS-MPC control

IV. Experimental Setup

The finite control set model predictive control has been so far experimentally verified on PMDC motor with OPAL-RT system. Design and experimental results can be found in [9].

As the second step FCS-MPC of permanent magnet synchronous motor will be experimentally verified. Therefore, a laboratory prototype of PMSM control board with a voltage source inverter was designed and built (Fig.2). It is based on dual CPU digital signal controller by Texas Instruments. The inverter will be used to test the position FCS-MPC theory in real conditions and to verify its possibility to implement such a theory into an embedded system.

The control board is single powered from 24 V DC-bus and is intended to supply a small servo actuator with permanent magnet synchronous motor and cycloidal gear. Rated current is up to 15 A and expected sample rate on the developed control board is from 32 µs to 25 µs with the computation time lower than 6 µs (including computation of actual states values, the Kalman filter, 7 predictions and the action). The control board is capable to measure actual DC bus voltage and currents in all three phases and to evaluate signals from incremental encoder with sine tracks.

Fig. 2. Control board with 3-phase inverter, based on F28377D

V. Further Steps

Next steps in the presented work are the implementation of position FCS-MPC on permanent magnet synchronous motor and comparison of results with a conventional control structure with PID controllers. FCS-MPC will also be tested for the position control of the two-mass system with elastic coupling.

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Haiku Poetry Generation

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Abstract—**The article proposes system for generating haiku poetry. Since humans interact mostly by speech, the proposed system for social robotics creates poems, the verbal part of interaction. Research consists of analysis of the current research projects in the field of computational creativity and poetry generation and design and implementation of system creating haiku poems.**

***Keywords*—computational creativity, haiku poems, poetry generation**

I. Introduction

Robots are spreading into everyday life and there is increasing need to create robots capable of social interaction.

People interact mostly by speech (verbal communication), gestures and facial expressions (non-verbal communication). Verbal communication means information exchange using words. It is basic element of human interaction.

The approach, described in this article, aims to computationally generate poetry, the verbal part of social interaction. When generating poetry by program, one can learn a lot about language, poetry and about creating it. The goal is to create meaningful poems using computer and by this to contribute to social robotics research.

In the first part of the article, a brief introduction into computational creativity and poetry generation is provided. Next section consists of analysis and description of related works. Last part is dedicated to description of the system and its architecture and implementation and further work on the system that is proposed.

A. Computational creativity introduction

Computational creativity is artificial intelligence subfield in which we study how to build computational models of creative thought in science and the arts [4]. Artefacts and the creativity that went into their production is judged within a context; where a context may include background information on how the creator feels about their work, what they think it expresses, how it fits in with other work done within their community, their mood before, during and after creation, and so on [5].

Computational creativity research crosses several disciplinary boundaries. The field is influenced by artificial intelligence, computer science, psychology and specific creative domains in which we implement systems, such as art, music, reasoning, story-telling, and so forth [6]. Currently many implementors of creative systems follow a creative-practitioner-type approach: produce a system then present it to others, whose critical reaction determines its worth as a creative entity.

Computational creativity is very innovative and exciting field of research. Main problem, besides creating a system that is considered creative, is the way how to scientifically evaluate its creativity. Mostly, human evaluation is used. Several research papers are dedicated to exploring ways, how to appropriately evaluate the creativity of a system.

B. Use of poetry generation

The possible usefulness of computer poetry is concerned with what the programmer can learn about language, about poetry, and about poets. The problems in designing computer programs to construct poetry include considerations in generating well-formed sentences which have the added restrictions that poetry requires: meter, rhyme, logic, diction, subject matter, and imagery [3].

C. Haiku poetry generation

Haiku poetry was originally developed in Japan. Haiku poem is often inspired by nature and captures a feeling [1]. Its modified form was adapted to English and other languages. In tradition, English haiku consists of 5-7-5 syllable pattern of English words in three lines. A haiku in English follows the form and style of Japanese haiku [2].

Generating haiku poetry was chosen because of its fixed form and simple idea of the content.

II. Related Works

In this section, several projects that are related to generating haiku poetry are described.

A. Fun generators

There are many poetry generators on the internet, that lack any intelligence and are created just as random selection of words. Examples of these fun generators are [7] and [8].

The poems generated by the engines rarely have meaning and are made to entertain users.

B. Interactive haiku generator

Interactive haiku generator [9] has a database of haiku models, extracted from famous haiku poems. User-inserted text serves as basis for dictionary, that is later used to form haiku poems based on prepared models.

The performance of the generator is very dependant on vocabulary provided by user.

C. Peter's haiku generator

Haiku and tanka (another genre of Japanese poetry) generator by Peter [10] uses pre-defined models of poems and thematic dictionaries.

Models consist of sequence of parts of speeches (word classes, such as noun, adjective, etc.). Dictionaries contain words together with their part of speech.

Poems are generated based on models. Words are randomly chosen from thematic dictionary based on its part of speech. When a poem is formed, syllable counting algorithm is used to determine the count of syllables. When the syllable count is not consistent with required poem form, new poem is generated. The generator tries 10 times to generate poem in required form and when it is not successful, it provides the last generated poem.

D. Poetry creator

Poetry creator [11] is a simple system that generates poetry based on words describing a subject, a synonym for the subject and a title for the poem, all three given by the user. The resulting text consists of pre-defined verse templates where gaps are filled with the words given.

E. Chart generation of rhythmpatterned text

Manurung's chart system [12] represents generate and test approach, where random word sequences are produced according to formal requirements.

Since poetry conforms to rhythm pattern, Manurung's system aims to create poems in syllabic stress metre. To achieve this, it uses charts. A chart can be viewed as a graph where nodes signify positions between words in an output string and the edges signify analyses spanning substrings in the input string.

This system was used to develop McGonnagall poetry generation system.

F. WASP system

WASP [13] is a forward reasoning rule-based system. Its input consists of a set of words and a set of reference verse patterns. Obtained fragments are used to produce the reference patterns. The output of the system is a set of verses that satisfy the constraints of some strophic form.

G. ASPERA system

ASPERA [14] uses case-based reasoning. As an input, ASPERA expects a prose description of the intended message and a rough specification of the type of poem – approximate length, rhyme structure, mood, etc. It will then select appropriate metre and stanza, generates a draft of the poem and requests user validation or modification. After, ASPERA updates its database with the information from usr validation.

ASPERA's construction algorithm is certain improvement of WASP system.

H. COLIBRI system

COLIBRI [15] is a system very similar to ASPERA. It also uses case-based reasoning, but the cases are stored in a very flexible representation using a Description Logic System.

COLIBRI system also incorporates an application-dependent ontology.

I. Strategy of Tra-La-Lyrics

This system [16] generates text based on the rhythm of a song melody, given as input.

After analysing the lyrics of a set of songs written in Portuguese, it was observed that, most of the times, strong beats in the rhythm are associated with the lexical stress in the words. The word choice follows rhythmic constraints but also syntactical constraints, given by sentence templates.

J. POEVOLVE system

POEVOLVE [17] is a system that uses evolutionary computation. The initial population is created from a set of words that include phonetic and stress information. Appropriately rhyming words that can appear at the end of each line are selected and then more words are selected to fill the rest of the line based on their stress information.

A genetic algorithm is employed and evolution is achieved by mutation and crossover operators that modify the words contained in the limericks.

Evaluation is performed by a neural network that was trained on human judgements.

However, POEVOLVE doesn't take syntax and semantics into account.

K. Manurung's McGonnagall system

This system [18] uses evolutionary algorithms for poetry generation. During the evaluation, the individuals are scored based on different aspects, such as form, phonetic pattern or semantics. Individuals are then selected according to their scores.

L. PoeTryMe

PoeTryMe [19] is a system for generating Portuguese poetry based on keywords. Basic semantic graph is searched and its subgraphs are chosen with the use of keywords. Sentence generator then generates verses as candidates for final poem. These verses are sorted out by applying grammar rules and final poem is created.

M. Gaiku

System that generates haiku poems based on associated norms [20] designs its own language model of haiku poem structure. This language model is generated from large corpus of haiku poems in English language. The goal of the application is to connect words based on word associations and putting them into haiku poems based on the rules from the generated haiku model.

This system had very good results when evaluated by humans.

N. Automatic poetry generation

Automatic poetry generation [21] system is working with database of words most commonly used in haiku poems. These words are then used for searching through various blogposts. Sentences containing the keyword are divided into smaller parts and with the help of TFIDF technique are some of them selected into final haiku poem.

III. Haiku generator

The system described in this article is implemented as web-based application. The user interacts with graphical user interface of web application. The goal of the user is to read several haiku poems generated by the algorithm of interactive evolution and evaluate them in means of aesthetic impression and meaning.

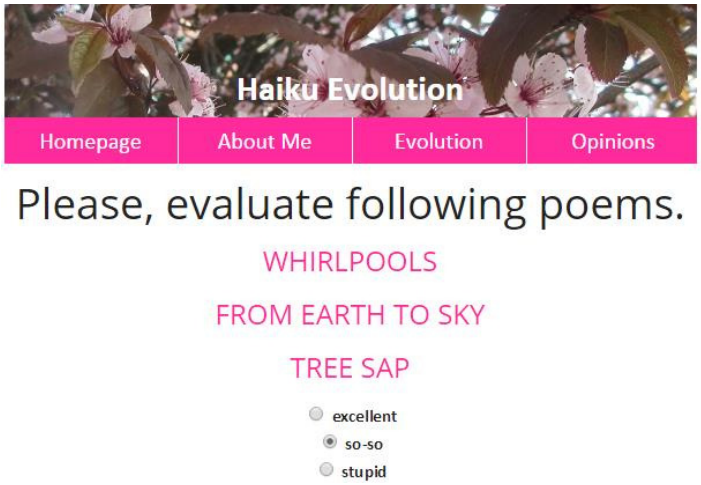

Fig. 1 Web application

The emphasis in current stage of development is on generation haiku poetry. The proposed system is work in progress. Current stage of development aims to improve haiku poetry generation.

The ground of the research is author's diploma thesis, where application for evolution of haiku poetry and its recitation by a robot was created. The interactive evolution was used to create haiku poems and adapts some voice characteristics of the robot and its gestures.

A. *Haiku corpus*

The corpus consists of haiku poems created by human authors, saved to a database. This database is the source for gathering the haiku specific words.

Haiku poems from following haiku portals were used to create the haiku corpus:

- AhaPoetry [22]
- DailyHaiku [23]

B. *Dictionary creation*

Data preparation phase includes creating a word dictionary. In first step, all haiku poems are split into words.

Then, each word is cleaned.

- It is put to lowercase.
- Numbers and other non-alphabetic characters are removed.
- Unnecessary spaces are removed too.

Each word is stemmed. All stop words are removed.

Following step includes metadata acquisition:

- part of speech is determined from online dictionary [24]
- syllables are counted by using online application [25]
- number of occurrences is computed

Only words with occurrence number higher than 100 are kept as haiku specific.

Dictionary of common words is loaded from [26]. Metadata for each word is acquired (in the same way as for haiku-specific vocabulary).

All words from dictionaries are saved to database table.

C. *Model extraction*

Models for haiku creation are generated from haiku corpus as a list of parts of speeches.

Example model:

ADJECTIVE NOUN
DEFINITE_ARTICLE NOUN VERB
PREPOSITION DEFINITE_ARTICLE NOUN

Only models with occurrence number higher than 10 are kept.

Models are saved to database table.

D. *Haiku generation*

Random model from extracted model list is used.

Syllables are divided randomly for each part of speech in the selected model based on strict form of haiku poem (5-7-5 syllable pattern).

Example syllable division for example model:

3-2
1-3-3
1-1-3

Words are selected from dictionary based on selected part of speech and word's syllable count.

The generated haiku is displayed and saved to a database table.

Quite nice and meaningful poem generated by the example model and syllable division:

beautiful rose
the horizon compares
on the seaside

Example of less meaningful haiku:

something which blossoms
conspire according cow
dry shadow outside

E. *Future plans*

The application will be later made accessible to wide public in order to evaluate and test the performance of poetry generator and continuously improve it. Since poetry is for everyone, the goal is to test and evaluate the system with people of different age and education.

Human interacts with computer via graphical user interface. It has to be designed in simple and clear way. Users have to understand the purpose of the evaluation easily and be able to orientate themselves in the interface quickly. The interface is crucial when users interact with the software because it determines their willingness to use it. The graphical user interface should be understandable, easy, simple and nice to look at. Several users tested the web application and evaluated the design of the interface and the process and the way of poem evaluation. The findings will be taken into account when creating the web application.

Last stage of development will be focused on developing recitation of the generated poems performed by a robot, that would be considered by human as natural and appropriate.

When robots started to spread into real life, their applications were focused on the development of robots as a tool, rather than machines capable of interaction and cooperation with people. New application domains, such as domestic, entertainment, healthcare, etc. will require robot that

is capable of this. The goal of social robotics is to make the interaction between human and robot simple and natural [27].

IV. Conclusion

Human interaction is performed mostly by speech. Non-verbal expressions support the verbal part of the interaction. As robots are spreading to everyday human lives, the need for robots that are capable of social interaction is rising. The ability for people to naturally communicate with machines is important and will become a necessity.

The motivation of the proposed system is to determine the right parameters of interaction among people and robots. Haiku poems are generated as a verbal part of the interaction and the implementation of the system on a robotic platform will adapt as well the non-verbal part of the interaction.

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Hidden Markov Model Based Speech Synthesis in Slovak Language

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***Abstract*—This paper presents the implementation results of the Slovak hidden Markov model based speech synthesis systems together with the description of the newly created Slovak subjective tests. Taken together, the speaker dependent speech synthesis systems were trained and evaluated with the help of the carefully designed phonetic balanced speech databases. Subsequently, a lot of experiments were implemented and evaluated also with the speaker independent techniques (adaptation and interpolation) where acoustic data from Slovak automatic speech recognition system were processed and reused. These newly created text-to-speech systems were then implemented into web applications where it is possible to synthesize artificial Slovak speech almost without any limits.**

***Keywords*—HMM, HTS, Slovak language, Speech synthesis**

I. Introduction

Text-to-speech (TTS) systems represent one of the most important part of the speech interaction with computer and the research in this area is carried out in many countries and companies around the world. Nowadays, the speech synthesis systems are represented by computer systems which can convert input text into output audio file. The main task of these systems is make life easier, either to people with physical disabilities such as the blind people or to totally ordinary people who use these systems to facilitate day to day activities. Research in this area is aimed to the point, when it will be possible to use these voices in various spheres of life, without that they were somewhat limited and acts unnatural. The research in the field of speech synthesis is focused on the development of new advanced methods and their improvement in order to make final speech output from these systems as similar to the human interpretation as possible. However, the human speech production is a complex physiological process and this complexity is also included in the development of text-to-speech systems.

Statistical parametric synthesis based on Hidden Markov models (HMMs) is one of the most effective and dynamically growing corpus-based method of speech synthesis in the last period [1]. This method uses statistical HMMs to model the spectral and prosodic parameters of the speech units. These models are trained using an input corpora which should contain phonetically balanced sentences that should have highest possible coverage of phonetic contextual units to provide high quality speech synthesis.

Recently, the HMM-based speech synthesis technique has been reported for many languages, such as for large languages including the Mandarin Chinese [2] or English [3], but the flexibility in development of those systems also enabled the integration of small languages, such as Thai [4] or Slovenian [5]. In this paper, implementation and evaluation of newly created Slovak HMM-based speech synthesis systems is described. The motivation for the development of comprehensive and applicable HMM-based speech synthesis system in the Slovak language was its absence as well as increased demand for the implementation of this type of speech technology in many newly created Slovak interactive applications.

II. HMM Based Speech Synthesis in Slovak Language

The implementation of Slovak language with the help of the HMM based speech synthesis technique can be divided into four main areas:

- Design of the subjective evaluation tests for the Slovak language – MRT and SUS test design
- Speaker dependent Slovak TTS systems based on HMMs
- Speaker independent Slovak TTS systems based on HMMs – experiments with an adaptation and interpolation
- Implementation of the newly created systems into web applications

A. Design of the Subjective Evaluation Tests for the Slovak Language

The intelligibility evaluation is a language dependent task in many cases. There are many tests by which it is possible to evaluate this parameter but they were implemented only for large languages. The two new Slovak test were designed and implemented for the intelligibility evaluation – namely MRT (Modified Rhyme Test) and SUS (Semantically unpredictable sentences test). In case of the MRT test, it was necessary to propose the 60 sets of monosyllabic words, where each of them consist six words with the construction: *consonant – vowel – consonant* and they differ in first or last consonant (for example: tak; vak; rak; jak; lak; mak) [6]. In case of the Slovak SUS test, the set of 250 semantically unpredictable sentences were designed where each of them is syntactically correct but it does not have any meaning (for example: Chutný

čechizmus vynára velikánsku tlupu.) [7]. It is possible to evaluate intelligibility with the help of these tests on level of words or sentences without any limits for Slovak language.

B. Speaker Dependent Slovak TTS Systems

Taken together, 6 new TTS systems (3 male and 3 female) were implemented and evaluated with the subjective and objective methods in case of speaker dependent Slovak HMM speech synthesis techniques. Recent statistical parametric speech synthesis methods including *Conventional*, *STRAIGHT* and *AHOcoder* speech synthesis systems were implemented and evaluated. Objective evaluation methods (Mel-cepstral distortion and fundamental frequency comparison) and subjective ones (Mean opinion score and Semantically unpredictable sentences test) were carried out to compare these systems with each other and evaluation of their overall quality. The result of this work is a set of text-to-speech systems for Slovak language which are characterized by very good intelligibility and quite good naturalness of utterances at the output of these systems [8,9].

C. Speaker Independent Slovak TTS Systems

The experiments within the speaker independent systems were made with the adaptation and interpolation techniques. In case of adaptation, the acoustic data from Slovak automatic speech recognition system were processed and reused. The result of this work is a set of more than 100 Slovak voices together with the huge male, female and common average voice models which can be used for the adaptation procedure. The voices were evaluated with the help of the mel-cepstral distortion and multidimensional scaling [10]. In case of interpolation, the main idea of this technique is to synthesize an artificial speech with unseen and untrained output speech characteristic by interpolating of the existing sets of the pre-trained models. The obtained results showed that the characteristics of the synthesized speech were changed from one male speaker to another one with the help of the interpolation ratio by which the Slovak voices with the new characteristics may be crated [11]. The attempt to synthesizing audio affect bursts on several levels of arousal were also implemented. It concerns 3 different types of affect bursts, disgust, startle and surprised expressions and each level of each emotion were modeled using Hidden Markov Models. A weighted linear interpolation technique was then used to obtain intermediate levels from these models [12].

D. Implementation of the Newly Created Systems into Web Applications

The newly created voices were also used as part of new version of *ZureTTS* system which is an initiative of *Aholab Signal Processing Laboratory of University of the Basque Country* to provide a personalized speech synthesizer to people with speech impairments and also to those who have completely lost their voice. The new version of *ZureTTS* system was undertaken by an international team of researchers during *eNTERFACE'14 ISCA Training School*, covering up to 8 languages: English, Spanish, Basque, Catalan, Galician, Chinese, German and also Slovak [13].

Many of the newly created TTS systems were also implemented within a web application which is able to synthesize artificial speech in Slovak language. There are three options on the web page how it is possible to convert text into speech. At first, it is possible to write text into a field, choose a voice and you can also modify couple of parameters (speed, fundamental frequency and so on); then you can use a document (doc, pdf or ppt) as an input for speech synthesis. The third option implement the interpolation into this application. There it is possible to use interpolation techniques to get a new voice online. You can choose between two, three or four sets of models and use interpolation ratio between them. The output is a new voice composed of selected set of models. The systems were also implemented for producing feedback to the operator and dialogue manager technology.

ACKNOWLEDGMENT

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Hierarchical Topic Modeling on Streams of Social Media Data

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***Abstract*—This paper provides brief introduction to topic modeling, area of natural language processing and survey of existing methods. Topic modeling shows a new way for search, browsing and summarization of large amount of data. It tries to find hidden structures within the documents in collection. In connection to social media, it can be useful tool in marketing, competitive intelligence, time-based analysis of crisis situations, etc. Some of the extensions in topic modeling are related to hierarchical modifications of conventional approaches, which offer deeper analysis of documents than classic topic modeling. Our vision is to introduce some conceptual data mining methods into the solution of this problem. Hence, some new possible approaches based on the usage of methods from the area of Formal Concept Analysis are discussed, which are suitable for creation of hierarchical concept structures from input data tables.**

***Keywords*—topic modeling, data streams, social media, formal concept analysis, GOSCL**

I. Introduction

In recent years, social networks became one of the strongest communication tool and interesting source of information. Users there daily publish large amount of contributions, for example at Twitter is daily published about 340 billion of contributions. These contributions usually reflect user opinions, attitudes on worldwide events, products, persons etc.

These data can be especially helpful in marketing, because marketing always depend on the data. Proper understanding and using of information can bring the company competitive advantage. Ignoring of them may lead to loss of market position. Data from social media bring to marketing new opportunities:

1. Interaction with users is no needed.
2. Companies can extract much more data than using classical methods.

On the other hand:

1. It is time-consuming to analyze such amount of data and find relevant information for particular company.
2. The length of contributions at social media is usually limited.

Social media data can be used in many different types of analysis, for example:

- Crisis analysis – for example in the time of tornado it is possible to monitor how user react and if it is necessary to take some appropriate action.
- Launching new product to the market – monitor user reactions, if they like new product, which bugs it have, etc.
- Protection of reputation - continuous monitoring of social networks in order to catch contributions with negative opinions on company, organization or person.
- Media – which are most interesting news, have hot news, search what are people interested in, etc.

As you can see analysis of contributions from social media is very useful, but as it was mentioned it is time-consuming. For that reason we need to make this analysis automatic. One of the possible ways is to use methods of topic modeling, which allow us to run automatic analysis and show us a new way for browsing, search and summarization of large amount of textual data on particular topics. Topic modeling is currently popular research area with many possible application in real world. Methods of topic modeling are able to uncover hidden thematic structures in large collection of data (in our case collection consists of contributions) and create topics which contains contributions with degree of membership and words with their informativeness for current topic.

For that reason we want to build topic modeling tool for automatic analysis and visualization of social media contributions.

II. Related Work

As we mentioned in previous chapter topic modeling tries to uncover hidden semantic structure from corpus of documents. Latent Semantic Analysis (LSA) [1] can be seen as one of the first method which solve this problem, because it tries to uncover semantic structure form text, but it is not usually introduced as standard topic modeling method. However, there are many extensions of this method which represent basis for some topic modeling methods, for example probabilistic latent semantic analysis [2] is basic for Latent Dirichlet Allocation (LDA) [3]. This method represents most commonly used approach for topic modeling. For that reason there has been created many extensions and improvements of LDA. Petterson et al. [4] in their paper used word information as features rather than as explicit constraints. Zhai and Graber [5] present interesting algorithm for online topic modeling, they proposed online version of LDA. In recent years there has

been created also other methods, not only modifications of LDA. Yee et al. in their paper [6] proposed hierarchical dirichlet process, Li et al. [7] proposed topic modeling based on moving average stochastic variation inference, Hofmann [8] presents method based on stochastic variational inference. All mentioned methods work well on medium or large size texts, however in context of contributions from social media (short texts) with limited length of text a lot of mentioned methods do not work well.

However there exist some methods which aim at analysis of short texts. Phan et al. [9] proposed method using conventional topic model based on external data. Sridhar [10] uses for topic modeling from short text Gaussian mixture models. Another interesting approach was proposed by Quan et al. [11], where they transform input short texts into long pseudo-document before the application of standard conventional method.

As you can see topic modeling is well studied area of research, but in the context of social media we need to think about texts which grow with time and change their topic, where the major of mentioned methods work only with static text collections and can process streams only in batches. Also standard conventional models do not offer enough information. In order to enrich the analysis of hierarchical topic models are expected to be more interesting in future work within this area. Griffiths and Tenenbaum [12] proposed hierarchical topic modeling method which allow us modeling topic in time with growing data. Another approach was presented by Hofmann [13].

As we mentioned existing conventional methods in this area has some limits if they are applied on short text streams. For that reason we want to work on method which exceed these limits and could be successfully applied in cases where hierarchical modeling can be useful.

III. Formal concept analysis

Formal concept analysis (FCA) [14] is data analysis method which popularity growth in recent years. It has been applied in different areas as knowledge discovery and data/text mining [15][16], association rule mining [17][18], or information retrieval.

FCA can be used similarly as an unsupervised hierarchical clustering technique. From input formal context (usually in form of table where rows represent objects and columns represent attributes as it is shown in Table 1) FCA generates output in form of concept lattice. A concept lattice is a collection of formal concepts (type of concept hierarchy) in the data which are hierarchically ordered as shown in Figure 1.

Table 1 Illustrative example of formal context

Obj, Atts	a1	a2	a3	a4
B1	0	0.3	2	1
B2	0	0.4	3	0
B3	1	0.5	0	1
B4	1	0.3	5	1
B5	0	0.4	0	0
B6	1	0.8	0	1

One of the current problems in FCA-based analysis is large number of generated concepts, which leads to some techniques for suitable selection of most relevant concepts from the analysis using reduction and dynamic visualization techniques. There exist several methods for building concept lattices, for example some of them are presented and compared in [19].

A. *Generalized One-Side Concept Lattice*

In FCA there are several approaches for generation of different types of FCA-based models, in this paper we shortly describe model known as Generalized One-Sided Concept Lattice (GOSCL). More details can be found in [20], [21] or [22].

GOSCL represents interesting model in the context of FCA. It uses one-sided fuzzification which means that one side is crisp (based on classic subsets) and second is represented by fuzzy set (attributes values are defined by fuzzy sets). Other advantages of this algorithm are:

- It is possible to generate concept lattice from objects which are represented by different attributes types like nominal, ordinal (scale-based), numeric, or any attribute with values defined by lattice-based structure.
- It is possible to create and update model of GOSCL using incremental algorithm, so it can be used to analyze data streams.

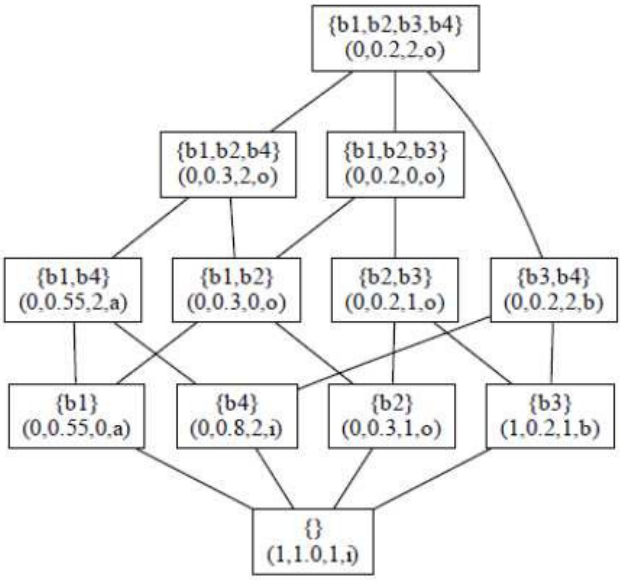

Figure 1 Illustrative example of concept lattice

B. *Concept lattice reduction methods*

As we mentioned in previous chapter FCA found its application in many different areas, however if it is used for analysis of medium or large size data, then generated concept lattice usually contains large number of concepts and links between them. Such concept lattices are not very acceptable in real life application, therefore some reduction of this concept lattice were needed. Several method for this problem has been proposed in recent years. Basic approaches are based on thresholding, where some ranking method is used to evaluate concept quality and concepts with quality lower than threshold are removed, simple approach can be based on removing concepts which contains less object than some threshold. Other more sophisticated approaches can be found in [23] or [24]. Another way for concept lattice reduction is to transform this lattice into tree-based structure, which means that some links are removed as in [25]. Other possible ways for concept lattice reduction are based on clustering of similar concepts to

separate groups and create from them pseudo-concepts, or reduce input formal context before generating concept lattice.

C. *Visualization of concept lattice*

Concept lattice visualization is one of the most important part of FCA. Proper visualization offers effective way for fast understanding and presentation of generated concept hierarchy. It is key element if this analysis is used for example in data mining or as decision support system. In context of formal concept analysis or concept lattice, visualization is not so much discussed. However in context of hierarchical data there exist several approaches. Wills [26] presented survey of several visualization techniques for hierarchical data visualization:

- Node-Edge Layouts - belongs to general graph layout techniques Each node in the hierarchy is displayed as a small circle or square and links their relationship in hierarchy
- Space-Filling Layouts - these technique lay out areas in proportion to sizes, and parents visually include their children.

In [27] authors present interesting way for hierarchical data visualization using tree-ring metaphor. Other approaches using arc-trees, classic or Voronoi tree-maps can be found in [28], [29], [30] or [31].

All previously mentioned approaches were designed to visualize hierarchical data where each node has only one parent. However concept lattices are structures where nodes can have multiple parents. Therefore other visualization techniques are needed. Hasse diagram is commonly use for this type of visualization, e.g. in [32] author used Hasse diagram for visualization and indexing of photos from social networks which were hierarchically ordered. This visualization technique was also applied in many other works like in [33] or [34].

Standard static visualization techniques are usually sufficient only for visualization of small concept lattices. From Figure 2 is clear that understanding the results of analysis from large lattices is very difficult. There is needed some dynamic version of presented visualization techniques. It means that we will not show the whole concept lattice to user, but only some subpart of it. It can be random part of hierarchy and we are able to look through other part of hierarchy, or it can show some part of lattice which we are interested for. In Figure 3 and Figure 4 we can see already implemented examples of our dynamic interactive visualizations based on dynamic Hasse diagram or Double-tree visualization with user-based selection of part of concept lattice.

IV. Topic Modeling Approaches Based on FCA

In this section new possible approaches for hierarchical topic modeling using FCA will be presented. As we mentioned FCA has many features which can be useful in hierarchical topic modeling:

- automatically build hierarchical structures
- incremental method of algorithm of GOSCL
- GOSCL can process attributes with various types of attributes within one input stream

However problems of direct usage of FCA for this task is that in its basic form it is not able to uncover hidden structure between input objects, it is possible only describe very precisely known relations between them.

So for now we assume that there exist two possible ways for using FCA in context of hierarchical topic modeling. First approach assume that it is possible to modify FCA for uncover hidden structure in input collections, with application of probabilistic methods, pattern structure approaches and combination with some other machine learning algorithms. Second way is using of some external method which describes hidden structures first (e.g, latent semantic methods) and FCA will be used for building of hierarchy of concepts from this preprocessed data. If we deal with topic modeling in text streams this external method need to be incremental. In both cases question of effective reduction method arises for incremental FCA, which should be studied in parallel with the possibility of application of FCA-based methods on hierarchical topic modeling.

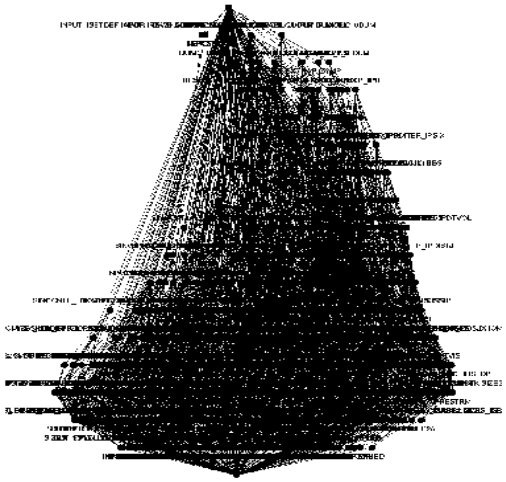

Figure 2 Illustrative example of concept lattice visualization by Hasse diagram

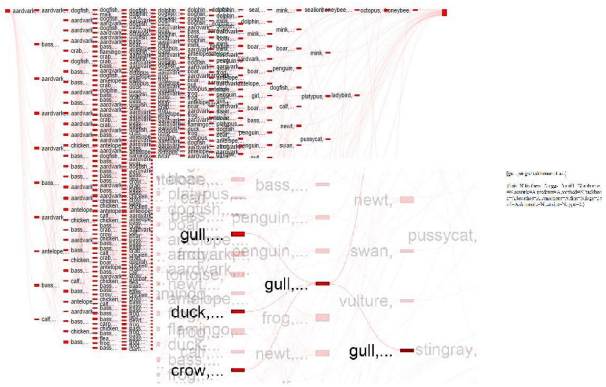

Figure 3 Example of interactive visualization of concept lattice and its parts based on dynamic Hasse diagram

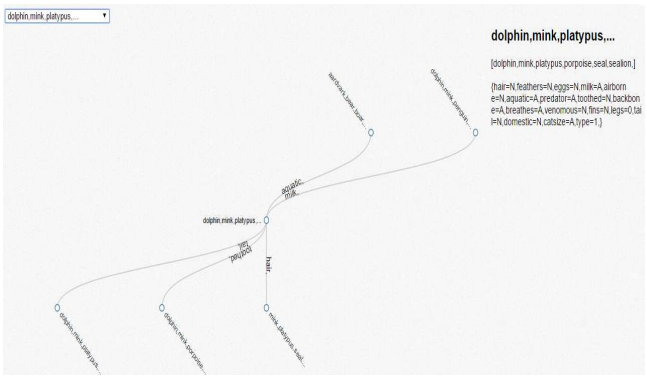

Figure 4 Example of interactive visualization of part of concept lattice based on Double-tree technique

V. Conclusion

This paper described area of topic modeling and also its hierarchical modification. Usage and importance in context of social media data was also briefly described. We also presented new way which can be possibly used for hierarchical topic modeling. In the future we want to test and evaluate this proposed approaches and compare them with existing solutions.

Acknowledgment

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High Frequency Soft Switching PWM DC/DC Converter with Active Rectifier

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***Abstract*—A paper is dedicated to a research process of new type of high frequency soft switching DC/DC converter. In the paper, first an already solved part of research task is described. Next, a description of currently solved part of research task is done and key research results are presented. At the end, future steps of research are proposed.**

***Keywords*—active rectifier, DC/DC converter, soft switching**

I. Introduction

The DC/DC converter is a fundamental part of switched mode power supply. In general, a value of switching frequency is an important parameter of DC/DC converter. The volume and weight of DC/DC converter can be reduced by increasing of switching frequency. Therefore, an effort is to use high switching frequency. But it is known, that switching losses in transistor switches can be increased also by increasing of switching frequency. Therefore, an application of soft switching technique to this type of converter is useful and effective. In Fig. 1, simplified idealized waveforms of soft switching of transistor switch are shown.

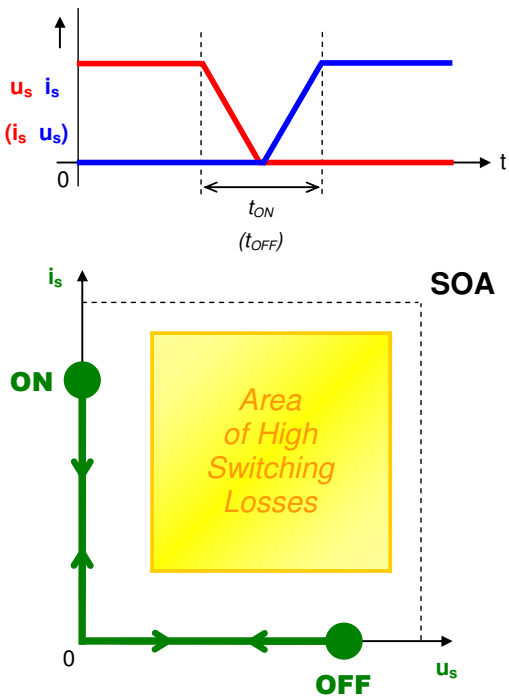

Fig. 1. Idealized waveforms of soft switching of transistor switch.

II. Already Solved Part of Research Task

The soft switching of transistor switches used in DC/DC converter can be partly achieved by using of DC/DC converter with active rectifier. This unusual DC/DC converter has one or several rectifier transistor switches. A proposed topology of DC/DC converter with active rectifier has one rectifier switch. In Fig. 2, a circuit diagram of this topology is shown.

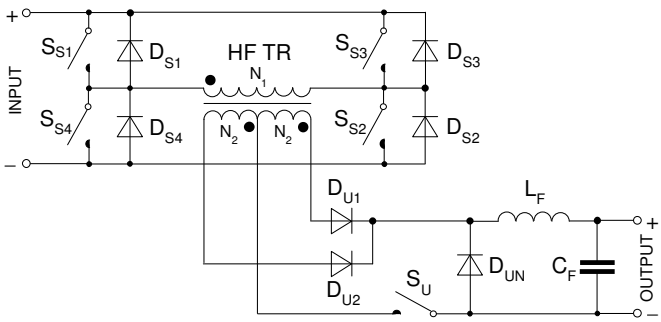

Fig. 2. Circuit diagram of DC/DC converter with active rectifier.

The proposed topology of DC/DC converter with active rectifier is controlled by simple pulse width modulation. In Fig. 3, a corresponding control algorithm of this converter topology is shown.

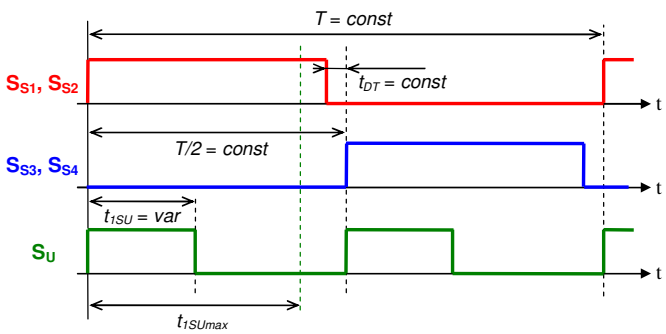

Fig. 3. Control algorithm of DC/DC converter with active rectifier.

An operation principle of this DC/DC converter topology was already analyzed. Simplified analytical time waveforms of this converter topology were also already derived. Equivalent circuit diagrams of all period time intervals were already derived, too. From the operation principle analysis was obvious that the entirely soft switching DC/DC converter could be designed by application of some kind of snubber.

III. Currently Solved Part of Research Task

To resolve this problem, a novel type of snubber was proposed. Therefore, the proposed topology of entirely soft switching DC/DC converter with active rectifier has active lossless snubber. In Fig. 4, the circuit diagram of this topology comprising active snubber is shown.

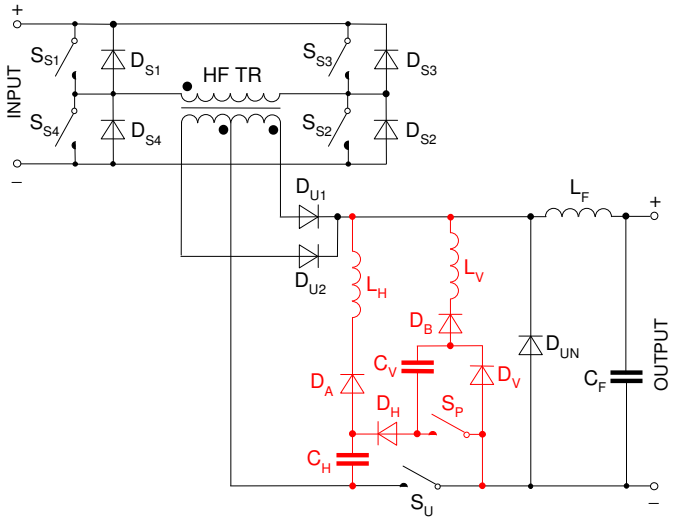

Fig. 4. Circuit diagram of DC/DC converter with active rectifier and active snubber.

A real function of proposed entirely soft switching DC/DC converter topology was verified by measurement of laboratory model of this converter. For this verification the 2kW laboratory model was made. The laboratory model was designed for nominal switching frequency f = 50kHz. The nominal value of input voltage of converter is U = 300V and nominal turn's ratio of step down high frequency transformer is p = 5. In Fig. 5, a picture of this laboratory model is shown. In the following, the key experimental results obtained from measurement of laboratory model are presented.

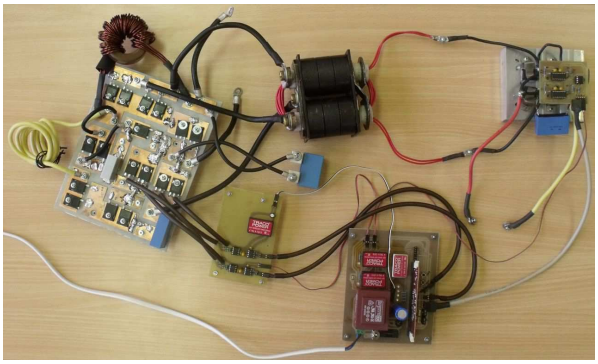

Fig. 5. Laboratory model of proposed soft switching DC/DC converter.

In Fig. 6, the measured time waveforms of output voltage u_{Ss3} and output current i_{Ss3} of inverter transistor switch S_{S3}, output voltage u_{Su} and output current i_{Su} of rectifier transistor switch S_U, output voltage u_{Sp} and output current i_{Sp} of snubber transistor switch S_P are shown. From all these time waveforms is obvious that the soft switching in the proposed topology of DC/DC converter comprising active snubber is achieved reliably. The switch S_{S3} turns on at zero voltage and also at zero current, and turns off at zero current. The switches S_U, S_P turn on at zero current, and turn off at zero voltage.

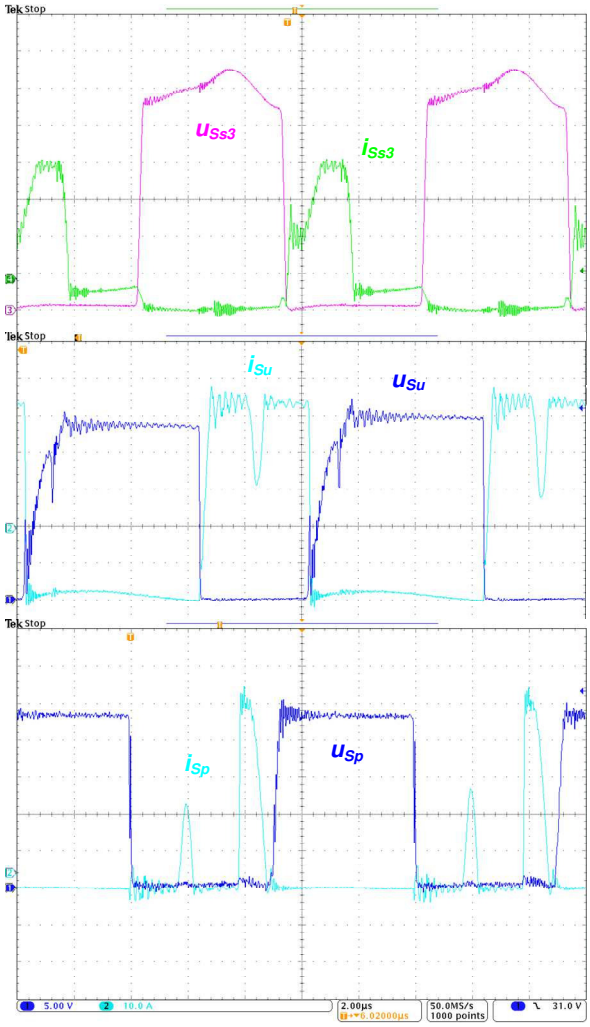

Fig. 6. Measured time waveforms of output voltage and output current of switches S_{S3}, S_U, S_P.

IV. Conclusion

The soft switching of all transistor switches is achieved. In the future, the laboratory model of proposed entirely soft switching DC/DC converter should be optimized, the analytical time waveforms of this converter topology and the equivalent circuit diagrams of all period time intervals should be derived. Also, another type of snubber could be developed. By this way, the complexity of snubber could be reduced. The load range in which the soft switching of all switches is achieved should be taken into consideration, too.

Acknowledgment

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Image Object Symbolization

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***Abstract*—In this work we would like to present approaches of image object symbolization. In the last year we have designed symbolization method based on direction vectors for description image objects. Subsequently we designed and implemented string classification method based on symbol cluster approach and direction vectors.**

***Keywords*—Object symbolization, symbol cluster approach, object detection**

I. Introduction

The ability of complex objects recognition is useful for several segments. From the medical sector to in the space sector. Therefore, researchers may achieve improvements in the complex objects recognition using different ways. Approaches based on neural networks offer good results but they have high hardware requirements. This weakness has roots in the architecture of modern computers. They are designed as fixed electronic circuits. These circuits are not able to create a new connection between electronic circuits as a result of a new knowledge obtained over time. However in the case of human brain it is possible. Plus, the human brain has higher level of parallelism than present computers. We think, that there exist approaches which are closer to the architecture of modern computers. One of these approaches could be grammars.

Grammars are present in the modern computers from the beginning. Modern computers allow us to modify executable code via programing languages. Because of this they are able to use modern computer architecture better than the neural networks. Therefore we want to review abilities of grammars for the complex object recognition.

II. Related work

We present existing related work in this section. Different signal types use different approaches such as hybrid systems based on symbolization described in Daida's work [1] or 3D symbolization of geographic information designed by Yongjun [2]. Takano [3] and Zhou [4] describe approaches based on image object symbolization and clusters of symbols. Methods in these two works are described analyze of complex image objects. In these works a process of clustering is able to adapt to a new input. This attribute is very important, since it allow us to design a large system of image object symbolization.

III. DVG - Direction Vector Grammar

In this section we would like to describe grammar based on direction vector. Use of this grammar is in the object detection field. Based on the works described in the section 2, we need grammar to the describe image objects. We have defined specific requirements for this grammar, such as:

1) Image size adaptation for different image sizes. We want to design method that is able to adapt to different image sizes. It means in different image sizes, method is able to describe the object by the same way.
2) Low level of image preprocessing. Method has to adapt to certain noise level and certain image rotation level. These aspects may provide better method performance. Better noise adaptation provides better results (denoising methods are not prefect, they are not able to remove all noise from image). Generally, rotated objects are problems with high impact to performance. To find effective description for rotated objects is important.

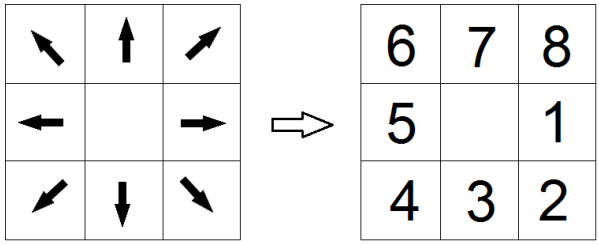

Fig. 1. Transformation between direction vectors and numerical values

Based on these requirements we designed method describing image objects with the use of direction vectors. Method has 8 basic vectors that are represented by numerical values from the 1 to 8. Transformation schema between vectors and numerical values is shown in the Fig.1. Vectors are obtained from circumference points of object. Process of vector creation is affected via two attributes. The first attribute represents the noise value. By this attribute we are able to change sensitivity of method to the image noise. Second attribute represents distance between two points. These two points will be used to the calculation of direction vector. Because number of direction vector may change based on the distance value or image size. We've defined form without vector redundancy. This form satisfies the first requirement. Example of this form is following:

Form with vector redundancy	Form without vector redundancy
111133355777777	1357

After this we focus on validation of string cyclicality. This property is able to adapt to the object rotation. Change object rotation affects position of vectors in result string. Let's see an example:

Original string	String after rotation
$[1, 2, 3, 4, 2, 1, 3, 5]$	$[2, 1, 3, 5, 1, 2, 3, 4]$

The noise value and this property satisfy the second requirement.

And after these steps we preformed test on the set of the Latin alphabet. We've used capital letters of this alphabet. Tests confirmed grammar properties. This work was published in [5].

IV. Cluster method based on DVG

In this section we would like to focus on description of cluster method based on the DVG. The basic concept is presented in Takano's [3] and Zhou's [4] works. Their cluster models are used for description complex objects of a image. Clusters creation is based on strings / symbols similarity. Similarly objects are clustered to the specific cluster. This process creates many clusters in cluster space. The cluster space represents a logical space where are all clusters (we called this cluster global cluster C_g). Based on Zhou's works we denote cluster C as:

$$C =< c, o, r, n > \tag{1}$$

where c represents the cluster identifier (cluster identifier equals to the result of CSM function, CSM function is described below). o is cluster center. This value represents average value of string CSM (for each string is calculated CSM's value) in cluster. r represents cluster radius. In our approach, cluster radius represents string dispersion based on their CSM's values. n represents number of symbols in the cluster. After this, we are able to denote C_g as:

$$C_g = \{C_1, C_2, ..., C_n\}, \qquad n \in \langle 0, \infty) \tag{2}$$

Furthermore we need to calculate CSM's value. For this goal we've defined a function for cluster selection method (CSM) for a symbolized string S (string is obtained from the DVG). We define CSM function as:

$$\mathrm{CSM}(S) = \sum_{i=0}^{n}((i+1)s(i)) \tag{3}$$

where S represents an input string, n is the number of a string symbols, $s(i)$ represents i^{th} symbol of string, and $(i+1)$ is an increment. This increment provides better cluster diversity. Without increment $(i+1)$ in the formula, the number of strings in clusters increases and the number of clusters decreases.

Although CSM's value creates relatively precise results, these results are not precise enough for string comparison. Because of this we defined a new method – strings comparison method (SCM). SCM allows us to compare string with desired precision. SCM is defined as:

$$\mathrm{SCM}(S1, S2) = \sum_{i=0}^{max(m,n)} (abs(s_1(i) - s_2(i))) \tag{4}$$

where m, n represent string length of $S1$ and $S2$. Function max returns maximal value from the pair m, n. Function abs returns absolute value of input. Functions $s_1(i), s_2(i)$ return i^{th} element of string. In case that m is not equals to n functions $s_1(i), s_2(i)$ return 0 at the indexes where i is upper than string length.

A. Experimental results

In this subsection we would like to focus on presentation of experimental results. We preformed tests on 5 different alphabets. First three alphabets represent phonetic alphabet type (we used Latin, Cyrillic and Arabic alphabet) and second two alphabets represent symbolic alphabet type (we used CJK and Hungul alphabet). Each test consists of 50 letters/symbols from specific alphabet. If alphabet consists of more than 50 symbols, we used the first 25 capital symbols and the first 25 lowercase symbols from that specific alphabet.

In the tests, we've mainly focused on these three attributes:

1) **Average cluster sizes**. We want to know value of average cluster sizes. Also, we want to compare average cluster sizes of alphabets each other.
2) **Value of average strings dispersions**. This attribute is very important for us. Because lower value of average string dispersions means worse ability to distinguish very similar objects.
3) **Number of clusters**. We want to know number of clusters and relation between this attribute and average string dispersions. Does higher number of clusters produce lower value of average strings dispersions?

Experimental results show possibility to recognize alphabet type based on value of average cluster sizes. Symbolic alphabets produce higher cluster size as phonetic alphabets. Furthermore, value of average strings dispersions has sufficient value for creation of large system based on this approach. Detailed results are shown in paper that is still unpublished.

V. Conclusion

In this paper we focus on presentation of our works. Our designed symbolization method allows description image object via direction vector. This approach is able to adapt to different image sizes and image rotation (or rotated objects in images). Based on this method we designed the method of string clustering. This method allows us to process and store different image objects (we used different alphabets in the experiments). In future research we would like to focus on analyzing more complex objects such as real world objects or objects in video sequences.

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Image Steganalysis

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***Abstract*—This paper is overview of my work for the last year of post gradual study. The aim of this paper is summarization of results that were reached in the design of image steganalytic tool. The last year of my work was dedicated to improvement of detection accuracy for steganographic methods embedded secret message in Discrete Wavelet Transform (DWT) domain. Proposed new statistical vector contains 46 statistical features extracted from images. Popular steganographic tools (e.g. F5, Outguess) and own proposed method embedded text secret message in DWT domain were used for testing of proposed steganalytic tool.**

***Keywords*—steganalysis, image, DWT, statistical features, classifiers**

I. INTRODUCTION

The main steganographic objective is to ensure a secret transmission of data in background of non-privacy communication without additional security elements. Steganographic method can be used to illegal activities as terrorism or applied in environment where communication channel is monitored and user needs to transmit a secret message.

On the other hand, there are different methods of steganalysis. Steganalysis is utilized to detect the subliminal channels established by steganography. These methods are based on the strong complex mathematical calculations. Classifier is the main part of such tools and an efficiency of steganalytic methods is also dependent on a type of classifier. Generally, the steganographic system is considered as broken once the steganalytic tool can decide whether testing medium contains a secret message or the original medium is intact while success probability is higher than random guessing.

II. THE INITIAL STATUS IN THE SOLVING OF THE RESEARCH TASK

Previous years, my research activity was focused on design of the steganalytic tool for detection of the secret message in static images. The principle of proposed method is based on the extraction of statistical features from Discrete Cosine Transform (DCT) domain of static images. The image database is created from the group of cover and stego images and database diversity (images from different types of camera, various image resolutions and etc.) should be respected. The group of extracted statistical features has assigned identifier depending on whether parameters were extracted from a stego or cover image. The output of this process is subsequently used for the training of model using specific type of classifier. Finally, the created model for the specific steganographic tool (e.g. F5 [1] and Outguess [2]) is utilized in the detection of secret message in still image. Extracted statistical features are compared by classifier with trained model and the output of this comparing is result, whereby tested features can be assigned to cover or stego image. Block diagram of proposed steganalytic tool is illustrated in Fig. 1.

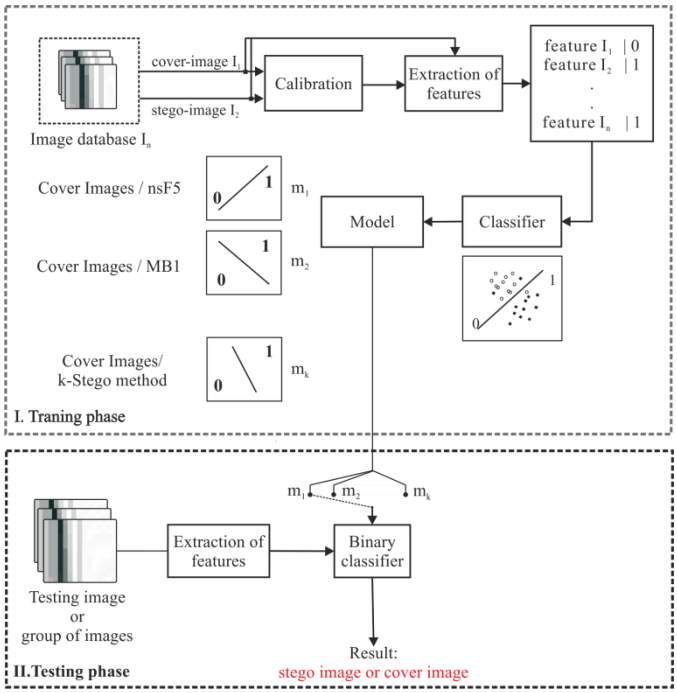

Fig. 1 Block diagram of proposed steganalytic tool for JPEG images

The disadvantage of proposed method was very low detection accuracy for the steganographic tool based on Discrete Wavelet transform (DWT), because statistical features extracted from DCT domain are not able to capture changes caused these steganographic methods. Therefore, the last year of my PhD study was dedicated to solving this problem.

III. OBTAINED RESULTS

The last year, my research was focused on improvement of detection accuracy for proposed steganalytic tool described in [3], especially for steganographic methods based on DWT. In this case, there was necessary to modify proposed statistical vector with 285 features from DCT domain.

Third level of 2D Haar DWT [7] is used on extraction

statistical features in proposed steganalytic method. Vi(x,y), Hi(x,y) a Di(x,y) represent detail coefficients of image in vertical, diagonal and horizontal direction and Ai(x,y) expresses approximation coefficients of specific level. This type of DWT is illustrated in Fig. 2.

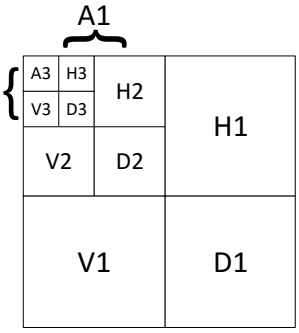

Fig. 2 Third level of 2D Haar DWT

Proposed new statistical vector contains 46 statistical features extracted from images. First feature is image entropy before DWT decomposition. The next, 36 statistical parameters are calculated from every direction of the detail coefficients. The values of error signals are defined by last 9 statistical features [5]. Comparison of detection accuracy for steganalytic tool extracted statistical features only from DCT domain and steganalytic tool extracted statistical features from combination DCT and DWT domain is illustrated in Table I.

TABLE I. THE COMPARISON OF DETECTION ACCURACY FOR DCT AND DCT+DWT IMAGE STEGANALYSIS

Verified method	bpnz	DCT (285)		DCT+DWT (285+46)	
		TPR[%]	ACR[%]	TPR[%]	ACR[%]
F5	0,25	49,1	75,1	48,6	76,1
	0,8	97,5	98,9	97,8	99,1
Outguess	0,05	56,9	76,1	57,9	77,1
	0,2	98,5	97,9	98,5	98,1
	0,4	100	98,1	100	99,1
Proposed method DWT	0,1	33,1	42,1	71,2	79,1
	0,4	48,3	41,4	84,3	89,1
	0,6	65,4	58,3	89,4	94,6

Results show, that DWT steganographic method can be also detected using statistical parameters from DWT domain, it was not possible for steganalysis based on extraction of statistical features only from DCT domain. [5]

The next part of my work was devoted the proposal of steganographic method. It was published in the proceedings of the international conference ELMAR in Croatia [6]. A novel algorithm of image steganography is proposed for the embedding of secret text message into a cover image using YC_bC_r color space model and 2D Haar Discrete Wavelet Transform. In this proposed technique, input text in ASCII code is encrypted by AES what ensures, that the relative letter frequency of a plain text secret message will be disturbed. Proposed technique also solves conversion between color space models RGB and YC_bC_r in spite of modification in component C_b by the secret message.

The flow chart of proposed steganographic tool is illustrated on Fig. 3 and the detailed description of embedding process is defined in [6].

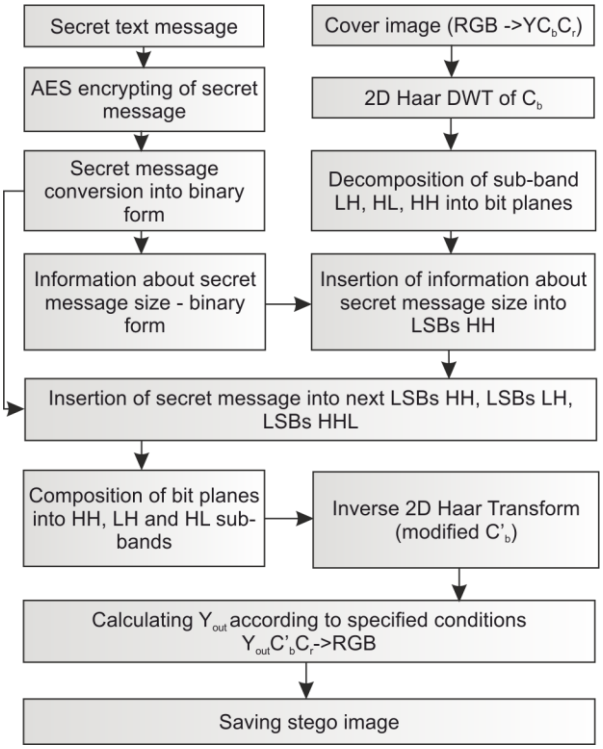

Fig.3 The flow chart of proposed steganographic tool – embedding process

IV. FURTHER WORK

Based on the analysis of previous results can be designed further research in the area of image steganalysis and steganography. The next step in this research could be focused on the feature selection before the classification. It can cause improvement of detection accuracy and reduction of computational complexity of proposed method. Now, all my work is centered on writing of the dissertation thesis, where all my research results and contributions will be summarized.

ACKNOWLEDGMENT

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Impact of interaction between radiofrequency electromagnetic field and biological and technical systems

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***Abstract*— The exposition of biological systems to radiofrequency electromagnetic radiation has increased with rapid development of wireless transfer of information. Every day the radiofrequency electromagnetic field of mobile phones, Wi-Fi internet, TV broadcast and even more interact with biological and technical systems. This paper is focused on the current research of impact of the interaction between electromagnetic field and biological and technical systems. In the end it evaluates future work and research of this interaction.**

***Keywords*— electromagnetic field, biological systems, exposure, tick**

I. Introduction

Whether this electromagnetic exposure is or is not dangerous for our health scientist are trying to find answer for. Electromagnetic pollution is responsible for interference between electrical devices, but it also affects the human body. The organism reacts to the electrical, magnetic and electromagnetic fields around it. The biological effects depend on the type, frequency and strength of these fields. The boom in the use of the cellular phone has led to a very evident increase of electromagnetic pollution [1].

The number of mobile phone users has increased exponentially recently and it has become an important device in human daily life. In 2014, there were more than seven billion mobile phone subscribers worldwide, a number that is expected to keep growing [2].

Radio frequency used in mobile communication has the ability to penetrate through the semi-solid substances like meat and living tissue [3]. Researches conducted show that the electromagnetic wave produced by the mobile phone might cause adverse effect to human especially at place near the ear region [4].

II. Recent research

In ongoing researches, great emphasis is given to the effects of EM radiation on the brain and nervous system. Therefore, several studies focus their attention on this very issue [5],[6],[7]. They use sources of radio-frequency (RF) radiation in the form of propagating waveguide, but also pulse radiation with high specific absorption rate (SAR). They are trying to demonstrate the impact of mobile phones, antennas or high-frequency emitters on the nervous system of animals and mostly on human.

There are concerns that radiation from mobile phones has a negative impact on brain activity, specifically on memory and learning disorders. A group of scientists [8] in order to protect the population and preventing possible negative effects on the human brain, tried to demonstrate the effect of radiation on the brain in male mouse. They used RF EM radiation in three different frequency levels (400, 900, and 2200 MHz) and the power absorption in the range from 2.05 to 35.7 W/kg. It was found that although this radiation irritated nervous system, it has lasting effect on the physiology and function [7],[8]. The current state of the problem suggests that mobile phones do not have a major impact on the functioning of the nervous system, because mobile phone manufacturers are trying to reduce the level of SAR at unchanged frequency.

Our preliminary works are conducted to previous research efforts of the team of Professor Karol Marton [9]. We applied non-ionizing electromagnetic field to expose several biological tissues for different time periods. We have chosen the frequency and power similar as it is with telecommunication devices. The very first experiences revealed that research methodology, laboratory procedures, analytical methods and sample logistics are suitable for designing of future research [10],[11].

The decision on realizing this experiment was influenced by the fact that this area of science is relatively poorly mapped, and the chances are high of obtaining new and especially beneficial results.

III. Current Research

Current research is aimed on exposing ticks (Fig. 1) to electromagnetic field, because there are concerns that ticks reacts to electromagnetic field. This research is done in partnership with scientists form Institute of Parasitology of the Slovak Academy of Science.

The aim is to expose the ticks to non-ionizing electromagnetic field with four different frequencies and observe their behaviour. The frequencies were chosen to be 900 MHz, 1800 MHz, 2400 MHz and 5000 MHz, two from mobile broadband and two from Wi-Fi broadband. The electric field intensity was chosen to be constant at one meter from antenna.

The output power was calculated for different frequencies according to (1).

$$P = E + 20\log(\mathrm{r}) - G_i - 107.78 - b \qquad (1)$$

where P [dBm] is output power, E [dBμV/m] is electric field intensity, r [m] is the distance between antenna and object, G_i [dBi] is gain of antenna and b [dBm] is cable attenuation.

The exposure is performed in anechoic EMC chamber (Fig. 2) for different frequencies, different time periods and differed number of ticks. The behaviour of the ticks exposed and not exposed to electromagnetic field is observed and statistically analysed.

Fig. 1 Lurking tick

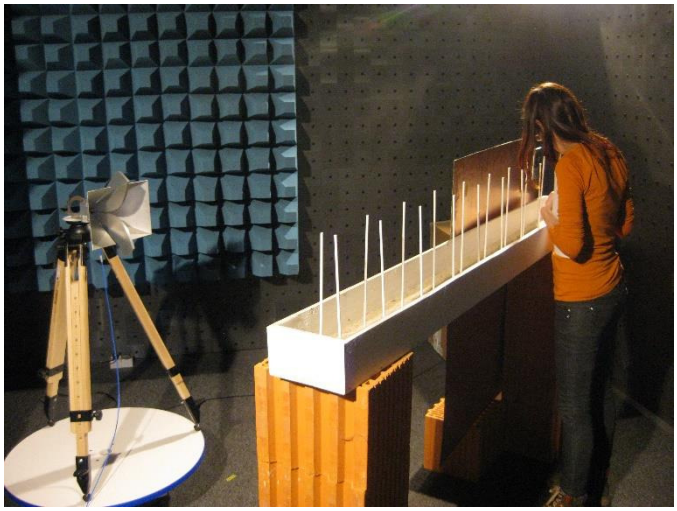

Fig. 2 Exposure set-up

IV. Future research

Subsequent analysis and consultation is concluded in an agreement with an expert on electromagnetic fields in practice for measurement of non-ionizing electromagnetic fields in various locations of the Slovak Republic and evaluating the effects on technical systems. In the future it is planned to find researchers in biology with required equipment and laboratory for providing biological tissue and for analysis of these tissues before and after electromagnetic exposure. Researching the impact of non-ionizing radiation will be assembled in the workplace with EMC chamber where biological tissue will be exposed to the non-ionizing radiations. For a better idea of penetration, distribution and impact of non-ionizing radiation on biological tissue will be creating a mathematical model and simulation in ANSYS software.

V. Conclusion

According to statistics the trend in various types of wireless communication is rising. It rises localized electromagnetic fields pollution in populated areas. On one side this calls for better bands management from technical, and on the other for deeper studies of possible negative effects from ecological and health risk standpoints.

Acknowledgment

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Improving Program Comprehension: Preliminary Results and Research Plan

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***Abstract*—In this paper, we summarize our preliminary research results in the area of program comprehension. The main focus is source code labeling, which is an assignment of metadata to source code elements. We also outline our next steps in the research plan.**

***Keywords*—program comprehension, source code labeling, annotations, user interfaces**

I. Introduction

Maintenance of existing program systems typically counts for about 60% of software development cost [1]. Before a part of a system can be changed, it must be comprehended [2]. Our work aims to improve understanding of existing programs by developers, i.e., *program comprehension*. Without proper tool support, understanding of software systems may soon become an unattainable task.

II. Program Comprehension Overview

In [3], we provided a general overview of program comprehension theories, approaches and tools, in a form of an *ad hoc literature review*. The selection of surveyed papers was unsystematic, coming chiefly from random browsing of interesting articles in the given research field, and suggestions of peers.

A. Theories and Research Methods

After a short definition and a delineation of the research field, we [3] discussed theories and research methods used in the area of program comprehension. Because there exist at least seven different comprehension models, it is difficult to come up with tools based directly on them, and empirical methods are prevalent.

B. Techniques and Tools

We [3] explored the comprehension process, from overall comprehension of a software system, to feature location, understanding of the details, to the investigation of the rationale. For each level of detail, notable existing techniques and tools were mentioned. Some ideas on how we can write new systems with regard to comprehensibility were also presented.

C. Trends in Program Comprehension

It is beneficial for researchers not only to find out which approaches exist in the area, but also to gain insight about their popularity over time. To analyze the development of trends in the research area of program comprehension, in [4], we decided to perform an automated *trend analysis* on the metadata of research articles published between the years 2000 and 2014 (inclusive).

We searched the citation databases Scopus and IEEE Xplore for the term "program comprehension" and its synonyms. Titles, abstracts and author-supplied keywords of 1885 articles were analyzed using a technique called n-grams. For each year, a frequency of every phrase among all phrases of the given length was determined.

The most rising trends, according to our analysis [4], are feature location and open source systems study. The most falling ones are program slicing and legacy systems.

III. Source Code Labeling

During attempts to comprehend a program, there is often a lack of information useful for humans contained in the code. A set of existing approaches, which we named *source code labeling*, aim to fill this gap by assigning additional metadata to source code elements. These metadata can come from diverse sources: from manual user input, to runtime values, to harvested instant messages. They can be of various types and presented in even more various ways. They can be permanently persisted in the source code or a database, or shown only for a split second in the integrated development environment (IDE).

A chapter in the written part of dissertation examination [5] contains a *systematic mapping study* – a form of a systematic literature review. It is devoted to summarization and assessment of source code labeling approaches. A manual search in titles and abstracts of relevant venues, a keyword search, along with backward and forward references scanning, resulted in a body of more than 2,000 articles, from which 23 were selected according to inclusion criteria. A taxonomy was formed and the articles were classified with respect to this taxonomy.

IV. Concern Annotations

A very practical form of source code labeling are concern annotations [6]. They are Java annotations over language elements, denoting concerns pertaining to a particular element. For example, if a method provides file per-

sistence, it can be annotated with `@Persistence(type = PersistenceType.FILE)`.

A. Empirical Studies

In [6], we first recapitulate the results of two *case studies* performed by Milan Nosáľ [7].

Next, we [6] present an original *controlled experiment* to compare how concern annotations affect program comprehension correctness, time and confidence. Two groups of participants (9 per group) were given the same small-scale Java project – one group with concern annotations available, the second one without them. The "annotated" group completed two maintenance tasks and three comprehension questions 34% sooner than the second. The results is statistically significant ($p<0.05$).

In an article under review [8], we describe a replication of the experiment. This time, a statistically significant 33% improvement of correctness was shown.

B. Automation

As manual annotation of all language elements is a laborious task, we introduced a preliminary semi-automated method in [9]. A technique of differential code coverage [10] is used. First, the program is run utilizing a concern (feature) of interest, then without utilizing it. A set of methods related to the concern is computed as a difference of sets of methods executed in these two runs. The resulting methods are automatically annotated, overwriting the source code.

V. Research Plan

Next, we will summarize our research plan presented in [5].

A. Measuring Program Comprehension

In scientific literature, it is often claimed that a particular technique or approach "improves program comprehension". According to Harrington [11], if you cannot measure something, you cannot improve it. Therefore, we plan to perform a systematic literature review of articles claiming something improves or hinders program comprehension to answer our first research question:

RQ1: How is program comprehension measured in existing literature?

B. Build Process Failures

According to anecdotal evidence, many open source systems fail to be built from sources to executables. If a program cannot be built, its runtime behavior cannot be observed and thus comprehended. We thus formulate a hypothesis:

H2: Open source systems often fail to be built because of systematic errors in the design of build tools, thus hindering program comprehension.

C. Terms in User Interfaces

Although recommended, programmers are not obliged to use problem domain terms in the source code. However, GUIs (graphical user interfaces) are shown to an end user and therefore they must contain suitable terminology. One could argue that all concepts in the GUI are present in the source code of the program, for example, as literals. However, modern program systems utilize immense number of resources – from configuration files, to databases, to remote web services – and blend them into the user interface. Knowing that running UIs contains more terms than the static source code would open new possibilities for source code labeling.

H3: There exist domain terms available in the UI of a running program which are not present in the static source code at all.

D. Labeling Source Code with Information from GUIs

If **H3** is confirmed, we will be able to continue to this step. A source code labeling method based on terms from GUIs could be designed.

So far, two approaches partially connect the the GUI world with the source code: UI tracing [12] (splitting a long method trace by UI action methods) and GUI-driven code tracing [13] (showing a GUI snapshot for a particular method call in the IDE). Nonetheless, they do not persist any results. Furthermore, only a graphical snapshot is associated with the corresponding methods. These snapshots can contain valuable domain-specific terms (see **H3**). We formulate the core hypothesis of our work and a sub-hypothesis:

H4: It is possible to assign textual labels to source code elements using information obtained from corresponding user interface controls.

H4.1: The new labeling approach improves program comprehension.

Acknowledgment

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Improving the Diagnostic and Backup System Using Experimental Identification Methods

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***Abstract*—The article describes the work and results obtained in the previous year of the PhD study. The research focuses on improving the proposed diagnostic and backup system that will be part of an integrated system health management for aircraft engines. The main objective is to increase reliability, efficiency and safety of aircraft turbojet engines. This paper compares nine experimental identification methods (artificial neural networks, polynomial models, deterministic methods) based on the test results of the created models using these methods on the small turbojet engine iSTC-21v.**

***Keywords*—Diagnostics, experimental identification, health management, small turbojet engine.**

I. Introduction

Modern aircraft turbojet engines represent a complex system where the issue of safety, efficiency and reliability come to the fore [1], [2]. To achieve these concepts is important to have a proper diagnostic and backup system that is able to detect failures of the engine [3], [4]. Such a system consists of models of engine´s parameters serving as a backup in case of sensor failure. These models are calculated by methods of experimental identification, so it is essential to use the methods that achieve the best results.

The term experimental identification [5] is defined as the experimental process in which is an abstract model or the physical object assigned to the original object. This process is based on the data sets that include values acquired by measurement. Methods of experimental identification require the existence of the studied object, in our case the engine iSTC-21v [6], and the possibility of experimentation with it, in our case in the laboratory LIRS LM. System validation is realized through simulation of model and comparison of each output, thus outputs generated by the model are compared with real measured outputs. The process ends when the desired similarity of the model with the real object is reached.

II. Initial State

Our primary goal is to create an integrated system health management (ISHM) for aircraft turbojet engines (see Fig. 1) [7], [8]. ISHM is used to process data, information and knowledge in order to ensure reliable engine operation, early detection of failures and their isolation, reduction of maintenance and operating costs, etc. These goals can be achieved by a combination of three health management techniques:

- Diagnostics and backup
- Prognostics
- Life extending control

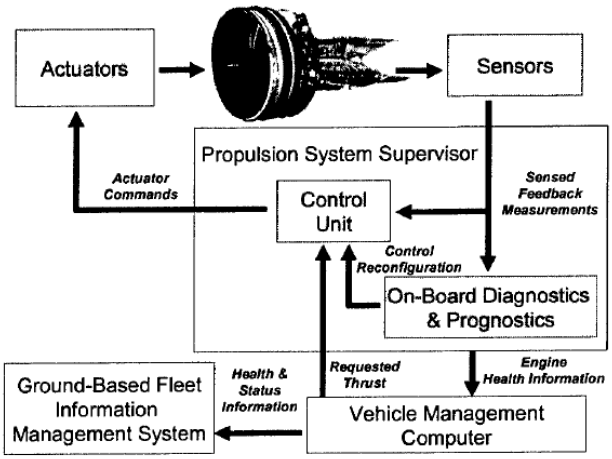

Fig. 1. Structure of the aircraft engine health management [7]

In the previous SCYR article [3], we have described our real-time diagnostics/backup system of the small turbojet engine iSTC-21v. Its function is to diagnose the condition of the engine, detect errors and isolate them by timely application of the designed backups, so they do not affect smooth operation of this engine. Next we decided to improve this system.

III. Solved Tasks in the Previous Period

In this chapter are summarized tasks solved in the previous year of my PhD study. Research mainly focused on the improvement of the proposed diagnostic/backup system through the decreasing amount of mean absolute error (MAE). This error represents the deviation between measured data of the selected parameters of the engine iSTC-21v and created experimental models.

A. Selected Methods of Experimental Identification

To increase the accuracy of the designed system, we have selected nine methods of experimental identification which can be used to create models of engine´s parameters [9].

These methods are divided into:

- Artificial Neural Networks
  - NARX
  - Time Delay Neural Network
  - Distributed Delay Neural Network
- Polynomial Models
  - ARX
  - ARMAX
  - Box – Jenkins
  - Output – Error
- Deterministic Methods
  - Method of Successive Integration
  - Area Method

B. *Comparison of Experimental Identification Methods*

In order to compare each method of experimental identification we have created over 4000 models with different configuration for all of the engine measured parameters. These parameters are pressures P_{2C}, P_{3C}, temperatures T_{1C}, T_{2C}, T_{3C}, speed of engine's compressor n and fuel flow supply Q_{Pal}. For the calculation of these experimental models was used programming environment MATLAB/Simulink.

As an example, the comparison of the measured parameter P_{3C} with the models of this parameter created using above mentioned experimental identification methods is shown in Table I. As you can see the most accurate was a NARX network with the amount of the mean absolute error MAE = 0.0089 At and the absolute percentage error MAPE = 2.2422 %.

TABLE I
COMPARISON OF THE METHODS OF EXPERIMENTAL IDENTIFICATION BASED ON THE AMOUNT OF MEAN ABSOLUTE ERROR (MAE)

Input	Output	Method	MAE [At]	MAPE [%]
P_{2C}	P_{3C}	NARX	0.0089	2.2422
		Time Delay NN	0.0092	2.2935
		Distributed Delay NN	0.0093	2.3106
		ARX	0.0151	3.8846
		Output – Error	0.0153	4.2007
		ARMAX	0.0155	4.2087
		Box – Jenkins	0.0155	4.2087
		Area Method	0.0346	7.9605
		Successive Integration	0.0767	12.4302

C. *Improvement of the proposed diagnostic/backup system*

Based on the results of the created experimental models we were able to increase the accuracy of the implemented diagnostic and backup system of the engine iSTC-21v. For example, the amount of the MAPE of parameter P_{3C} has been reduced from 5.0378 % to 2.2422 %, representing an improvement of 44.5 % compared to the last year results.

IV. CONCLUSION AND FUTURE RESEARCH

In this paper, we have shortly presented the results of the work done in the last year. The main objective was to increase the accuracy of our real-time diagnostic and backup system of the small turbojet engine iSTC-21v. For this purpose, we have compared nine methods of experimental identification for each parameter of the engine and chose the best ones. This resulted in a reduction of errors in the experimental models as well as in the entire diagnostic system.

We are currently working on the classification of the failures detected by the system, so it will be able to correctly identify the exact type of error and properly respond to it.

Future research will be focused on life extending control for damage reduction of engine parts and on prognostics for prediction of future failures. Along with the diagnostic/backup system will form the health management system for aircraft turbojet engines.

ACKNOWLEDGMENT

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Inductive and capacitive sensors based on film technology

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***Abstract*— Sensors are devices widely used for measurement of quantities or qualities of different parameters. Some of the most known sensors are capacitive and inductive sensors. Inductive sensors are being used primarily for proximity sensing of metal objects. Capacitive sensors can be used in different configurations for measurement of pressure, distance, movement or proximity. This paper describes construction of inductive and capacitive sensors from the film technology view and offers solutions for driving and signal conditioning of given sensors.**

***Keywords*—inductive sensors, capacitive sensors, LTCC, planar structures**

I. Introduction

Massive expansion in field of consumer electronics in last years forces an electronic developers for producing highly reliable and cost effective products. When talking about smart electronics, a lot of devices are needed for communication between user and electronic device. Sensors, as this devices are being called, allows sensing a lot of different parameters. Proximity sensors, such as inductive and capacitive sensors, offers reliable solution when sensing of metal or non-conductive objects because of absence of any mechanical components. The use of low temperature co-fired ceramic (LTCC) as a basic substrate allows using sensors in harsh environment conditions.

Driving electronic circuits are another important part of sensors needed for driving and signal conditioning of sensors. Standard sensor´s electronic driving circuits that have been used for many years are nowadays being replaced by one chip solutions that offers a lot of advantages (will be described later). If LTCC is used, driving electronics with sensor element can be integrated into one compact and reliable module.

This paper focuses on basic principle of capacitive and inductive sensors operation, using LTCC as a basic substrate for these types of sensors and offers solutions for construction and driving capacitive and inductive sensors.

II. Inductive sensors

Inductive sensors are proximity sensors used for detection of metal objects at typical measurement ranges of 0.5 mm to 15 mm with nanometer resolution [1]. Electromagnetic field that penetrates into the sensed object is generated by passing an alternating current through a coil´s winding. Electrical currents induced in the sensed object generate different electromagnetic fields that reacts together (Fig. 1). Inductive sensors are immune against material in the gap between a sensor element and a target object, so they can operate in environments where oil or other liquids may appear. They can be used to detect defects in conductive materials [2], for proximity, vibration sensing or thickness measurement [3].

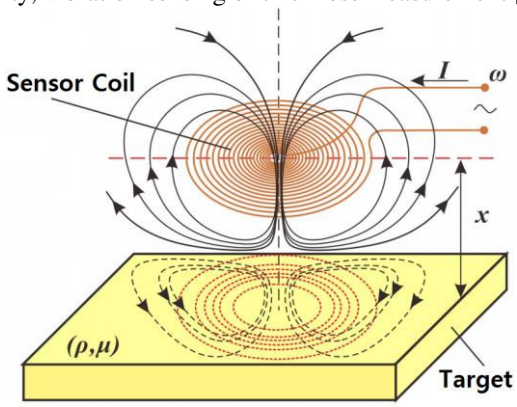

Figure 1. Electromagnetic field generated by circular planar coil [2]

When designing an inductive sensor element, several considerations must be taken in account [4]:

1. Material, shape and thickness of sensed object. Because of inductive sensing principle, only metal objects with minimum thickness can be sensed. Conductivity and permittivity of material also affects a measurement.
2. Type of motion (lateral, orthogonal, rotation). When sensing a rotational movement, for precise measurement and minimizing error a set of sensing coils may be used instead of single coil.
3. Distance between sensing coil and sensed object. Higher the distance, higher inductance of sensor element is required.
4. Maximum sensing coil´s dimensions. When designing planar sensor coil, limited space for coil winding is available. If higher inductance is needed, coil´s multilayer structure can be used.
5. Excitation frequency. Improper coil´s layout results in low self–resonant frequency that limits maximum excitation frequency.
6. Technology to be used. Spacing between paths of the coil, width of the conductive path, thickness of the substrate material, number of turns and of coil layers,

existence of ferrite core. These parameters have a crucial impact at the primary parameters (inductance, series resistance, quality factor) of the coil.

7. Environment working conditions. High temperature, aggressive chemicals, moisture and other working conditions may have negative impact on a sensing and a lifetime of a sensor. Choosing suitable material as a substrate of sensor for given working environment is crucially important.

Various shapes of planar inductive sensor´s coil can be defined for specific purposes of sensing (Fig. 2) [4]. As a circular spiral coil with symmetrical magnetic field and minimal series resistance is the most suitable for orthogonal proximity sensing in given area (Fig. 3a), a rectangular coil with non – uniform spacing can be more suitable when sensing of lateral shift is required (Fig. 3b) [2].

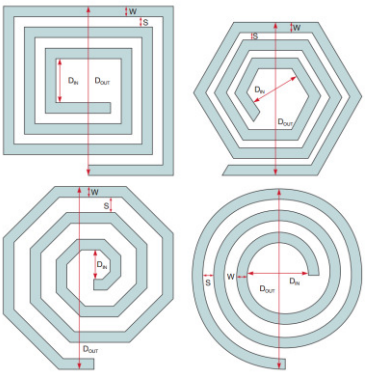

Figure 2. Example of possible planar inductor shapes [5]

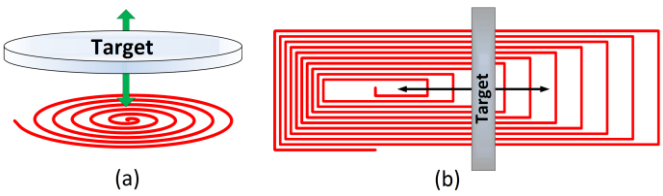

Figure 3. Circular spiral coil for orthogonal proximity sensing (a) and rectangular coil with non-uniform spacing for lateral shift sensing (b) [2]

To calculate an inductance L of a single layer planar spiral inductor, equation [5] is used:

$$L = K_1 \mu_0 \frac{n^2 d_{AVG} c_1}{1 + K_2 \rho} \left(\ln\left(\frac{c_2}{\rho}\right) + c_3 \rho + c_4 \rho^2 \right) \quad (1)$$

where μ_0 is the permeability of free space, n is the number of turns of the planar coil, K_1, K_2 and c_1 to c_4 are constants geometry dependent on the shape of the inductor [6], ρ is the fill ratio of the inductor and is equal to:

$$\rho = \frac{d_{OUT} - d_{IN}}{d_{OUT} + d_{IN}} \quad (2)$$

where d_{IN} and d_{OUT} is the inner and outer diameter of the coil, respectively, and d_{AVG} is the average diameter of the turns equal to:

$$d_{AVG} = \frac{d_{IN} + d_{OUT}}{2}. \quad (3)$$

Quality factor $Q(x)$ of the coil defines the ratio of stored energy and average power dissipated in the coil and is frequency dependent. To minimize power loses in inductive sensor system and to obtain high sensitivity and stability, coil with high quality factor is required.

RFID (Radio Field IDentification) is another possible application of coils in field of technology. Planar coil with parallel capacitor tuned to exact resonant frequency is used as a scanning antenna/transceiver to provide the RFID transponder with the energy being used for communication with transponder [7, 8].

For the fabrication of the inductive sensors, LTCC technology offers many advantages [9]:

1. Oscillation and signal processing circuit used for measurement changes of inductance can be integrated with the coil onto one ceramic substrate.
2. Operation in harsh and high temperature environments. LTCC is stable up to 600°C [10] and it can withstand a wide range of chemicals.
3. A 3D structure using LTCC technology allows miniaturize overall coil dimensions.
4. Potential to realize low-loss coils with high quality factor in LTCC multilayer technology.

LTCC technology offers possibilities for fabricating coils even small with area of 4.7 mm × 2.4 mm [11]. Inductor of such a small dimensions has low inductance due to small dimensions and the quality factor of fabricated coil is low. To increase the quality factor up to 2, using embossed conductor paths (35 µm thick after firing) instead of printed paths (7 µm) can be used to minimize series resistance [9].

III. Capacitive Sensors

Capacitive sensors can be used for detection of conductive object´s position or nonconductive object´s thickness with typical measurement ranges of 10 µm to 10 mm with 2 nm resolution [1]. Unlike inductive sensors, capacitive sensors are sensitive to the material in the gap between a sensing element and a sensed object, so they cannot be used in harsh environment.

Two parallel electrodes forms a capacitor. Capacitance C of a parallel – plated capacitor can be calculated using equation [12]:

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \quad (4)$$

where ε_0 is permittivity of free space, ε_r is relative permittivity of material between electrodes, A is the area of capacitor´s electrodes and d is the distance between electrodes.

Capacitance between sensor´s electrodes can be measured using two methods [12]:

1. Self-capacitance. Capacitance between single sensor electrode and ground is being measured when using self-capacitance method (Fig. 4a). Voltage between current driven sensor´s electrode and ground is measured. When a sensed object with different ε_r (e. g. finger) reaches electrical field of capacitive sensor, measured capacitance is increased.
2. Mutual capacitance. Capacitance between two electrodes – transmitting and receiving is being measured when using mutual capacitance

measurement method (Fig. 4b). A digital voltage switching system is applied to the transmitting electrode and the amount of charge received proportional to mutual capacitance on receiving electrode is being measured.

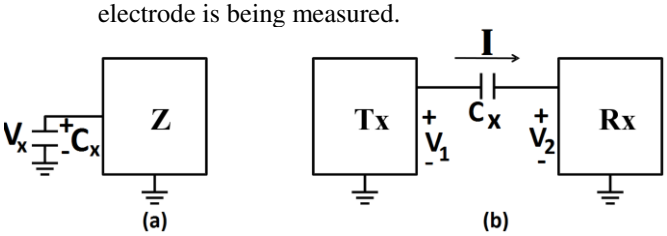

Figure 4. Self-capacitance (a) and mutual capacitance (b) of capacitive sensor [12]

Using capacitive measurement principle, a measurement of different variables can be obtained:

1. Humidity measurement. Relative permittivity of air with different level of humidity changes sensor´s capacity.
2. Temperature measurement. Measured capacity is proportional to the change of sensor´s temperature.
3. Pressure measurement. Pressure applied on one of the sensing electrodes deforms the shape of the electrode and thus changes the distance between electrodes that results in change of capacity (Fig. 5).
4. Motion measurement. Adding material with different relative permittivity between capacitive sensor´s electrodes results in change of capacity. Amount of change is proportional to the electrode/material area ratio.

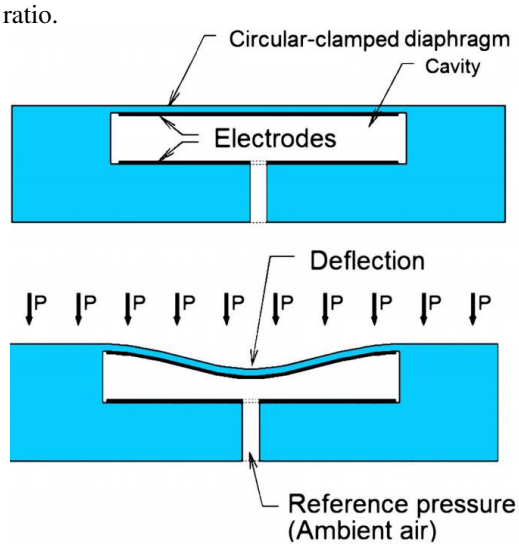

Figure 5. Principle of capacitive sensor for pressure measurement [13]

Designing a capacitive sensor requires a proper sensor design to minimize the stray capacitances and other parasitic elements that influences the sensor´s performance. There are several options to optimize capacitive sensor´s characteristics. Using guard ring electrode increase of resolution can be obtained.

Capacitive sensor for measurement of pressure in range of 0-10 kPa was fabricated using LTCC as a basic substrate (Fig. 6) [13]. This sensor achieves the typical sensitivity of 4 fF/kPa and resolution of 50 Pa.

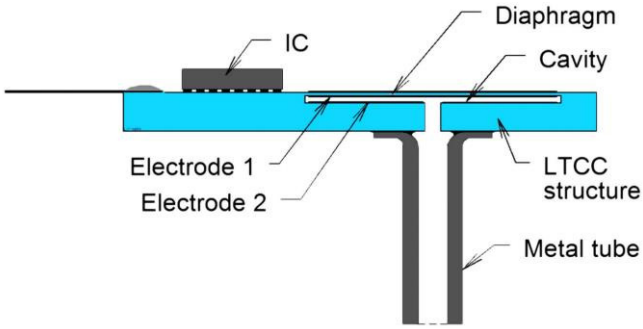

Figure 6. Capacitive sensor for pressure measurement realized using LTCC [13]

Additional experiments [14] shows influence of atmosphere's air humidity on the stability of capacitive pressure sensor. Condensed water may appear on outer walls of the LTCC module that parasitically influences stability of sensor when humidity >70 %.

IV. Driving Electronics for Inductive and Capacitive Sensors

Electronic circuits used for driving inductive and capacitive sensors and for processing sensor´s output values are another important part of sensing system. These circuits determines stability, sensitivity and other important parameters of sensors.

Driving an inductive sensor element requires an amount of energy. To minimize this energy and power consumption of whole sensor, a parallel capacitor is added to sensing coil to form a LC resonant circuit. There are several possibilities for driving an inductive sensors:

1. Fixed crystal or oscillator. Using fixed crystal or oscillator brings advantages of simple circuit design and frequency and temperature stability. To reach defined oscillation frequency, an inductor or capacitor tuning is required. When another oscillator frequency is needed, new driving electronic circuit must be build. Another electronic system (e.g. microcontroller) is needed for processing measured values.
2. Collpits, Clapp or Hartley oscillators. These types of oscillators are known for wide frequency range and frequency stability [15].
3. Demodulation circuits, such as frequency modulation (FM), amplitude modulation, phase detection and balanced bridge [16]. High resolution, high linearity, high frequency response and low noise are the main advantages of using FM. Schematic of complex FM system consisting of a precise sine-wave generator, AC bridge, a two-channel quadrature demodulator and two output amplifiers is shown in Fig. 7.
4. Inductance-to-Digital converters (LDC). These integrated circuits with minimum required external components provides measurements in wide frequency range from 1 kHz to 10 MHz with 28 bit resolution [17]. Measured value of coil´s inductance and driving frequency LDC directly converts and sends them to the microcontroller using I^2C [18] bus. Integrating LDC chip onto one module with inductive sensor element compact and highly reliable sensor module can be obtained. Block diagram of LDC1612 LDC is shown in Fig. 8.

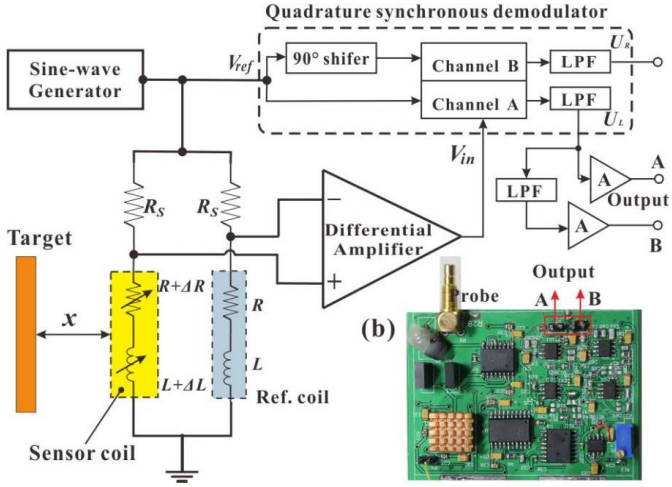

Figure 7. Complex frequency modulation system for signal processing of inductive sensor [16]

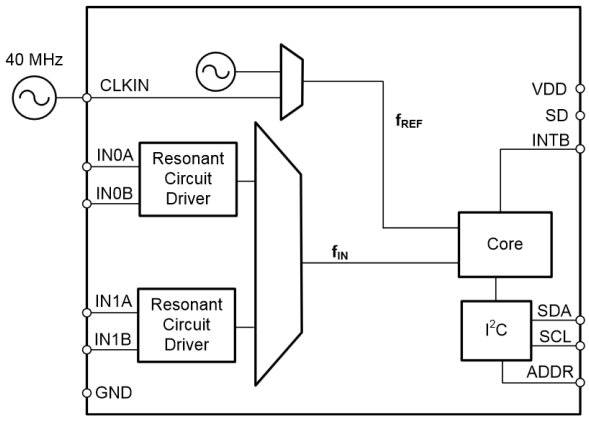

Figure 8. Block diagram of LDC1612 Inductance-to-Digital converter [17]

Capacitive sensors are popularly driven by Capacitance-to-Digital converters (CDC). CDC with minimum external components required includes excitation and signal processing circuit in one chip. CDC offers up to 24 bits of capacitance resolution (4 aF) with 4 fF accuracy, 0.01 % linearity and very low power consumption of 5mW in active and 2 mW in idle state [19]. There are both available options of CDC´s for fixed (grounded) or floating (one or two channel) capacitive sensors. When very precision measurement is needed, additional hardware and software filtering is required. Block diagram of AD7745 CDC is shown in Fig. 9.

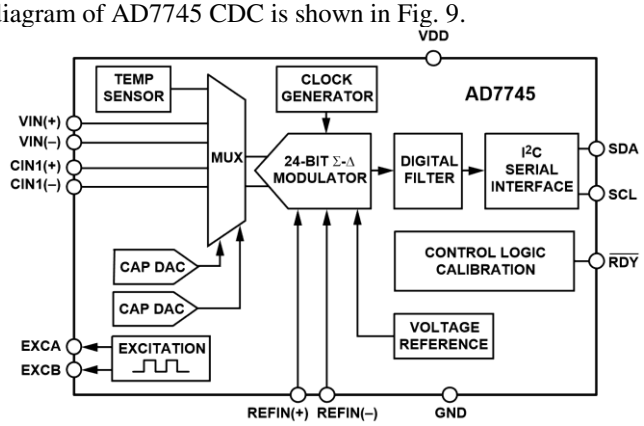

Figure 9. Block diagram of AD7745 Capacitance-to-Digital converter [19]

V. Conclusion

This paper deals with problematics of inductive and capacitive sensors. Design considerations of both types of sensors were described and possible applications for using these sensors were presented. Advantages of using LTCC as a basic substrate for sensors were described. Possible solutions for driving and signal processing of inductive and capacitive sensors and advantages and disadvantages of every of this solution were described and discussed. The aim of thesis is to consider possibilities of realization and to develop and inductive and capacitive sensor using LTCC.

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Influence of Nonlinear Degradation Mechanisms in All Optical Fiber Communication Systems

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***Abstract*—This article deals with phenomena affecting the signal transmission in optical fibers. The core of the work is focused on nonlinear phenomena such as stimulated Raman scattering and stimulated Brillouin scattering, these are one of the dominant nonlinear effects in optical communication systems. Next pages describe an overview of nonlinear effects and work on postgraduate studies. Research in this scope is still actual. Problems with increase losses are partially solved combinations many variables in transmission path. For decrease unwanted effects are created structures with properly type optical fibers, right transmission power, appropriate wavelength, etc. Nonlinear effects are significant in dense wavelength division multiplex (DWDM) and speeds higher than 10 Gbit/s. All experiments performed during postgraduate studies are focused on standard using of coarse wavelength division multiplex (CWDM) and DWDM. The main goal is created the purest silica waveguide and devices on path with the lowest possible losses.**

***Keywords*—Nonlinear effects, Optical fibers, Stimulated scattering, xWDM.**

I. Introduction

Progress in scope transmission systems brings us every year new opportunities to spread not only over short distances of tens meters, but also between continents. Current is the best, the fastest and the most reliable choice for transmission are optical fibers. We live in an imperfect world, it is needed to take into account the imperfection of things around us. Optical transmission paths are influenced by two basic factors: linear and nonlinear effects. Linear effects are out of scope this article. Nonlinear effects are key aspects that affect the signal transmitted in an optical fiber. Nonlinear effects in optical fibers are based on using of materials to manufacture the waveguide, transmission speed, modulation techniques and other important and less significant impact. The area of interest include study of nonlinear phenomena mainly stimulated scattering, specifically stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS). Their common feature as well as all nonlinear phenomena are appearance especially in high speed networks [1], [2], [3], [4], [5], [6].

At present, for the transmission is used a number of techniques. Recently they were used channels with time division but it was under pressure from increasing demands unsustainable. Current solutions are coarse wavelength division multiplexing (CWDM) and dense wavelength division multiplexing (DWDM). Depending on the requirements on the transmission system is selected either CWDM or DWDM. Each option contains advantages and disadvantages [7].

Combating of undesirable influence has a number of solutions. Among others is very important the proper selection of encryption of source data. The following studies will be given to experiments with combining different modulation and coding techniques.

II. Knowledge and Results Obtained During a Previous Year

A. Dense Wavelength Division Multiplexing and Coarse Wavelength Division Multiplexing

Technology that brought a breakthrough in the transmission of more information is wavelength division multiplex (WDM) and its associated various modifications. Currently the focus is on DWDM. This standard ITU has wide application and it will be suffice for the long time because currently used optical lasers, modulators, demodulators and other parts of the transmission system do not reach their maximal capacity. DWDM systems offer in comparison to CWDM number of advantages that allow transfer more information with the same bandwidth. The rapid increase of transmission capacity is the main demand for multiterabit/s transmission. DWDM is becoming the next generation in large-capacity systems in field 40 Gbps transmissions. Transmission systems are using a 1310 nm laser, a second laser at 1550 nm is usually added. The reason for choosing these wavelengths is that they lie in the "windows" or ranges of least attenuation [7], [8].

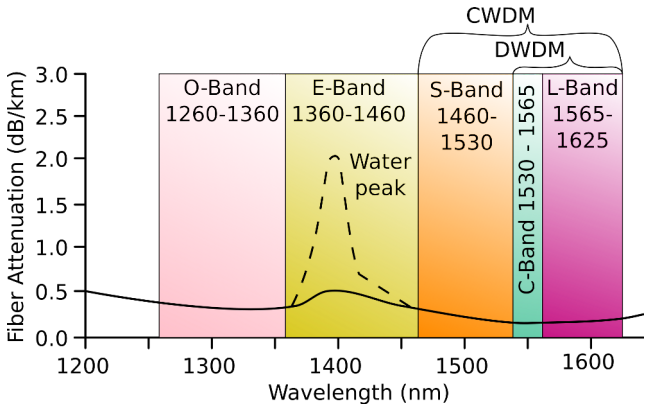

Fig. 1. Graph of dependencies between fiber attenuation and wavelength for individuals bands.

B. Data eye diagram fundamentals

The eye diagram (Fig. 2.) is an oscilloscope display of a digital signal, repetitively sampled to get a good representation of its behavior. It could be used for examining the signal integrity in a pure digital system, e.g optical systems, network cables or also on a circuit board [9].

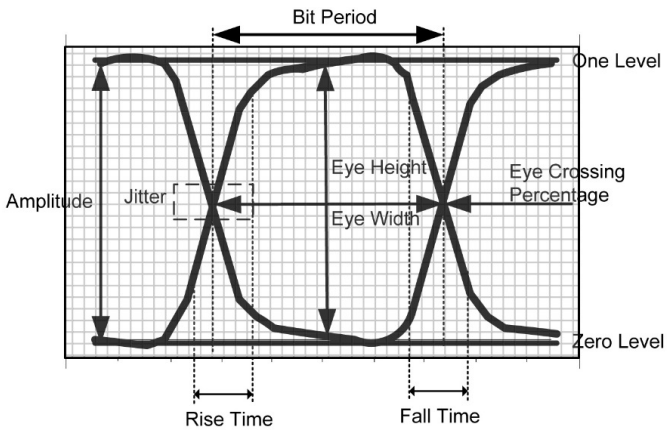

Fig. 2. Typical eye diagram measurements.

C. Behavior of optical signal in different conditions

1) Change of distance optical fiber: Very important feature is length of optical fiber. Eye diagrams of optical fibers with different length are showed in Fig. 3.

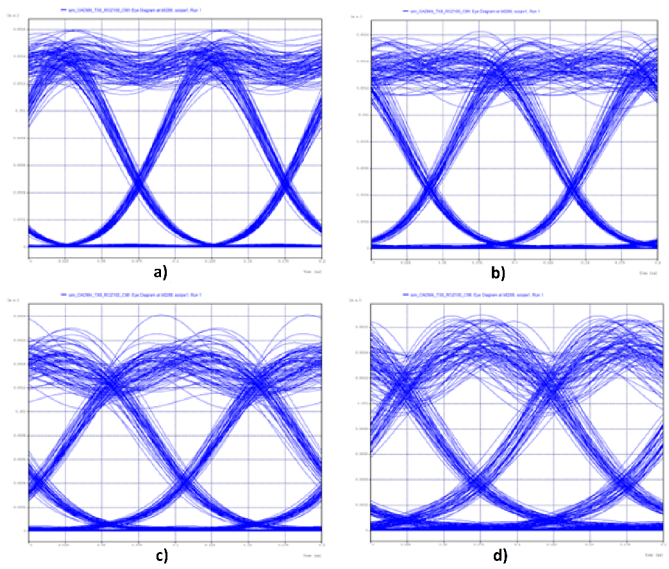

Fig. 3. Eye diagrams for length of fiber: a) 50 km, b) 100 km, c) 150 km and d) 200 km.

2) Comparison of spectrum with different SBS gain: In Fig. 4. are spectra at the ends of the transmission system. Amplification on the transmission path is involved in increase sideband noise about 10 dB. In the fiber happens dispersion of the useful signal, it results in decrease its value on output of the fiber. After amplification is gain approximately on the same value again, but also the side noise.

III. Conclusion

In the field of nonlinear phenomena, there is still a wide variety of approaches as partially suppress an unwanted phenomena. During the study, stimulated Raman scattering and

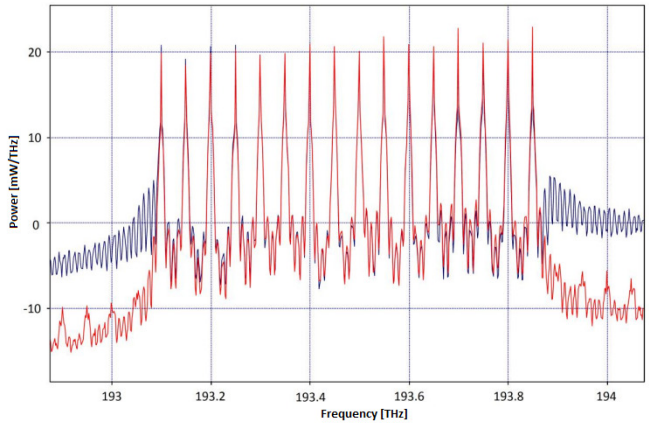

Fig. 4. Comparison of spectrum at the end of communication system for SBS gain $3 * 10^{-11}$ (red curve) and SBS gain $3 * 10^{-9}$ (blue curve).

stimulated Brillouin scattering have so far investigated the impact on the quality of the useful signal a change length of the optical fiber, change of the width of the transmission channel spacing and change the baud rate. Choice of optical fiber plays an important role. It is needed to know the environment in which will be located and for which transitions will be used. Another way to reduce the unwanted effects is the correct selection of signal encoding and modulation technique. These options could increase the resistance of signal against degradation due to nonlinear mechanisms. It will be investigated in the near future.

Acknowledgment

This work was supported by Cultural and Educational Grant Agency (KEGA) of the Ministry of Education, Science, Research and Sport of the Slovak Republic under the project no. "006TUKE-4/2014 - The Use of TUKE PON Experimental Model in Teaching". This work is also the result of the contract no. "APVV-0025-12 - Mitigation of Stochastic Effects in High-Bitrate All Optical Networks" supported by the Slovak Research and Development Agency.

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Laboratory model for lower limb rehabilitation

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***Abstract*— The article describes design and realization process of a laboratory model for lower limb rehabilitation. Designed laboratory model allows therapist to set up the optimal rehabilitation training for each patient individually. In conclusion are determined next steps for future work.**

***Keywords*—rehabilitation device, lower limb rehabilitation, CPM therapy.**

I. Introduction

Spinal cord and spine injuries are one of the most serious injuries. Functional disabilities are generally the extent that affected invalidating. Some are dependent on the use of the wheelchair, some need another person to help and some are confined to bed permanently. Statistics indicate that spinal cord and spine injuries occurs in 20 to 40 person per million. It is a typical accident healthy young men, and most of the victims are in working age from 15 to 40 years [1]. The result of spine and spinal cord injuries is paralysis the limbs and trunk of varying size - the emergence of paraplegia (complete paralysis of both lower limbs) or tetraplegia (complete paralysis of all four limbs).

The overall aim of rehabilitation is full or at least partial return of the lost function. Timely and comprehensive rehabilitation of paraplegic patients with the correct application of physical motion therapy and assistive devices may shorten the time spent in the hospital. Medical rehabilitation with the individual levels of motion therapy elements, psychological interventions and excellent nursing care greatly influences the final effect of the treatment. The motion element in the medical rehabilitation includes the implementation of passive movements with limbs and a process of allocating active movements to the rehabilitation program. The required motions are carried out by rehabilitation devices.

II. Present state of rehabilitation devices

The trend of the current design and development in rehabilitation robotics is a device that can restore lost motor functions of the patient. These devices should have the same effect as a qualified therapist. In the field of rehabilitation robotics are exists two elementary techniques of rehabilitation. The first uses controlled movements with the limbs of the patient and other functional electrical stimulation limb muscles.

For rehabilitation the musculoskeletal system are most commonly used motor splints. Motor splint provides continuous passive motion therapy - therapy CPM.

Motor splint gradually moves with patient´s affected limb according to the prescribed angle and speed over a long period of time.

Ultimately CPM therapy improves joint mobility and range of motion, while help to reduce the inconvenience caused due to immobilization, such as muscle stiffness and joint pain. CPM therapy providing systems are Prima Advance and Motomed [2].

A. Rehabilitation device Prima Advance

Motor splint Prima Advance is intended for the treatment of knee and hip joint.

Medical rehabilitation by Prima Advance is used primarily to prevent injuries caused by immobilization. It is important for the early resumption of painless movement with lower limbs and accelerates the therapy process with a good functional outcome [2].

Fig. 1. Rehabilitation device Prima Advance

B. Rehabilitation device MOTOmed

MOTOmed is a rehabilitation device also designed for wheelchair users, for people with limited walking ability and for paraplegic patients.

In the case of immobile patients rehabilitation consists of passive practicing musculoskeletal system, while lower respectively upper limbs must be fixed with orthoses. The movement is generated by an electromotor. In the case of patients with a certain level of residual strength, rehabilitation is carried out by active exercising of functional muscle groups. It is possible to regulate the individual load resistance [3].

III. Design and realization of laboratory model

For simulation purposes was created a laboratory model for lower limb rehabilitation. Laboratory model provides various setting options for the optimal rehabilitation for each patient individually. Laboratory model allows rehabilitation in both

the horizontal and the vertical plane. The main device settings are the maximum angles of flexion/extension and speed of the actuators individual for hip and knee joint. The primary objective in the design of laboratory model was to eliminate the shortcomings of commercially available systems. The disadvantages of motor splints such as Prima Advance are the inadequate extension of the hip joint and connected movement of the hip and knee joints. Inadequate extension was solved by allowing the rehabilitation in vertical plane. The connected movement of hip and knee joints was solved by two actuators, which allows individual movement for each joint.

A. *Design of electro-mechanical part*

The device structure made of aluminum and steel. From steel are produced attaching items for actuators and the fixing plate which allows fixation to the table in case of vertical or to the bed in case of horizontal rehabilitation. The thigh and lower leg parts are made from aluminum due to the light weight and these parts can be adjusted according to patient's leg length. Finally they also serve as a link between the joints. In Fig. 2 we can see the structure of the laboratory model.

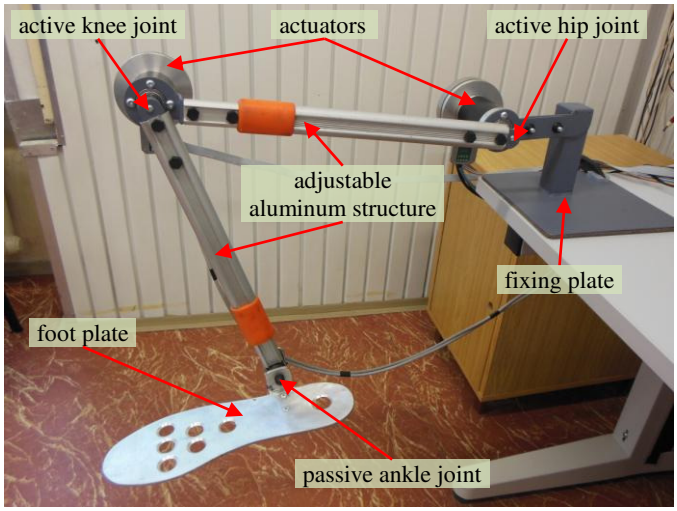

Fig. 2. Structure of the laboratory model

The proposed model provides three degrees of freedom (each joint has one degree of freedom) in the direction of the sagittal plane. Ankle joint connection is passive, while the hip and knee joint connections are actively actuated. As Actuators are used BLDC motors equipped with two-channel encoder, which provides 1024 count per turn. Maxon flat motors have 90W power and are equipped with planetary gearbox. Each gearbox has a gear ratio 150:1 and together with motors provides sufficient power and torque to perform the required movements. In Fig. 3 we can see Maxon EC90 flat motor with integrated encoder and Maxon GP52 planetary gearhead.

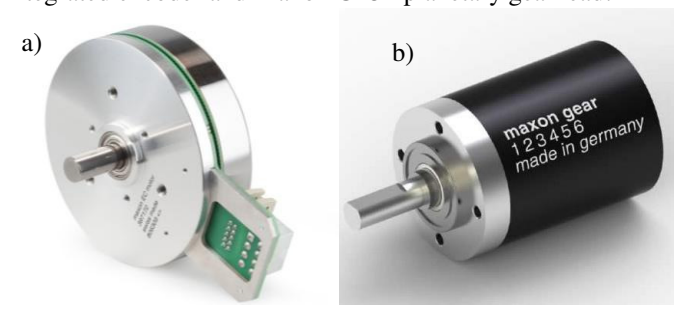

Fig. 3. a) Maxon EC90 flat BLDC motor with integrated encoder, b) Maxon GP52 planetary gearhead

B. *Design of software application*

Using programming environment LabWindows/CVI intended for development laboratory applications was created graphical user interface (GUI). GUI allows settings like speed and maximum flexion/extension angles of the hip and knee joints. It also allows the therapist to immediately stop the movement if it is necessary. Laboratory model is also equipped with secondary motion setup like acceleration and deceleration. In Fig. 3 we can see the proposed graphical user interface.

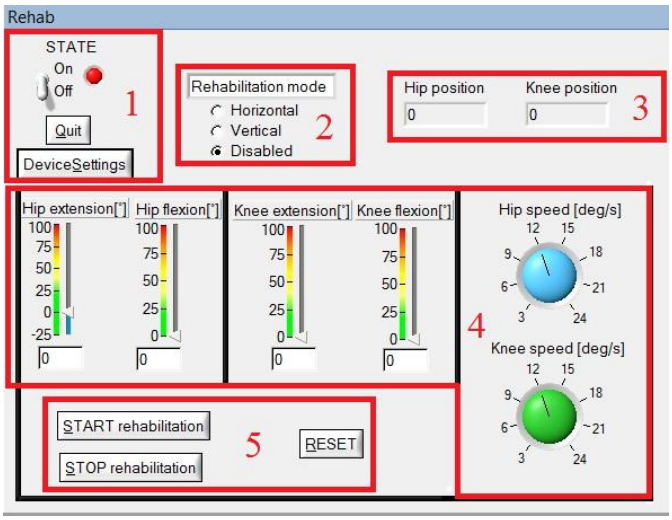

Fig. 3. Graphical user interface of laboratory model

Figure description: 1- basic communication settings, 2- rehabilitation mode selection, 3- actual hip and knee position, 4- motion settings, 5- motion control buttons.

IV. Conclusion

The proposed laboratory model in the future will serve as the base model of vertical rehabilitation device, which allows the transfer of the patient. The next step will be the design and implementation of the 6-channel pressure sensor. The pressure sensor will located at the bottom of the foot plate with evaluation electronics. The overall aim is to create an automated system that can manage lower limb movements, based on the information from the sensor. Finally, it is necessary to create a feedback to the patient about the feet position.

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Making Software Development a Little Less Cumbersome by Preserving a Programmer's Intent

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***Abstract*—One of the major problems apparent in software development is a lack of expression of *intent* in software artifacts which is an obstacle for program comprehension. This paper presents approaches regarding program comprehension, intent capturing and intent extraction. Finally, a possible direction of future research involving language oriented programming and information retrieval techniques is considered.**

***Keywords*—program comprehension, preserving intent, intent extraction, reverse engineering**

I. Introduction

According to Greenfield et al. [1] the two main problems of software development are *complexity* and *change*. Complexity is "a measure of the difficulty of solving a given problem" [1] and may be essential, i.e. inherent, and accidental which is artificial and occurs when fine-grained abstractions are used where coarse-grained ones would suffice [1], [2]. Change, on the other hand, refers to a need to adapt software with regard to changes in requirements but also in a platform the given software runs on [1]. Ward [3] mentions another two properties of large systems that cause problems: *conformity* (to currently valid regulations, laws, etc.) and *invisibility* (of software system structure, there is no "blueprint" – even if a documentation exists it tends not to reflect a current state).

Based on my observations made mainly during my work on a real-world software system (a web-based information system), I believe that frequent problems are:

- "plumbing work" [4], i.e. "wiring" all components, e.g. user interface to its model, controllers to services, services among themselves, etc. – a programmer has to discover and understand interfaces of components he or she wants to connect and many times also has to overcome discrepancies between them,
- data mapping – this is tightly related to the previous problem and is about proper transforming, formatting, and conversion of data, e.g. object-relational mapping or JSON marshalling of server replies in REST communication,
- a discrepancy between UI shown to a user and a data model a programmer works with,
- code maintaining and understanding the *intent* of a code written by someone else.

One of the mentioned reasons why software development is cumbersome is a lack of expression of a programmer's original *intent* in a source code of a program [5]. *The intent* and its *preserving* in order to improve *program code comprehension* is a key topic of this paper.

The *intent*, according to Greenfield et al. [1], consists of mental images of requirements and design decisions made during implementation phase. One intent may of course lead to different implementations. There are also situations when one implementation may be a consequence of different intents. It is obvious that a mapping between these two is not clear, definite, but rather ambiguous.

To put it in other words, the *intent* is an idea, a concept, a reasoning that is behind some code that a programmer writes. The lower level programming language, the more likely the intent is blurred or even lost completely. It is obvious: for instance, the intent being a predicate "student's name is John", this intent is still apparent in an expression `student.name == "John"` but certainly not that apparent when written in the assembly language as a list of processor instructions.

Preserving the intent may be seen from two perspectives [1]:

1) proactive preserving in a sense that programmers try to *capture* their thoughts in a way that they can be later easily understood,
2) preserving by additional (later) analyzing, reverse-engineering and *extracting* the original information from existing code.

II. Program comprehension

Maalej et al. [6] reported about approaches used by programmers to comprehend programs. The most interesting fact Maalej et al. implies is that software engineers are really not keen to use *dedicated tools*, addressing some specific problem, made *by the researchers*; furthermore many of developers do not even know some standard features of IDEs (e.g. they would use "search & replace" instead of "rename" dialog for refactoring).

Damevski et al. [7] conducted a study about finding features in source code. Again, the study confirms that developers do not want to use search tools that have *limited applicability* (e.g. "Open Type" dialog in Eclipse IDE designed for searching for a class) but rather more general tools.

III. Capturing the intent

Preserving intent in advance requires some effort, additional work on developer's side. It may be captured in many ways [1]: in a documentation, obviously – but it tends to get unsynchronized with an actual state; in minds of developers – but developers forget and fluctuate; formally; etc.

A. Long-term endeavor

The idea of conscious, explicit expressing of programmer's intent is definitely not new – in early 80's Knuth [8] designed a programming language named *Web* that encouraged programmers to tangle a documentation with a corresponding code. He claimed that this approach will make software more comprehensible but also more correct. I think Knuth's idea of better documented code is of course good but the realization requiring such an exhaustive documenting might be considered extreme, it would be a big burden for a programmer.

B. The language

Reasoning about capturing the intent and ideas leads to a debate about basic medium for expressing of ideas – *language*. A programming approach where the language, simply put, is given priority and is the starting point is *language oriented programming* (LOP). This approach will be considered from two perspectives.

First, Dmitriev [9] compares:

- a classical view on programming which consists of (1) thinking of a mental model of a solution; (2) implementing that solution in a general purpose language; and finally (3) compiling sources to an executable form (this is automated task);
- a language oriented approach: step (1) remains the same; step (2) is different because a programmer implements his solution in *appropriate* domain-specific language (DSL) – the key is that mapping from the mental model to this DSL is more straight-forward; (3) transforming the solution expressed in DSL into an executable form may be either fully automated (when using existing DSL) or "semi-automated" when a programmer needs to define a mapping from his/her DSL to a general purpose language.

Defining an own DSL is the topic which Dmitriev is concerned with the most in his paper [9]. He describes the specific platform for language oriented programming – *Meta Programming System* (MPS). After experimenting with this platform I think the platform as a whole is an interesting idea but the innovative approach used for representation of models (programs) – graphs instead of standard text – is problematic. It is hard to say, though, if the idea itself is flawed or just its current implementation. On the other hand, the MPS system has certainly a real-world application – the paper [10] describes its use in area of data analysis in biology.

From the second perspective on LOP, Ward [3] states that the first stage in LOP method is "the design of a formally specified, domain-oriented, very high level programming language". He identifies this method with *middle out development* (as opposed to more common top-down or bottom-up methods) because that high-level language we start with is the "middle layer" – between high-level requirements and low-level implementation. In my opinion the great advantage of this method, not emphasized enough in the paper [3], is that after initial DSL design the development may split into two branches – implementing of the required system in the new DSL and implementing of this DSL itself – which can be carried out in a parallel, saving the time.

Model-driven development (MDD) [11], [1] changes the view on models in software development – they are no longer just documentation artifacts but become a significant part of a system. To accomplish this, use of abstract but precise, unambiguous, *formal* models – expressed in some domain-specific *language* – is required. The components which would otherwise have schematic repetitive code are generated from these models. Martínez et al. [12] advocates use of MDD approach based on their comparison of traditional, model-based and model-driven development. This paper concludes that even though MDD is difficult it seems to be very useful. The paper [13] also advocates MDD and additionally suggests use of DSL instead of UML.

To conclude this topic, the common denominator of the mentioned approaches is the use of some kind of a very high level domain specific *language*. Using higher level languages raises the level of abstraction which leads to more straight-forward and comprehendable expression of the *intent*. One could argue that UML modeling, for example, also raises the abstraction level, which is true, but UML is only *semi*-formal technique [1] (as opposed to mentioned approaches), so the lower level of automation is achieved.

C. Comments

Much domain knowledge is preserved in *identifiers* (i.e. names of classes, functions, variables, etc.) [14] and *comments*. It is no surprise. These comments serve to other *programmers* trying to comprehend the code, but also may be automatically or semi-automatically processed by *tools*.

Kaelbling [15] presented very interesting opinion regarding comments in source code – even though the idea is almost thirty years old, it's still applicable. Ordinary commnents have no explicit connection to surrounding code. In some situations it might be helpful to know *exactly* the part of the code the comment is related to. This connection according to the paper of Kaelbling [15] may be enforced by a grammar of a programming language or just by using a convention – special characters inside a comment.

The paper of Fluri et al. [16] suggests that code and appropriate comments unfortunately do not evolve together. However, it is questionable if three examined projects are enough to base the experiment on because commenting practice is very different and human-biased among programmers. Anyway, in my opinion, it would be interesting to provide a manner to enforce correspondence between code and its comment.

Finally, the paper [17] analyzes possible applications and types of comments. Usually, comments are stripped as early as a lexical analysis is in progress. An interesting fact is that there are also *stored* comments which retain and can be retrieved in run-time, e.g. Python documentation comments. Regarding the comment usage, the authors mention *documentation* and *maintenance* purposes.

To summarize the meaning and usage of comments, we can say that when one programmer uses another programmer's functions, he or she has to comply to a specific interface (contract). Some aspects of the interface are enforced by a language (parameters, return value) but some aspects like pre-/post-conditions or the order in which methods may (not) be invoked are just silently assumed or written in comments/documentation in a non-formal way. It seems there is a pursuit for a better, more formal declaration of these assumptions (*intents*), for instance: non-null/nullable annotations in Java [18] mitigating a common problem with unexpected and unhandled null references, or language support for method pre-/post-conditions in the new Vala programming language[1] by using the `requires/ensures` keywords which is a revival

[1] http://www.vala-project.org/doc/vala-draft/methods.html, Contract programming

of Meyers's idea of a "design by contract" implemented in Eiffel language [19]. So it seems that for specific purposes it is better to have an appropriate language construct instead of a comment with a vague form.

D. Other approaches

There are of course other approaches not discussed here because the topic is very broad. Briefly: for "cross-cutting" concerns, i.e. concerns (intents) that would be spread among many places in a source code, it is advantageous to use *aspect oriented programming*; for recording of the intent, *annotations* (also called attributes) may be used [20].

When adhering to *behavior driven development* (BDD, "improved" version of test driven development), the intent may be captured in the initial phase of development in a form of "scenarios" written in a natural language with only a few keywords (`given-when-then` sentences). The paper [21] describes this and goes further – tries to extract information from that natural language to build a skeleton of test cases.

IV. Extracting the intent

The advantage of this approach is that no additional effort on a programmer's side is needed. All work is up to some tool which tries to regenerate the original information from available artifacts (which is not a straightforward process).

A. Formal Concept Analysis

Extracting and later processing and "understanding" of the information is not an easy task. A formal mechanism might be helpful in this situation.

Formal Concept Analysis (FCA) is "a method for data analysis, knowledge representation and information management" [22]. It is described in the book of Ganter and Wille [23]. According to the paper of Priss [22], it is a method applicable not only in IT but also in psychology, linguistics, etc. The paper also suggests that this method (or more precisely its parts) is very intuitive because it has been discovered many times independently.

Basic concepts of FCA will be explained following the paper of Arévalo et al. [24]. Concept analysis manipulates with groups of *"elements"* and *"properties"* (or *(formal) objects* and *(formal) attributes* respectively, or finite sets E and P respectively). Of course, these are abstract terms and their meaning depends on a concrete situation and application. Let the relation meaning that an element from set E has a property from P be a binary relation R, hence $R \subseteq E \times P$. These three sets form a triple called a *"context"* C, so $C = (E, P, R)$.

Still following [24], there are operations:

- for selected elements X: their *common properties* $\sigma(X)$,
- for selected properties Y: their *common elements* $\tau(Y)$.

Or concisely mathematically said:

$$\sigma(X) = \{p \in P \mid \forall e \in X : (e, p) \in R\} \text{ where } X \subseteq E$$
$$\tau(Y) = \{e \in E \mid \forall p \in Y : (e, p) \in R\} \text{ where } Y \subseteq P$$

And finally, a *"concept"* is a maximal set of elements that have common properties, i.e. it is a pair (X, Y) such that $Y = \sigma(X)$ and $X = \tau(Y)$ must hold.

Regarding the application of this method in the software engineering, the trick is that there are various ways in which software artifacts (e.g. modules, classes, methods, variables, ...) can be mapped to above-mentioned *elements* (objects) and *properties* (attributes) and using FCA should simplify operations regarding the analysis of chosen concepts and connections [24].

For example, the paper of Arévalo et al. [24] describes their *XRay* tool, which tries to improve a single class (in object-oriented sense) *understanding*. In their work, methods and attributes (fields) of a class are represented as formal elements and access and invocation relationships among them as formal properties.

The survey of Tilley et al. [25] describes a multitude of applications of FCA, examples being the refactoring of existing code, requirement analysis, re-engineering class hierarchies, recovering design patterns and more.

B. Comments

Comments are mentioned again, but now they are seen from a different perspective – examining already existing comments.

For example, Tan et al. [26] analyzed comments in Linux source code in order to find potential bugs and detect bad (misleading, invalid) comments. Since they analyzed C sources, which is considered a low-level language, comments dealt with things like locks, memory management, threads, etc. They wanted to "understand" information expressed in comments documenting functions and check if usage of these functions is consistent with this information. The "understanding" part is difficult, so the key idea of their approach was to focus only on "hot topics" (as Tan et al. call them). To prove their concept, they created a heuristic tool dedicated specifically to find locks-related information in comments and then checked the code for potential inconsistencies.

There are tools like *Javadoc* that extract documentation from specially formatted comments. Adhering to some rules is required in order to achieve a desired quality of a resulting documentation. Gamalielsson et al. [27] conducted an experiment in this area – they analyzed three open source projects and checked the structure of documentation comments. They reported that most frequent errors involve a function being not documented at all, missing tags (e.g. `@return`) in a comment and a wrong format (`//` instead of `/**`).

C. Information Retrieval Techniques

Another problem worth consideration while discussing preserving of the *intent* is so called *information retrieval* (IR) based on some query (the query might be an "intent" a programmer wants to find a related code for).

A documentation and a source code "live their own life" – they are written at different levels of abstraction and many times by different people, so it is hard to keep them synchronized. The paper of Marcus et al. [28] deals with a problem of traceability between documentation and source code. The goal was to extract the meaning of parts of a source code, extract the meaning of parts of a documentation and establish links based on similarity of particular parts. The question is how to calculate this *similarity*. There are mathematical models – heuristic information retrieval techniques. *Latent semantic indexing* (LSI) was chosen in [28]. It is based on *vector space model* (VSM) but overcomes some of its problems.

Antoniol et al. [14] conducted a similar research – regarding recovering traceability links between source code (classes) and documentation (manual pages and functional requirements in particular). However, they used *vector space model* and compared it to the use of *probabilistic models*.

Vector space model [14] is based on an interesting representation of a document and a query – two elements which we want to determine similarity between – and that is two *vectors* in n-dimensional space where n is the number of words of a vocabulary built from documents. For a *particular* document its vector $[w_1, w_2, \ldots, w_n]$ consists of weights of each word of the vocabulary. Determining the weight of a word is a problem itself – a frequency of a given word in a given document may be used for example. In the specific case of Antoniol et al. [14], a "query" is built from identifiers extracted from a class they wanted to find a matching document for. Having two vectors (for a query and a document) it seems logical to compute the similarity as the cosine of the angle between these vectors.

Regarding a comparison of the three above-mentioned information retrieval techniques, according to [28] better results can be achieved using *latent semantic indexing* than with *vector space model* (LSI is more respectful to natural language, more flexible and better for automation) but its underlying theory is more complicated. The paper of Antoniol et al. [14] compared *vector space model* with *probabilistic model* and concluded that they performance is similar and both have advantages in specific situations.

To conclude, *information retrieval* is a broad topic. According to [29] there are many other retrieval strategies, namely: inference networks, extended boolean retrieval, neural networks, genetic algorithms, fuzzy set retrieval and other.

V. Future work

The problem of preserving intent in software artifacts is very broad and acute. The way the majority of software is developed nowadays is an evidence that this problem is definitely not solved.

Regarding intent capturing, the future might be in *language oriented programming* [3], [9] and in use of domain specific languages. DSLs are of course frequently used already but they are still only some kind of addition, bonus to the "main part" of an application written in some general purpose language. The reason is that developers use mainly existing DSLs. However, we need custom-made DSLs appropriate for the given system and for this we need a tool that allows us to quickly develop such DSLs. MPS [9] is in my opinion worth considering but future work might involve altering its approach for model storing and manipulating.

It seems that extracting intent in form of some reverse-engineering of code and information retrieval from comments and/or documentation is a problem that we will not have a satisfying solution for in a foreseeable future. The reason is a complicated nature of human language. The future work might therefore consist of building upon techniques mentioned above (LSI, VMS). One of the questions is which of the methods of IR should be utilized.

VI. Conclusion

The goal of this paper was not to deliver a complete enumeration of all possible intent-preserving approaches because there certainly are papers on this topic already. There are rather techniques and approaches described here which I managed to try or study or considered interesting. At the end there are problems, solving of which is currently being considered.

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Material tracking with Dynamic Torque Adaptation in Wire Rod Mill

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***Abstract*—The paper presents and analyses methods of material tracking and load identification in wire rod rolling mill. New approach of material tracking system with advanced load identification is proposed and introduced to existing control system in wire rod mill Slovakia Steel Mills, a.s., Strážske.**

***Keywords*—wire rod rolling, tension control, rolling torque**

I. Introduction

Wire rod mill usually consists of roughing, intermediate and finishing mill. Each group includes several stands (*STD*), individually driven by motors [1]. Roughing mill and intermediate mill consist of 6 and 8 stands in horizontal-vertical rolling sequence, respectively. Finishing stand consists of finishing block of ten stands, all driven by one motor [2]. To maintain a stable and high quality process operation, it is required to control speeds according to tension conditions between the stands [3]. During the stable rolling conditions, speed ratios between these stands must be constant to maintain stable mass flow. If mill speed varies (due to the action of tension controller in consequent stands, or due to the production speed change), cascade speed control is implemented to maintain stable speed ratios, i.e. stable tension conditions, for rest stands [3], [4].

Traditional tension control systems are based on the minimum tension control for roughing mill and the loop control for intermediate and finishing mill. Minimum tension control assumes that the billet dimension and material temperature profile remain constant along the billet. A motor torque feedback during the time interval with and without the connection with consequent stand is used as a tension indicator. To control the intervals, knowledge of actual front end position of billet in the mill is required [4], [5]. Since there is no sensor or other measurement in roughing mill, motor torque and speed are used for tracking system.

II. Tracking system

During rolling operation, billet by billet is rolled in the mill. Because of high production capacity demand, minimum interbillet time is required and two billets can be rolled in the same time. When tail end of the first billet leaves first stand, next billet is already prepared to enter it, according the optimal interbillet time calculation. Consequently, billet tail end and front end must be tracked to manage the speed control, cobble tracking and other service functions. For these purposes, motor load is only indicator of the billet position. Load level, i.e. motor torque level, can be determined by stand operation during free running or rolling and an optimal value can be selected for each stand of mill. However, due to the rapid speed changes by loop control operation, motor torque can be affected by load coming from acceleration/deceleration torque. Since the rolling mill is highly coupled system and speed of each stand is connected to all upstream stands by cascade control, dynamic effect of a downstream stand causes the proportional effect to all upstream stands [3]. With high filtered motor torque feedback, effect of dynamic torque can be suppressed, but it has influence on tracking precision and consequently on tension control quality.

III. Dynamic torque adaptation

To calculate dynamic part of the motor torque, which can be excluded from motor torque feedback, *Dynamic Torque Adaptation* algorithm was proposed.

During the rolling sequence, total motor torque is given by (1), where T_0 is friction torque, T_d is dynamic torque, T_r is rolling torque, T_{ft} is forward tension and T_{bt} is backward tension [4], [6]. During the free rolling, only T_0 and T_d act on

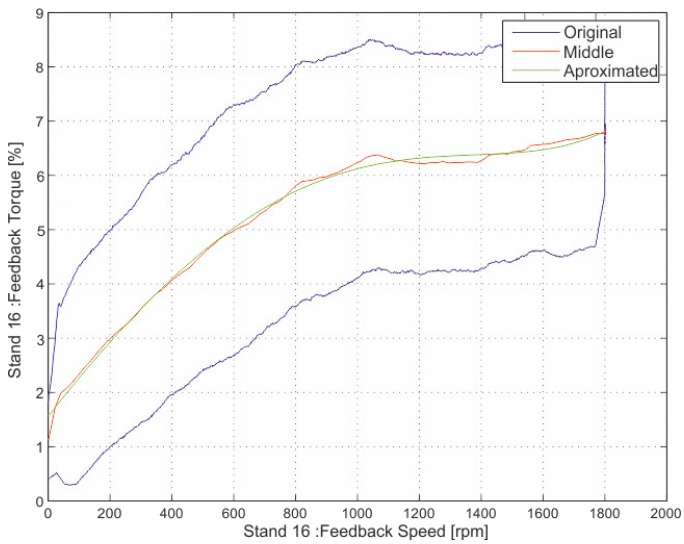

Fig. 1 Friction torque of *STD16* in relation to actual motor speed. *Original* - measured motor torque during acceleration, free running and deceleration. *Middle* - difference between motor torque during acceleration and deceleration. *Approximated* – polynomial function obtained from this measurement.

TABLE I

Stand	ST01	ST02	ST03	ST04	ST05
J [kgm^2]	8,97	21,87	10,41	22,67	18,49
Stand	ST06	ST09	ST10	ST11	ST12
J [kgm^2]	29,97	19,47	26,27	20,81	28,74
Stand	ST13	ST14	ST15	ST16	FBLK
J [kgm^2]	19,97	35,16	23,39	41,13	1960,66

Inertia of each stand of rolling mill calculated by speed change in defined time interval with determined motor torque.

motor shaft. T_0 depends on actual friction conditions, T_d is given by (2).

$$T = T_0 + T_r + T_{ft} + T_{bt} + T_d \tag{1}$$

$$T_d = J\frac{d\omega}{dt} \tag{2}$$

$$J = (T - T_0)\frac{\Delta t}{\Delta\omega} \tag{3}$$

$$T_{load} = T_{fbk} - J\frac{\Delta\omega}{\Delta t} \tag{4}$$

Inertia of each stand depends on invariable factors, i.e. mechanical parts such as gearboxes, shafts, motor and variable factor, the working rolls. Mass and size of the rolls varies according the pass schedule and roll wear. If these changes are compared to total mass inertia of the whole stand, they can be neglected.

To determine the mass inertia of all stands, measurements of motor acceleration with limited torque were performed. If the motor torque is maintained on stable level, T_0 is known, and motor speed feedback is recorded for a defined time interval, T_d can be determined and total inertia J is given by (3) [7]. Friction component of load torque T_0 was determined as a speed depended polynomial function which was obtained by measurements of motor acceleration with slow speed reference ramp. Fig. 1 shows the relation between speed and torque of *STD16* and its approximation by 4 degree polynomial equation. Calculated inertia of each stand is shown in Table 1 and they are implemented to calculate total load

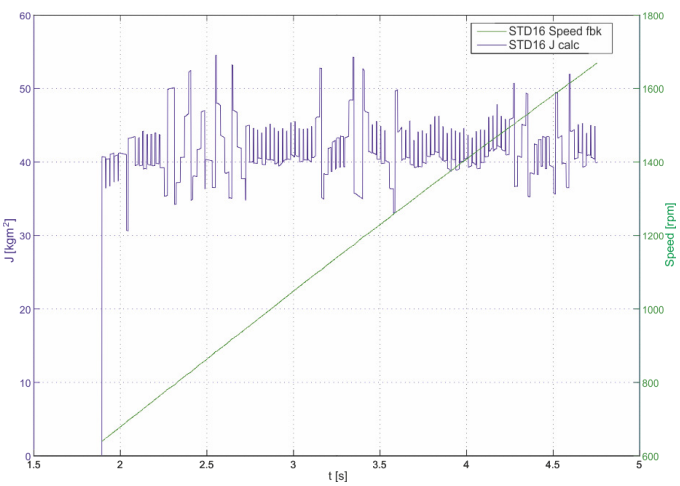

Fig. 2 Partial calculations of J related to motor speed for *STD16*. Motor is accelerated with defined torque limit and inertia J is calculated according the equation (4). T_0 is represented by 4th degree polynomial function obtained from measurements. Since the speed feedback from the encoder is not smooth, partial calculations vary with the $\Delta\omega$ deviation. Total stand inertia is calculated as an average value of these partial calculations.

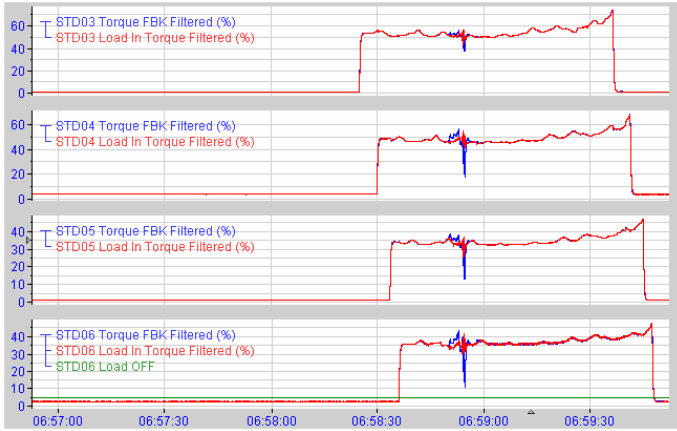

Fig. 3 *Load In Torque Filtered* - compensated value of motor torque Tl_{oad}, *Torque FBK Filtered* - filtered motor torque from drive T.

torque T_{load}. T_{load} is a torque without dynamic component T_d and it is given by (4), where T_{fbk} is a filtered value of actual motor torque feedback, J is stand inertia, $\Delta\omega$ is change of filtered value of angular velocity feedback in defined time interval Δt. *Dynamic torque adaptation* calculates T_{load} in *10*ms intervals and actual stand load is securely determined. In Fig. 3 can be seen the filtered motor torque feedback T_{fbk} and total load torque T_{load} during rolling operation with high dynamic speed changes. Rapid speed changes causes a torque droop, which can lead to failure in load identification and consequently to tracking fault.

Before the implementation of *Dynamic torque adaptation*, there were approximately 5 tracking faults per month, sometimes with consequent cobbles in the mill. Since the modification, rolling load is determined securely and there was no tracking fault due to the rapid speed changes any more.

IV. Conclusion

In this paper tracking system and stand rolling load identification in wire rod mill was analyzed. In addition, improvement in rolling load identification by *Dynamic torque adaptation* was proposed and implemented to existing control system. Method of implementation and result of practical test are also presented. Next step is to use T_{load} as a torque feedback for new tension control algorithm to increase tension control accuracy.

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Measurement of the Dielectric Properties of Materials

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***Abstract*—The understanding of dielectric properties of materials is very important for developers and engineers in a lot of subjects of a research. This paper focus on the methods of measurement of dielectric properties of materials. Especially the paper focus on on the measurement of the permittivity and the permeability. At the begin of the paper is a chapter about a dielectric theory. Then, the paper focus on a basics of the electromagnetic wave propagation as the main tool of the acquire data about materials. At last, the paper describes main methods of the acquiring the data by the impedance measure techniques.**

***Keywords*—Dielectric properties, Measurement, Permeability, Permittivity**

I. Introduction

A wide variety of industries need a better understanding of the materials they are working with to shorten design cycles, improve incoming inspection, process monitoring and quality assurance. Every material has a unique set of an electrical characteristics that are depends on its dielectric properties. Accurate measurements of these properties can provide a scientist and engineers with valuable information to property incorporate the material into its intended application for more solid designs or to monitor a manufacturing process for improved quality control.

A dielectric materials measurement can provide critical design parameter information for many electronics applications. For example:

- The lost of cable insulator [1]
- The impedance of substrate [2]
- The frequency of a dielectric resonator [3]
- The radars systems [4]
- The ferrite absorber [5]

More recent applications in the area of an aerospace, an automotive, a food, a medical industries and an architecture have also been found to benefit from knowledge of the dielectric properties.

A material evaluation measurement system is comprised of three main pieces. These elements include [6]:

- Precise measurement instruments
- Test fixtures that hold the material under test
- Software that can calculate and display basic material parameters

Various measurement methods for permittivity currently exist, however this paper's primary focus will be on method that employs impedance measurement technology, which has the following advantages [6]:

- Wide frequency range
- High measurement accuracy
- Simple preparations for measurement

These methods of acquiring dielectric properties of materials exist for impedance measurement technology:

- Coaxial probe [7] [8]
- Transmission line [9] [10]
- Resonant cavity [11] [12]
- Free space [13] [14]
- Parallel plate [15] [16]
- Inductance measurement method [17] [18]

Dielectric theory, electromagnetic wave propagation and measurement techniques are described in the following parts of this paper.

II. Dielectric theory

There exists two main properties which ones will be discussed here. They are permittivity and permeability. Resistivity and conductivity are another type of the properties which will not be discussed here. It is very important to note that, the permittivity and the permeability are not constant. They are complex numbers which can change the value with respect to frequency, temperature or molecular structure of the material [19].

A. Permittivity

Permittivity, also called dielectric constant, describes the interaction of a material with an electric field. A material is classified as dielectric if it has the ability to store an energy when an external electric field is applied [19].

From the point of view of electromagnetic theory, the definition of electric displacement (electric flux density) D_f is [19]:

$$D_f = \epsilon E, \tag{1}$$

where ϵ is permittivity and E is the electric field.

If a DC voltage source is placed across a parallel plate of a capacitor, then more charge is stored when a dielectric material is between the plates instead of that the no material (the vacuum) is between the plates. The dielectric material increases the storage capacity of the capacitor by neutralising charges at the electrodes, which ordinarily would contribute to the external field. On the base of this knowledge, we can consider [19]:

$$\epsilon = \epsilon_0 \epsilon_r, \tag{2}$$

where ϵ_r is the relative permittivity of the material and ϵ_0 represents free space permittivity,

$$\epsilon_0 \approx \frac{1}{36\pi} \times 10^{-9} F/m \tag{3}$$

If an AC sinusoidal voltage source is placed across the same capacitor, the resulting current will be made up of a charging current I_c and a loss current I_l that is related to the dielectric constant. The losses in the material can be represented as a conductance in parallel with a capacitor [19].

Fig. 1 shows easy principle of the capacitor.

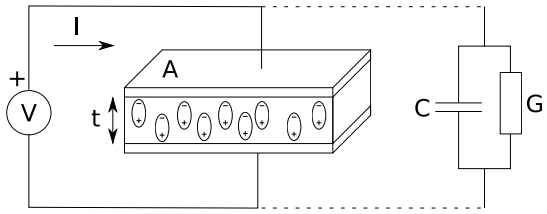

Fig. 1. Principle of the capacitor

A is the area of the capacitor's plates and t is the distance between them. For the DC voltage, we can consider that the principle digram of the capacitor in Fig. 1 consist only of the capacitance C without losses represented by G. Then [19]:

$$C_0 = \frac{A}{t}, \tag{4}$$

$$C = C_0 \epsilon_r^{'} => \epsilon_r^{'} = \frac{C}{C_0}, \tag{5}$$

where C represents capacitance of dielectricum and C_0 is capacitance of freee space.

However, Neglecting of the conductance G is not possible for the AC voltage,. Then we can notice that:

$$\begin{aligned} I = I_c + I_l = V(j\omega C_0 \epsilon_r^{'} + G) = \\ = V(j\omega C_0 \epsilon_r^{'} + \omega C_0 \epsilon_r^{''}) = \\ = V(j\omega C_0)(\epsilon_r^{'} - j\epsilon_r^{''}), \end{aligned} \tag{6}$$

where ω is the angular frequency of the source. On the base of this issue, we can consider that:

$$\epsilon = \epsilon_0 \epsilon_r = \epsilon_0(\epsilon_r^{'} - j\epsilon_r^{''}) \tag{7}$$

The real part of the permittivity $\epsilon_r^{'}$ represent how much energy from an external electric field is stored in the material. The imaginary part of the complex permittivity $\epsilon_r^{''}$ is called the loss factor and it is a measure of how much dissipative a material is to an external electric field. $\epsilon_r^{''}$ is always greater then zero and is usually much smaller then $\epsilon_r^{'}$. The loss tangent of the material is defined as [19]:

$$D = \tan\delta = \frac{\epsilon_r^{''}}{\epsilon_r^{'}} = \frac{1}{Q} \tag{8}$$

D denotes dissipation factor and Q is quality factor.

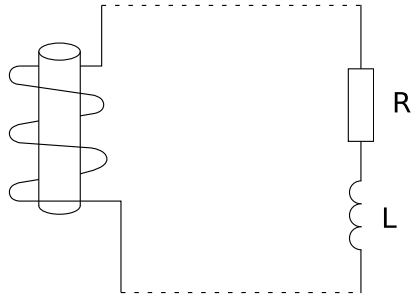

Fig. 2. Principle of the inductor

B. Permeability

Permeability μ describes the interaction of the material with a magnetic field. A similar analysis can be performed for permeability using an inductor with a resistance to represent core losses in magnetic material [19].

Fig. 2 shows principle of the inductor.

If the DC current source is placed across an inductor, the inductance with the core material can by related to the permeability by:

$$\mu_r^{'} = \frac{L}{L_0}. \tag{9}$$

In the equation (9), L is the inductance with the material and L_0 is inductance of the free space. $\mu_r^{'}$ is real relative permeability. If an AC sinusoidal current source is placed across the same inductor, the resulting voltage will be made up of an induced voltage and a loss voltage that is related to permeability. The core loss can be represented by a resistance in series with inductor. Then we can consider [19]:

$$\mu = \mu_0(\mu_r^{'} - j\mu_r^{''}), \tag{10}$$

where $\mu_r^{'}$ represents the energy storage term, $\mu_r^{''}$ represents energy loss term and μ_0 represents free space permeability, which [19]:

$$\mu_0 = 4\pi \times 10^{-7} H/m \tag{11}$$

III. Electromagnetic wave propagation

In the time-varying case (i.e. a sinusoidal), the electric field and the magnetic field appear together This electromagnetic wave can propagate through the free space at the speed of the light $c = 3 \times 10^8 m/s$ or through materials at slower speed. Electromagnetic waves of various wavelengths exist. The wavelength λ is inversely proportional to its frequency [20].

$$\lambda = \frac{c}{f} \tag{12}$$

Consider a material (MUT) in space, with a TEM wave incident on its surface. There will be incident wave, reflected and transmitted waves. Since, the impedance of the wave in the material Z is different from the free space impedance Z_0, then there will be a impedance mismatch and this will create the reflected wave. Part of the energy will penetrate the sample. Once in the material, the wave velocity v is slower then the speed of the light c. Since the material will always have some loss, there will be attenuation or insertion loss. Of course, the same principle is performed at the second border of the material [20].

IV. Measurement techniques

A. Coaxial probe

The coaxial probe is one of the basic measurement techniques. The features of this method are:

- Broadband
- Simple and convenient
- Limited $\epsilon_r^{'}$ accuracy and $\tan\delta$ low less resolution
- Best for liquids or semi-solid

The Material assumptions are:

- "Semi-infinite" thicknes
- Non-magnetic
- Isotropic and homogeneus
- Flat surface

The example of the coaxial probe are shown in Fig. 3.

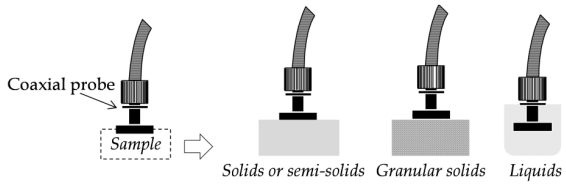

Fig. 3. The examples of the coaxial probes

The open-ended coaxial probe is a cut off section of a transmission line. The material is measured by immersing the probe into a liquid or touching it to the flat face of a solid material. The fields at the probe end "fringe" into the material and change as they come into contact with the MUT. S_{11} parameter of the signal can be measured and related to ϵ_r.

B. Transmission line

Transmission line method involve placing the material inside a portion of an enclosed transmission line. The line is usually a section of the rectangular waveguide or coaxial line. ϵ_r and μ_r are computed from the measurement of the reflected signal by S_{11} parameter and the transmitted signal by S_{21} parameter. Material assumptions for this mothod are:

- Sample fills fixture cross section
- No air gaps at fixture walls
- Smooth, flat faces, perpendicular to long axis
- Homogeneus

Method features for this method are:

- Broadband
- Limited low loss resolution
- Measures magnetic materials
- Anisotropic materials can be measured in waveguide

Coaxial transmission lines cover a broad frequency range, but a toroid shaped sample is more difficult to manufacture. Waveguide fixtures extend to the mm-wave frequencies and the samples are simpler to machine but their frequency coverage is banded.

The example of the coaxial transmission line is shown in Fig. 4.

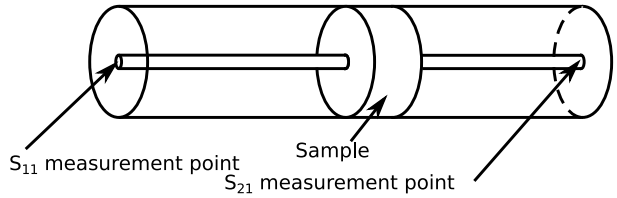

Fig. 4. The example of the coaxial transmission line

C. Free space

In the case of the free space method, the material assumptions are:

- Large, flat, parallel-faced samples
- Homogeneus

The method features are:

- Non-contacting, non-destructive
- High frequency
- Useful for high temperature
- Antenna polarization may be varied for anisotropic materials
- Measures magnetic materials

Free-space methods use antennas to focus energy at or through a the slab or the sheet of the material. This method is non-contacting and can be applied to materials to be tested under the high temperatures and hostile environments.

High temperature measurement are easy to perform in the free space because the sample is never touching or contacting with MUT. The calibration of a measured system is challenging for the free space method. The calibration can be as simple as a response calibration or as complex as a full two-port calibration depending ont the convenience and desired accuracy.

There exists two ways for the free space method to get permittivity of the material:

- Transmission method
- Reflection method

The permittivity and the permeability is possible to measure by the transmission method instead of the reflection method which can measure just the permittivity of the material. The main advantage of the reflection technique is that, the measure is made just form the single side of the material, what is a benefit in the measure of big objects as for example walls.

Fig. 5 shows the example of the free space technique

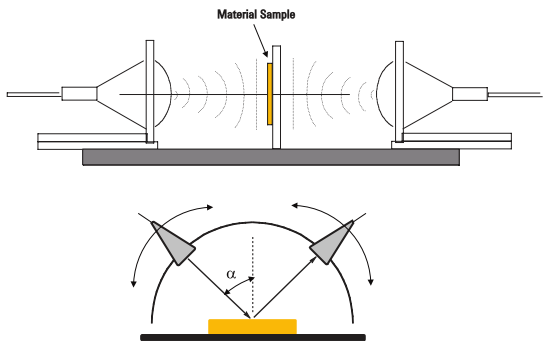

Fig. 5. The example of the free space method

D. Resonant cavity

The resonant cavity methods can be selected into two categories: Resonant techniques and broad band techniques. The features of both techniques are:

- Resonant techniques:
  - High impedance environment
  - Reasonable measurements are possible with small samples
  - Measurements at only one or few frequencies
  - Well suited for low loss materials
- Broadband techniques:
  - Low impedance environment
  - Requires larger samples to obtain reasonable measurements
  - Measurement at "any" frequency

Resonant cavities are high Q structures that resonate at specific frequencies. A piece of sample material inserted into the cavity affects the resonant frequency and quality factor of the cavity. From this parameters, the complex permittivity of the material can be calculated at a single frequency.

In depend on the manufacture of cavity, we know:

- Split cylinder resonator
- Split post dielectric resonator
- Cavity pertubation

The example of the split post type of the dielectric resonator is shown in Fig. 6

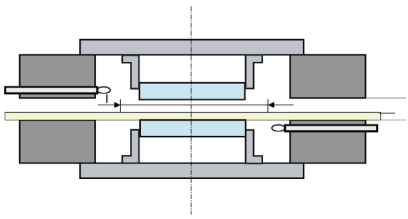

Fig. 6. The example of the resonant cavity

E. Parallel plate

Parallel method is also called the three terminal method in ASTM standard, involves sandwiching a thin sheet of the material between two electrodes to form a capacitor. The measured capacitance is then used to calculate the permittivity. The impedance measuring instrument would measure vector components of the capacitance and the dissipation. On the base of this measurements is possible to calculate permittivity and loss tangent. The method works at the low frequencies of a thin sheets or liquids.

F. Inductance measurement method

Relative permeability of magnetic materials derived from the self-inductance of a cored inductor that has a closed loop is often called effective permeability. The conventional method of measuring effective permeability is to wind some wire around the core and evaluate the inductance with respect to the ends of the wire.

V. Conclusion

This paper describes basics of the measuring the dielectric properties of the materials. Especially, the paper describe the methods of the measurement. By the coaxial probe is possible to measure just ϵ_r. This method is suitable for measurement of liquids. The transmission line technique can measure both parameters and it is suitable for measurement of the machinable solids. The free space method can measure both parameters too and it is eligible for measurement in high temperatures or a big flat sheet. The resonant cavity can measure just ϵ_r with high accuracy, but samples have to be small. The parallel plate is not so accurate as the resonant cavity method and it can not measure high frequencies, but it is the simplest method. At last, the inductance measurement can measure just μ_r and can be used just for a core structure of material, but it is very simple method, too.

Acknowledgment

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Measuring of shielding effectiveness of electromagnetic field

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***Abstract*— This paper deals with measuring of shielding effectiveness of electromagnetic field. The measurements were focused on measuring of shielding effectiveness of building materials. Measurements were preformed according IEEE Standard, Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures. Measurements were performed in the non-reflection chamber because exterior influence. The results are compare with previous results.**

***Keywords*—electromagnetic field, shielding effectiveness, brick.**

I. Introduction

Electromagnetic interference can cause severe problems, and it should be taken into account in the design of new power plants. The term Electromagnetic Compatibility is closely related to the notion of shielding electromagnetic field.

Everyone is exposed to a complex mix of electric and magnetic fields, both at home and at work, from the generation and transmission of electricity, domestic appliances and industrial equipment, to telecommunications and broadcasting [1]**Chyba! Nenašiel sa žiaden zdroj odkazov.**.

Research activities on my PhD study are focus on the measuring of shielding effectiveness and reflection of electromagnetic fields. Measured objects were building materials – polystyrene, eco-materials and brick. On the base results it possible to determine absorption of electromagnetic field.

II. The initial status in the solving of the research task

Shielding effectiveness can be calculated according to the relations (1–4) if the value of the transmitted signal is set in logarithmic unit [3][4].

$$SE = \left|E_{1\log}\right| - \left|E_{2\log}\right| \text{[dB]} \tag{1}$$

$$SE = \left|H_{1\log}\right| - \left|H_{2\log}\right| \text{[dB]} \tag{2}$$

$$SE = \left|V_{1\log}\right| - \left|V_{2\log}\right| \text{[dB]} \tag{3}$$

$$SE = P_{1\log} - P_{2\log} \text{[dB]} \tag{4}$$

where E_1 and H_1 are the intensity of electric field and magnetic field in the absence of the shielding, respectively E_2 and H_2 are the intensity of electric field and magnetic field within the shielding, V_2 is voltage reading within the shielding, V_1 is voltage reading in the absence of the shielding and P_2 is power detected within the shielding, P_1 is the power detected in absence of the shielding.

Formulas (1), (2), (3) and (4) are used according to the available measuring equipment.

The main factors which determine the shielding effect are the capability of shielding materials (the electric and magnetic conductivity and the permeability), the thickness and the frequency of the incident wave. If we know all these factors, the materials shielding effects can be calculated by (5). If these factors are unknown, we can measure the intensity of electric field and magnetic field when there are shielding materials or not, and then *SE* could be calculated by (1). According to [3] shielding effectiveness is the sum of the reflection *R*, multiple reflections *B* and absorption *A* of electromagnetic field derived as:[3][4]

$$SE = A + R + B \tag{5}$$

$$SE = 15{,}4t\sqrt{f\mu\sigma} + 168{,}16 - 10\log\frac{\mu_R f}{\sigma_R} + 20\log\left(1 - e^{\frac{2t}{\delta}}\right)$$

where t is material thickness, σ is electrical conductivity of shielding material, σ_R is the relative conductivity, μ_R is the relative permeability of shielding material, μ is the magnetic permeability of shielding material, f is frequency, δ is depth of penetration. For the simplicity, it is possible to determine the shielding effectiveness *SE* also as (6) without the multiple reflections *B*.

$$SE = A + R \tag{6}$$

$$SE = 8{,}69\frac{t}{\sqrt{\frac{2}{\omega\mu\sigma}}} + 20\log\left(\frac{1}{4}\sqrt{\frac{\sigma}{\omega\mu_r\varepsilon_0}}\right)$$

where μ is permeability which included permeability of the shielding material, ε_0 is electric permittivity of vacuum. The expression (6) is simplified expression of (5). Both terms are correct except of other literatures. From equation (6) we can see, the relative permeability and relative conductivity affect shielding effectiveness *SE*.

III. Task Solved in the previous year

Measurements were performed in the non-reflection chamber because exterior influence. The workplace for purpose of measuring of shielding effectiveness of electromagnetic field is shown on Fig. 1 (block scheme) and Fig. 2 (view of measuring of shielding effectiveness of brick wall in the chamber).

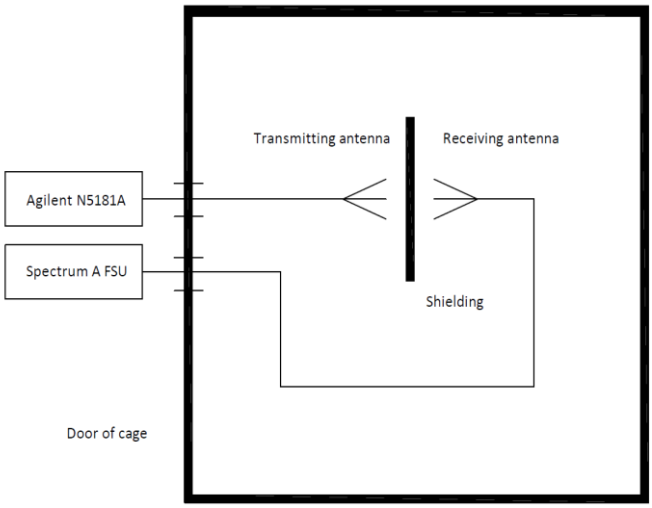

Fig. 1. Block diagram for purpose of measuring of shielding effectiveness of electromagnetic field

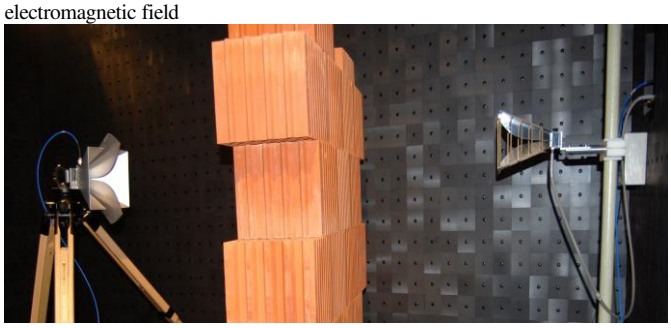

Fig. 2. View of the measuring in the chamber

View of the measuring in the chamber is shown in Fig. 2. The measuring results of shielding effectiveness *SE* of electromagnetic field in frequency range 1 GHz to 9 GHz for building materials shown Fig.3. Dependences shown increasing trend of shielding effectiveness in frequency range 1 GHz up to 9 GHz. Further results are disclosed in [5][6][7][8], or are in print.

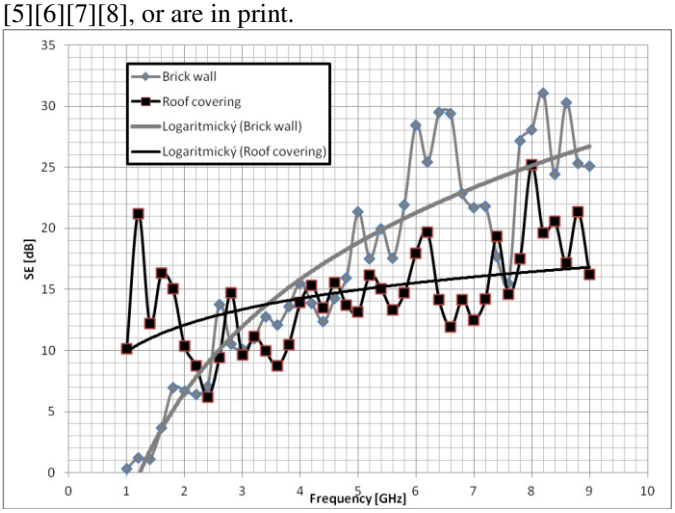

Fig. 3. Dependence of shielding effectiveness of electromagnetic field in the frequency range from 1 GHz to 9 GHz for brick wall and roof covering

IV. Proposal for the Next Steps in the Next Period of Time

I would like to continue in measuring shielding effectiveness and reflection of electromagnetic field of building materials other materials in next period of PhD study. From the measured data, it is possible to calculate absorption of the electromagnetic field. These results will be helpful for planning of antenna place or Wi-Fi transmitter in indoor of building.

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Methodology for the Modelling of Mobile Robot with Differential Chassis

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***Abstract*—The research presented in this article is focused on the author's work done last year according to dissertation thesis Application of Methods of Artificial Intelligence in Modeling and Control Robotic Systems.**

***Keywords*—differential chassis mobile robot, kinematic model, dynamic model, actuator modelling, robot position control.**

I. Introduction

The precise mathematical model of mobile robot can be very helpful mainly in the early stage of mobile robot or control algorithms design. The knowledge of mobile robot's mathematical model allows the creation of simulation model, that can show expected behaviour of the relevant real mobile robot to user or algorithm inputs. This cybernetic approach, which is the core of author's dissertation thesis, also allows to define limitations or problems, which can be resolved just before the robot's prototyping phase of design. Also, the cybernetic simulation can verify the control algorithms before implementation into real mobile robot. The knowledge of mobile robot's mathematical model is essential for application and validation of control approaches that use neural network approximation models

This article briefly describes and summarizes the author's last year's selected results in fulfilling the dissertation theses as it was done in last conference paper [1].

II. Previous analysis and achieved results in research field

In the previous years of study, a multiple fields of robotics were subject to author's research, that will ultimately link together in the resulting dissertation thesis. The robotic arm description and kinematics, which was the subject of author's first year of research is presented in [2]. The robotic systems, both static and mobile, share similar traits and problems, therefore the focus of interest was changed to mobile robot modelling and control, as presented in papers [1], [3]. The created mobile robot simulation models, together with virtualization options and control structure components, such as trajectory generator presented in [1] or controllers are grouped in the *Mobile Robotics Blockset*, a Simulink library which is one of the dissertation thesis program outputs.

The most of work done was supported by project Vega No. 1/0286/11 Dynamic Hybrid Architectures of Multiagent Network Control Systems, completed in 2014 and by University Science Park Technicom for innovative applications with knowledge technology support, co-financed by the ERDF, that will finish this year and achieved results was presented in paper [4]. Moreover, the educational results of the author's work are supported by grant Kega - 001TUKE-4/2015. The author is also a member of Alice Collaboration in CERN Alice experiment.

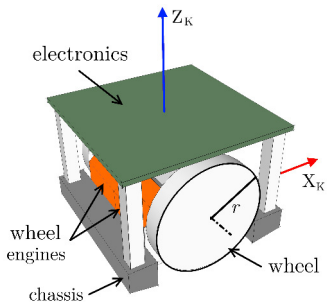

Fig. 1. Illustration of mobile robot with differential chassis common concept

III. Solved tasks and results

In order to achieve the mathematical model of differential driven two-wheel mobile robot that is suitable for simulation experiments, it is required to take into account various physical, mathematical or technological characteristics that define this kind of mobile robot. The differential driven two-wheel chassis concept that have wheels placed in the same axis of rotation is a popular choice for its mobility in plane and simplicity [5].

A. Differential chassis holomomic constraints and kinematics

If we know the exact geometric dimensions of chassis and wheels, we can define holonomic constraints even for other kinds of wheels, common types are illustrated in Fig. 2

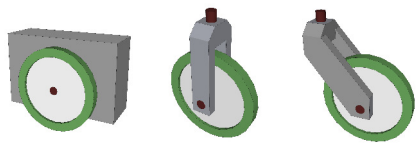

Fig. 2. Common robot wheels - fixed, centred and castor type of wheel

The kinematics of chassis concept depicted on Fig. 1. is defined within nonholonomic constraints [6]

$$\begin{bmatrix} -\sin\varphi & \cos\varphi & 0 & 0 & 0 \\ \cos\varphi & \sin\varphi & b & -r & 0 \\ \cos\varphi & \sin\varphi & -b & 0 & -r \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\varphi} \\ \dot{\theta}_R \\ \dot{\theta}_L \end{bmatrix} = 0 \qquad (1)$$

where x, y are the mobile robot centre of gravity plane Cartesian coordinates, φ is overall robot orientation, θ_R, θ_L are wheel angular positions, r is wheel radius and b is half distance between wheel mounts.

B. Actuator modelling and internal control

As actuators, the mobile robots use DC motors, usually with gearboxes that can produce enough torque force to set them into movement [7] . The relation between applied voltage U_m and DC motor rotor axis angular velocity Ω_m can be modelled in form of linear transfer function

$$F_{\Omega_m/U_m}(s) = \frac{K_\tau}{(I_r s + B_r)(L_r s + R_a) + K_\tau K_e} \qquad (2)$$

where R_a is armature resistance, L_r is rotor inductance, I_r is rotor moment of inertia, B_r is friction coefficient, K_τ is motor torque constant and K_e is back electromotive force constant. Model (2) can be furthermore extended with the gearbox, more precise friction model, the inertia of load, that the motor moves or disturbance effects [8]. Because of practical aspects, the angular velocity of motor rotor is usually controlled indirectly, using the additional internal loop through the armature current - this approach reduces the unwanted high acceleration. The DC motor as an actuator is also used as a dynamics component of robotic arms too [9].

C. Dynamics model of mobile robot

In general, the mobile robot's dynamic model can be considered as an disturbance effect that have to be suppressed. The basic mobile robot dynamic model, which minimally incorporate the robot's mass and moment of inertia, can be obtained using Newton-Euler or Lagrange approach. Also, this dynamic model can contain the frictions effects [6] or the actuator dynamics [7]. An internal control loop, depicted on Fig. 3. with PI controllers should be used [5], [10]. The mobile

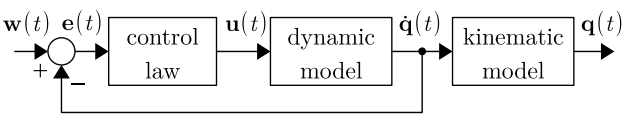

Fig. 3. Mobile robot internal control loop that suppresses the dynamic effects on robot movement

robot is controlled by desired angular velocities $\mathbf{w}(t)$ and the internal control loop should minimize the velocities errors $\mathbf{e}(t)$ with particular forces/torques represented by action $\mathbf{u}(t)$. The real robot velocities $\dot{\mathbf{q}}(t)$ are using the kinematics model transferred into position vector $\mathbf{q}(t)$. The kinematic model is used as a simple odometry sensor, but in real application, a position correction using the sensors as gyroscope or cameras is recommended.

D. Mobile robot control structures

The basic control task for mobile robot is to get the robot to specific position. If a mobile robot contain the internal control loop (Fig. 3.), it is possible to use feedforward control to move the robot into position [1]. This approach is not sufficient, because the position error grow with the distance travelled, even in straight line motion. Therefore, a feedback loop is required to correct this error [5]. The usual, more complex mobile robot control scenarios are

- **posture control** - include robot orientation,
- **path following** - move on path defined as points or postures,
- **trajectory following** - include time aspect,
- **obstacle avoidance** - reaction control with mapping.

IV. Proposal for next steps

The precise simulation model of mobile robot with dynamics and actuators will serve as source of training and validation data for feed-forward and inverse neural network models. Mentioned control scenarios can use classical approaches, but in some cases, the artificial intelligence methods will be used as in [5] to compare the overall control performance.

Acknowledgement

This work has been supported by the Research and Development Operational Program for project: Realization of control/expert tasks within resolving the project University Science Park Technicom for innovative applications with knowledge technology support - 2nd phase, co-financed by the ERDF (80%) and by grant KEGA - 001TUKE-4/2015 (20%)

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Methodology of multi-objective optimization of assembly lines

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***Abstract*— Paper summarizes my research work and its results during my postgraduate studies within the topic of multi-objective assembly line optimization. Visions and goals for the future research are mentioned in the last part of the paper.**

***Keywords*— assembly lines, decision making, modeling, objectives, optimization**

I. INTRODUCTION

Assembly lines are the most common way of production process realization nowadays. In comparison to the former production methods, there is minimum or no human intervention into production process, possibility of production process optimization etc. These factors can result in building cost and time-efficient systems for product realization.

In most cases, main criterion for optimizing assembly lines production is profit optimization. But many other criteria can be defined to make this problem more complex and focused also on the other aspects of production process:

- maximization of reliability and safety,
- maximization of efficiency resp. minimizing overload,
- minimization of manual interventions,
- minimization of environmental affects,
- minimization of initial investments,
- minimization of production time. [1]

Main motivation in my research is definition of the complex methodology in the field of multi-objective assembly lines' optimization for solving tasks in various areas, like assembly lines' modeling by using simulation models ,configuration of assembly lines and scheduling the orders by using multi-objective decision-making methods, and last but not least, optimizing of production process realized by multi-objective optimization methods. Methods and models used in solving assembly line balancing tasks can be found in [2] and [3].

II. PREVIOUS TASKS AND ACHIEVED RESULTS IN THE RESEARCH FIELD

At the first place, theoretical background of multi-objective optimization had to be studied, in order to be applied in the research. Summary of these methods and their application in MATLAB simulating system is the subject of [1] and [4]. Afterwards, application for solving multi-objective optimization problems for 2 optimized factors was created in MATLAB. Detail description of this application is published in [5]. All these research papers were supported by projects Vega, KEGA and USP Technicom.

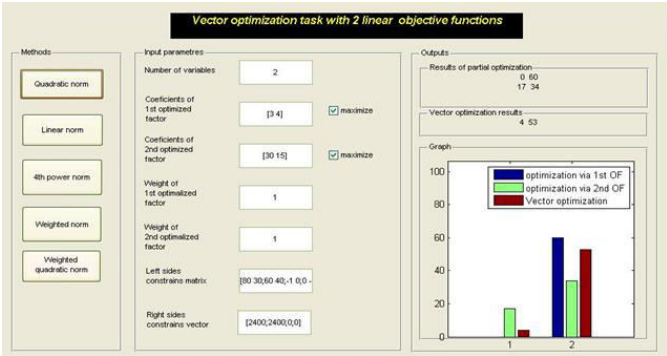

Fig. 1 Application for solving multi-objective optimization tasks

Possible usage of this application (shown in Fig. 1) in optimizing the production plan (maximizing profit and maximizing amount of saved time) and also in economical sphere (maximizing profit and minimizing the riskiness of investment at the same time) is the main subject of [6]. This research work was the part of realization of the project USP Technicom mentioned above.

My work was also focused on designing and creating the information system for assembly line model situated in DCAI laboratory. This system was created mainly to manage tasks dealing with users and order management. Information system was also interconnected with RDBS Oracle, which was used as data acquisition system providing users with data from real production. Details of this task were published in [7] as results of the contribution to projects KEGA and USP Technicom.

III. TASKS AND RESULTS SOLVED IN LAST YEAR

Both tasks closely described in this chapter are the part of work of our group within DCAI. Other activities of our group are the main topic of the paper [8].

A. *Stateflow model of assembly line*

In order to find proper results for multi-objective assembly line optimization, creating a model of this assembly line is the necessary step. Purpose of building simulation model is to simulate the production processes in details and also to find most of mistakes from assembly line design phase. Simulation model of Flexible Assembly Company (laboratory model of

assembly line placed in DCAI) was designed in MATLAB simulating system using Simulink blocks.

Main part of this model (

Fig. 2) was realized with Stateflow diagrams, which are included in the Simulink library. This model is properly divided into blocks, which represents particular posts of assembly line. Production is realized simultaneously in every post, but particular posts are exclusive (there can be only one active state in the moment within the post). Outputs of this model are: execution times of particular posts, final execution time for each product and the status of warehouse.

Simulation results are published into the Excel spreadsheet as well as on the screen. Outputs of the model can be used as data source for building the mathematical model of assembly line, which would be resolved by using multi-objective optimization methods in further research process.

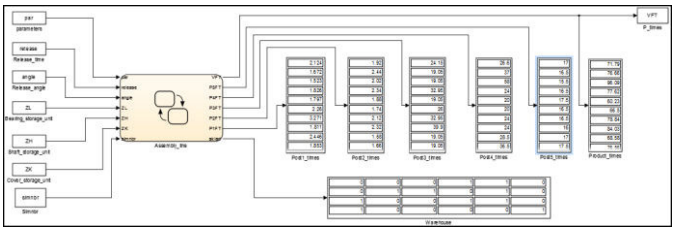

Fig. 2 Stateflow assembly line model

Model can be used also in resolving assembly line configuration task, e.g. how another workstation placed in particular post will affect the final execution time, the idle times etc. Results from the model can be the source for multi-objective decision-making task used for optimal assembly line configuration. Model and real assembly line is detailly described in [9], where Stateflow model of every post is placed, as well as comparison of real and created simulation model. This paper was made in contribution within participating on projects USP Technicom and by grant KEGA.

B. Solution for multi-objective decision making task

Another part of the research activities was focused on solving multi-objective decision making task dealing with finding optimal configuration of assembly line, where 7 possible configurations (Fig. 3) were compared according to 4 criteria: profitability (weight 0,69), minimization of idle times (0,08), environmental effects (0,06) and value of investment (0,17).

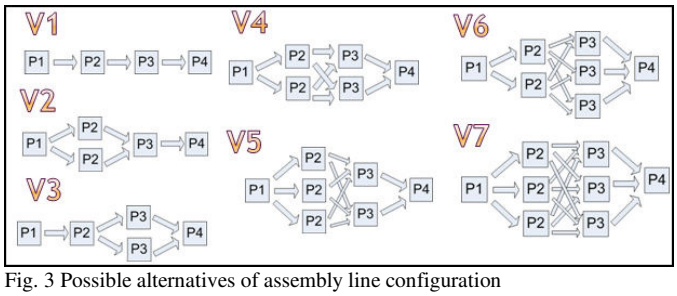

Fig. 3 Possible alternatives of assembly line configuration

Multi-objective decision-making methods were applied to find optimal solution: ELECTRE III, TOPSIS, AGREPREF. Results were raised from application designed and realized in MATLAB simulating system. Descending order of all configurations counted by all methods is displayed in TABLE 1. From the results is clear that the best configuration according to selected criteria is the configuration with 3 parallel workstations in post 2 and with 3 workstations in post 3.

TABLE 1 Order of alternatives sorted by multi-objective decision making methods

ELECTRE III	TOPSIS	AGREPREF
V7	V7	V7
V5	V5	V5
V4	V6	V6
V2	V4	V4
V6	V2	V2
V1	V1	V3
V3	V3	V1

Detail description of whole task is the part of my dissertation prospectus - [10].

IV. Future Research Steps

My future research will be focused on definition of complex methodology for multi-objective assembly line optimization. Correctness of this methodology will be tested on laboratory assembly line models within DCAI, solving mainly tasks dealing with optimal configuration, production plan and orders' schedule. In this case it is inevitable to complete partial tasks like models of other assembly lines etc. In terms of proper definition of assembly line mathematical model, queuing system theory will be applied.

Acknowledgment

This work has been supported by the Research and Development Operational Program for project: Realization of control/expert tasks within resolving the project University Science Park Technicom for innovative applications with knowledge technology support – 2nd phase, co-financed by the ERDF (80%) and by grant KEGA - 001TUKE-4/2015 (20%).

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Methods of detection in Vertical Traffic Signs Recognition System

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***Abstract*—This paper is focused on possible detection methods of vertical traffic signs in Vertical Traffic Signs Recognition (VTSR) system. One step of vertical traffic signs is the traffic signs detection process. Traffic signs detection process is used to locate the area of the traffic sign (ROI – Region of Interest) from the complicated captured image background. The process of location of the traffic signs might be based on different methods. The detected ROIs are compared with the reference traffic sign by Optical Correlator in recognition phase.**

***Keywords*—Cambridge optical correlator, detection of traffic signs, recognition of traffic signs, vertical traffic signs recognition system.**

I. Introduction

Nowadays, the driver assistance systems (DAS) are very popular in automobile industry. DAS increase safety and comfort of a driver. The road infrastructure is very important to social and an economic development of each state. The traffic signs are one of the most important components in the road infrastructure. They are used to visual guidance of the vehicles and other road users in the traffic. So, the traffic signs recognition systems include the driver assistance systems as the major part. These systems are used to recognition of speed limits, warning signs, regulatory signs and subsequently warn the driver in certain dangerous situations. They can be used for collecting information about traffic signs (GPS position) too. This collected information might be stored in database and used in other systems [1, 2].

In this paper we will focus to our proposed Vertical Traffic Signs Recognition system, more specifically to detection methods of vertical traffic signs. Optical Correlator is used as a comparator in the recognition phase. Experiments were done with the static images captured from video of real traffic.

II. Vertical Traffic Signs Recognition System

The traffic signs are used to control the traffic flow, to give information about the direction or distance to destinations and to alert the driver in case of unsafe sections. They differ from one another mainly by their colour and shape. In view of this fact, detection of the traffic signs might be based on the colour or shape information [1-4]. The principle of operation in the vertical traffic signs recognition system is shown in Fig. 1.

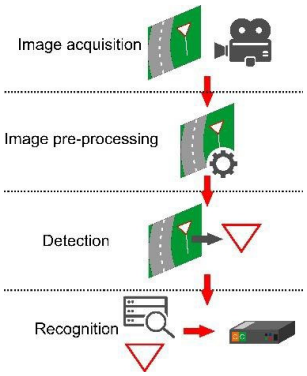

Fig. 1. Procedure of VTSR system

The first step of operation in the VTSR system is acquiring an image by using colour HD video camera. This colour HD video camera captures the scene in front of the vehicle.

The next step after the image acquisition is the image pre-processing. In this step, the captured image is modified for purpose of easier acquisition of necessary information from it. The noise from the image is removed by using a Gaussian filter. The properties such as a brightness, a contrast and a gamma are changed too. Thus the pre-processed image is prepared to the detection phase.

The main task of the detection phase is to find the real candidates of the vertical traffic signs in the pre-processed image. The traffic signs are designed to be principally distinguishable from the natural or human-made backgrounds. They are characterized by many features which make them recognizable. They are designed in the standard geometrical shapes like triangles, circles, rectangles and octagons. The main colours of the traffic signs are chosen to be far away from the environment, so they are easily recognizable by the drivers. They use colours to represent the main information to the drivers. The typical colours used for the traffic signs are red, blue and yellow. So, the information about shape and colour can be used in the detection. With this in mind, the detection can be based on shape, colour or both of them.

Colour-based detection method is based on colour segmentation, e.g. process of partitioning image into multiple sets of pixels that have similar colour properties. In VTSR system, HSL colour space is used. The base of shape-based detection method are algorithms that are used to search some well-known traffic shapes of traffic signs. Of course the colour segmentation in this method is omitted. Hybrid detection method combines above mentioned methods together [2-6].

In all of these methods, digital image processing is used. We can divide digital image processing to simple operations that process image in different way. Each method uses different number of operations in different orders (Figure 2.)

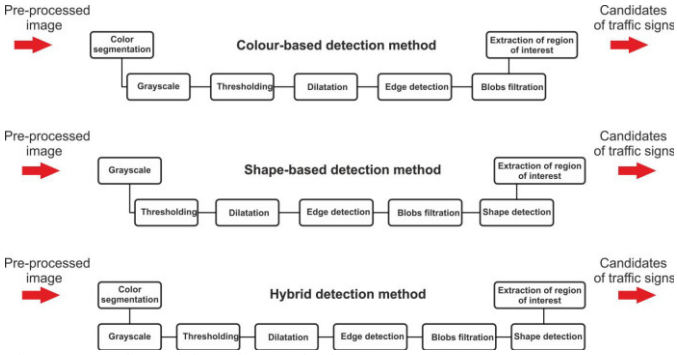

Fig. 1. Procedure of detection method

The last section is Recognition. The output of the Detection is list of candidates that might represent the vertical traffic signs. This list is forwarded to the recognizer for further evaluation, and then based on the result of recognition this recognizer decided whether the candidates in the list are traffic signs or either rejected objects.

In VTSR system the Cambridge Optical Correlator is used as a recognizer. The Cambridge Optical Correlator is a basic device that uses the optical processing technology. It is a type of Joint Transform Correlator where process of optical correlation is formed by two consecutive Fourier transforms. The Cambridge OC is used to compare the input images with the reference images based on their similarities. The input scene is created by these images and then the process of optical correlation is done. The optical output of the Cambridge OC contains highly localized intensities – correlation peaks, which size reflects the measure of similarity of the images at the input scene. The position of these peaks is the same as the position of the input images [7-9].

In our case, the candidate represents the input image and it is compared with the reference vertical traffic signs. The reference vertical traffic signs are stored in created database. As was mentioned above, the optical output contains highly localized intensities and their value might be in within the range <0;255> where value "255" refers to total match and value "0" refers to mismatch. The equation (1) means percentage match between images situated in the input scene, where I_1 and I_2 are intensities of the correlation peaks

$$\text{Match} = (I_1 + I_2)/510 * 100. \quad (1)$$

III. Results and Conclusion

We realized an experiment with static images. These images were captured from the video of real traffic in Slovakia. Each captured image of real traffic contains at least one vertical traffic sign. The database of reference traffic signs was designed. It contains 43 vertical traffic signs that were found in video of real traffic in Slovakia. Our experiment consists of two phases – detection phase and recognition phase.

The main task of detection phase is to found real candidates of vertical traffic signs from images of real traffic. We used three mentioned methods to find 43 candidates from the captured images. In this section of our experiment were obtained 43 candidates by each detection method.

In the second part of our experiment, the 43 founded candidates of vertical traffic signs by each method were compared with the reference traffic signs. The resulting values of the average intensities and percentage match between candidates obtained by each method and reference traffic signs are shown in TABLE I.

TABLE I
RESULTING VALUES OF RECOGNITION PROCESS

Colour-based method	
Recognized traffic signs	34
Average intensity value	190,1
Percentage intensity value	74,9%
Shape-based method	
Recognized traffic signs	35
Average intensity value	195,8
Percentage intensity value	76,8%
Hybrid detection method	
Recognized traffic signs	40
Average intensity value	200,2
Percentage intensity value	78,5%

The highest number of positive recognized vertical traffic signs (40) were detected by hybrid detection method. The percentage of the intensity value was 78,5%. Colour-based and shape-based detection method achieved similar results in number of positive recognized traffic signs.

The video of real traffic was obtained by HD colour video camera in early hours. So, the lighting conditions had a significant impact on the detection. The success rate of detection for each method depends on the weather.

Acknowledgment

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Modelling and Analysis of a Continuous Production Line with Strip Tension and Strip Elongation Control

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***Abstract*—The paper describes a model of a multi-motor drive system of a continuous strip tension levelling line which allows to control strip tension and strip elongation within pre-set boundaries. We have focussed on behaviour of the line during its operation with developed tension and its elongation. Especially, for maintaining the tension in line sections two new tension controllers have been designed: for the line section with a low and with a high tension. The results were verified experimentally on a real processing industrial line.**

***Keywords*— Elongation mode, tension mode, tension controller, stepper controller, ramp generator**

I. Introduction

Continuous strip processing lines are driven by multi-motor drive system where the motors are mutually mechanically coupled by processed material. To achieve required material output quality the tension in the strip and its elongation in each line section should be controller within specified, pre-set boundaries.

The paper presents the simulation model of the line with a possibility to control both the tension and elongation modes of the strip. Two tension controllers have been designed, simulated, and also practically verified on a real line. They are used in the strip levelling section and in the oven section of the analysed line.

II. Nonlinear Model of a Continuous Production Line

The drive system of the considered tension levelling line consists of 11 drives (Fig. 1) where the drive P21 is the speed master drive. All drives except of the drives P14 and P21 contain a pre-set torque limitation. To create the tension in the strip during the line standstill, every drive except of P21 has a speed offset. For creating the tension in the strip all drives to the right side of P21 turn faster and all drives left of P21 turn slower.

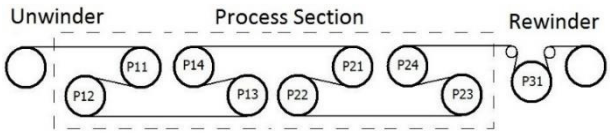

Fig. 1. Arrangement of the drives in the simulated production line

In the elongation control mode two drives in the line are working without torque limitation and without any offset: the speed master drive P21 and the drive P14 ensuring the strip elongation (controlled via speed setpoint for the drive P14).

The drives are simulated as DC motor drives, [1], [2]. For simulation of the strip elongation an improved mathematical model of the strip was designed in which we have taken into consideration a variable nonlinear prolongation of the strip outside of range of validity of the Hook's Law, [3]. The block diagram of the simulated line model is shown in Fig. 2.

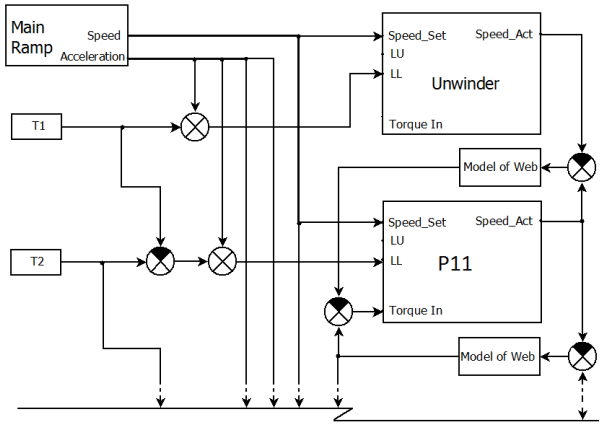

Fig. 2. Entry part of the simulation model of the production line

The actual elongation of the strip is calculated from the speed difference between the rolls in the section. The model of the strip was designed based on material properties taken from the Strain-Stress Curve (in our case it was Aluminium alloy 6016).

III. Strip Elongation Control

The simulation model of the line enables to adjust the strip speed and to set different tensions in each from the line sections. To achieve smooth courses of the tensions without steps during the operation, the moment of inertia of each drive should be compensated. Fig. 3 shows the strip speed during line starting (in time of 1 s all drives turn with a low negative speed until the tension in the trip is being developed).

The relation between circumferential speeds of the tension rolls v_1 and v_2 in the selected line sections is calculated as:

$$\frac{v_1}{v_2} = \frac{(l+\Delta l_1)/dt}{(l+\Delta l_2)/dt} = \frac{1+\frac{\Delta l_1}{l}}{1+\frac{\Delta l_2}{l}} = \frac{1+\varepsilon_1}{1+\varepsilon_2} \quad (1)$$

If the first drive in the section (the speedmaster) has the circumferential speed of the roll v_1, the second drive should have the speed offset depending on required strip elongation in the section: for creating the tension ε_2, the second drive should have the following circumferential speed of the roll:

$$v_2 = v_1(1+\varepsilon_2) \quad (2)$$

The tension courses in all section of the line are shown in Fig. 4. On the speed course (Fig. 3) a small deviation of the speed is observed in time of 12,5 s, which is caused by starting the elongation mode. The switching from the strip tension control mode into the strip elongation mode begins by increasing the torque limitation of the drive P14 to its maximum possible value. If the speed setpoint for the drive P14 is lower than the speed setpoint for the following drive P21, the strip elongation is increased what is observed on the graph in Fig. 5.

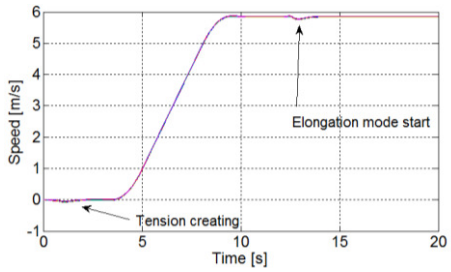

Fig. 3. The speed of the strip at line starting

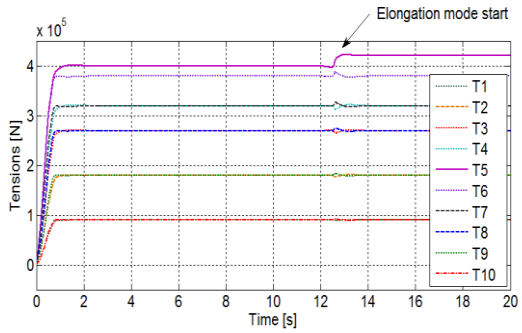

Fig. 4. Time courses of tensions in the sections (T1 – T10) with compensated the moment of inertia

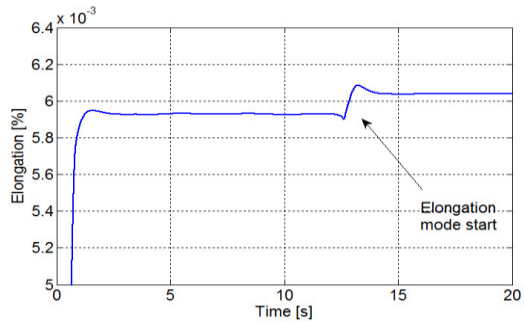

Fig. 5. Time courses of tensions in the sections with compensation of the moment of inertia

IV. Strip Tension Control

Strip tension in the line is measured by a tension transducer. The actual values of the tension are processed by tension controllers. Two new special tension controllers were developed:

1. A tension controller with the ramp (Fig. 6) for the line section with a high strip tension (this is the case of a straightening section called Levelflex in the line, where, for obtaining the best flatness of processed material, the tensions in the strip should reach the highest values. The smoothly changed value is maintained by the ramp generator which is active when a tension control error occurs. If the difference lies within the tolerance region, then output of the ramp generator is stable. From the technological plan it follows that it is allowable when the pre-set tension can vary within boundaries of ± 1%.
2. A stepper tension controller tension for the section with low strip tension (Fig. 7). In the strip levelling line it occurs in the part of the annealing furnace (a very long line section without intermediate drives where the strip is raised by pressure of air). The controller operation is based on increasing or decreasing its output (the set tension value) in steps: the controller works until the control deviation is lower or higher than the pre-set range. In case of any difference between the set and actual value of tension the counter increases or decreases number of pulses. The output from the controller is divided among the drives.

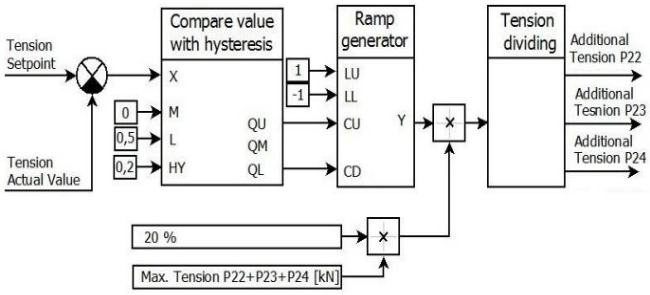

Fig. 6. Tension controller with a ramp

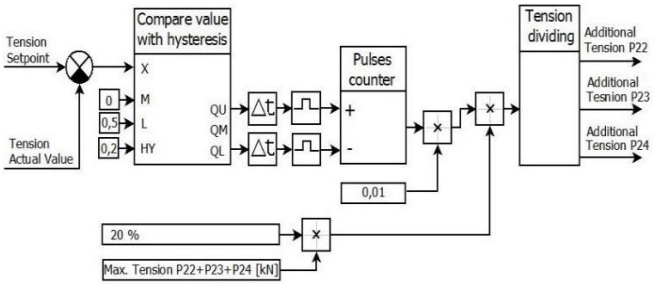

Fig. 7. The stepper tension controller

V. Conclusion

The contribution describes a simulation nonlinear model of a continuous line with indirect strip tension control and with strip elongation control. Two new tension controllers were developed and described. The simulation model enable to test the line dynamical properties both in the tension and in the elongation modes.

Acknowledgment

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Modern Trends in Mobile Robotic Systems Development – From 3J to Autonomous Skoda Fabia

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***Abstract*—The paper deals with short overview of modern trends in mobile robot's sensorial systems development. Some of new principles of indoor navigation are described and three indoor robots are introduced, which were developed on Department of Electrical Engineering and Mechatronics.**

***Keywords*— mobile robotics, sensorial system, machine vision, mapping, controll**

I. Introduction

Mobile robots play important role in many areas of everyday life. Many households have small robotic vacuum cleaners, which are the type of small autonomous mobile robots. This robot is capable navigate itself in unknown environment and create simple plan of its motion across a hall [1]. For their small sizes and versatility of motion subsystem, they became popular development platform for robotic researches on universities across the world [2]. The mobile robots are also used in industrial field. The well known application, where there are used, is as autonomous logistic trucks [3].

Common sign of all mobile robots is navigation system, which provides information about actual robot pose and orientation in the environment. Sensorial systems operate on many principles and they use different sensorial hardware modules and different approach to process information from them.

One of the most simply approaches is using artificial sings in the environment for determine the safety path for robot. The standard for determine path for industrial trucks is using of magnetic black stripe on the floor of industrial hall. The robot scans the stripe by Hall probes and keeps it in the middle of the front of the robot and follows it [4]. Advantage of this system is precise and safe navigation. On the other side, path of the robot is strictly defined by stripe and every change of path requires mechanical stripe removing and new sticking. Service life of the stripe is also short.

Second approach for navigation of mobile robots is using only sensors placed on the robotic platform without processing any artificial signs in the environment. This approach requires advanced techniques of localization and mapping [5].

II. Visual odometry

One of the new and advanced techniques for navigation in the indoor environments is use visual information from mono or stereo cameras. The output of stereo camera is pair of images, which are mutually displaced (Fig. 1). We can determine true dimensions and distance of each point in the space based on images displacement. Necessary condition, for proper determination of all dimensions in the space, is properly calibrated camera. The camera calibration is realized by calibration chessboard with known dimension of squares and theirs number.

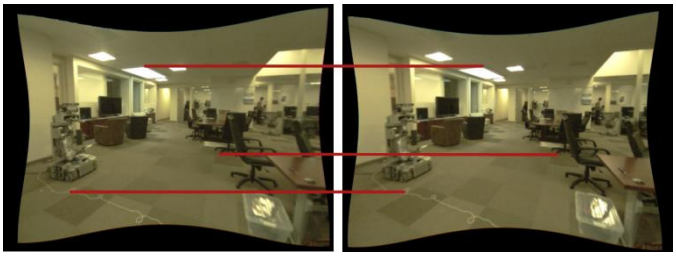

Fig. 1 Graphic user interface for visual odometry visualization

III. Laser scan techniques

For navigation without artificial sing in the environment is typical using of laser scan sensors. Laser scanner provides distance measurement of points around the sensor measurement plane. In the classical frame-to-frame laser navigation, each laser scan is compared to the previous scan. The transformation between the two is aggregated over time to calculate the position of the robot in the fixed frame. Disadvantage of this technique is that some noise in the scans is inevitable. Thus, even for a robot standing still, the incremental transformations might be non-zero. This could result in a slow drift of the pose of the robot.

IV. Mapping and path planning

When we have information about surrounding robots environment from visual odometry or laser scan, next step is creating reconstruction of real environment and visualizing it as two or three dimensional maps. Maps are important for application path planners, because contain information about static and dynamic obstacles. Path planning is an important issue as it allows a robot to get from point A to point B. Global path planners are used for plan movement with regards to static obstacles in the map and local planners are used for avoiding dynamic obstacles.

The best known planners algorithms are A* or RRT (Rapidly exploring random tree).

V. Mobile ROBOTS

During PhD study we developed several mobile robots based on different sensorial systems. The simplest one is 3J (Fig. 2), which was result of engineering thesis. Robot operates in the maze, what is strictly determined environment. Sensorial system consists of infrared distance and mechanical sensors. The main goal of sensorial system is keeping robot in the middle of corridor and finding crossings. Path planner is very simple and is based on right-hand rule. The robot doesn't create any type of map.

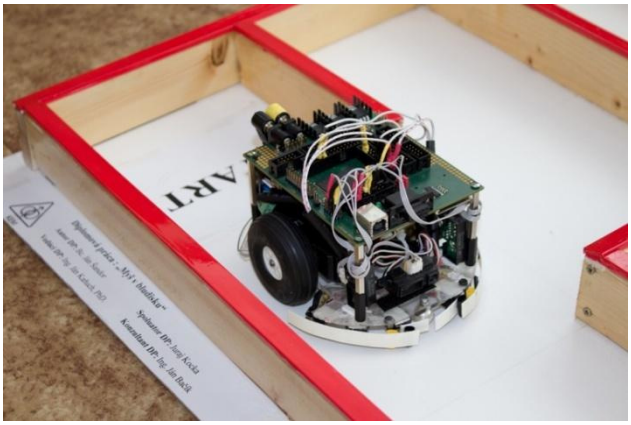

Fig. 2 Mobile robot – 3J

SRSbot (Fig. 3) is more complex robot. It is able operate in any indoor environment and all sensors are onboard. The main sensors are laser scanner SICK LMS100 and Microsoft Kinect sensor.

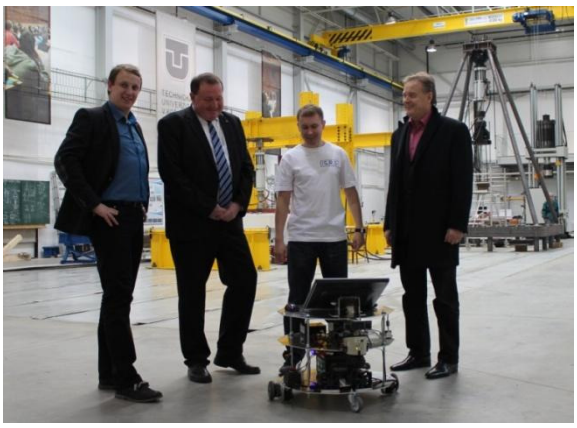

Fig. 3 Mobile robot – SRSbot

Laser scanner is used for localization and creating 2D maps. It can work in two different regimes. First regime is simultaneous localization and mapping. Second regime is localization in the known map. We can use map, which was created by SLAM or original ground plane of the building transformed to the map format.

To get depth image of the environment, we used Microsoft Kinect sensor. Depth image is used for extension of 2D map, created by laser scanner, to complex 3D map (Fig. 4). Three-dimensional map is not necessary for ground robots, but is very important for navigation of flying mobile robots – drones.

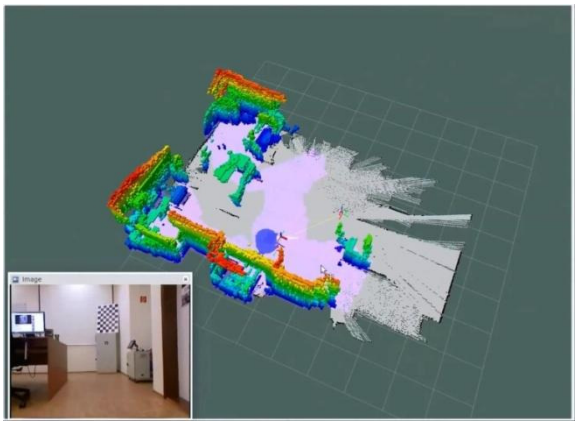

Fig. 4 3D mapping by SRSbot

All experiences obtained during mobile robots development are resulted in Skoda Fabia sensorial system (Fig. 5). We started to develop complex sensorial system for localization of mobile car as the first research team in Slovakia.

Fig. 5 Prototype of autonomous car Skoda Fabia

The main goal of project is testing navigation algorithms in worse conditions, which the outdoor environment is. Also more vibrations and more noises are presented in the vehicle as in the mobile robot, which operates on smooth floor of the industry hall.

Development of navigation systems is first and necessary step to design first completed autonomous car developed in Slovak republic. In this project all previous effort, in the field of mobile robotics, is reflected.

Acknowledgment

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Modulation and Channel Coding for FSO and RF Links

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Abstract— **Free space optical communications (FSO) are fast emerging as a promising approach to address the "last mile" bottleneck for the broadband access network. FSO, contrary to its counterpart the optical fibers, remains weather dependent, and counteracting atmospheric attenuation is still a major challenge. This paper describe novel approach to improve the performance of the systems by introducing higher state modulation and channel coding formats in the FSO links.**

***Keywords*—Channel coding, Modulation, Reed Solomon codes, Turbo codes.**

I. Introduction

Applying techniques of electrical modem design to the optical domain requires the translation of principles developed primarily for the RF (Radio Frequency) links to FSO.

The free-space, direct detection, optical intensity-modulated channel offers the modem designer interesting new challenges. Most practical FSO systems use LED (Light Emitting Diodes) or laser diodes as transmitters and PIN (P Injected N) photodiode or APD (Avalanche Photodiodes) as receivers forming a relatively simple communication system. These devices modulate and detect solely the intensity of the carrier, not its phase, which implies that all transmitted signal amplitudes are non-negative. Furthermore, biological safety considerations (eye safety) constrain the average radiated optical power, thereby constraining the average signal amplitude [1].

II. Modulation Schemes

Communication systems transmit information from a transmitter to a receiver through the construction of a time varying physical signal and the transmitted signal is corrupted by deterministic and random distortions due to the environment. The goal of communication system design is to develop signaling techniques which are able to transmit data reliably and at high rates over these distorting channels. For efficient design, a detailed knowledge of the channel characteristics is necessary. The transmission of information using optical intensity channels differs significantly from the conventional RF channel. Unlike the RF technologies, where the carrier amplitude, phase or frequency are varied, the information sent on most optical channels lies in the intensity of the transmitted signal. This electro-optical conversion process is termed optical intensity modulation and is usually accomplished by a LED or a LD (laser diode) [2]. Using incoherent, diffuse light sources (for eye safety reasons), only the intensity of the optical signal can be varied, which must remain positive [3]. The photodiode detector is said to perform direct detection of the incident optical intensity signal and its response is the integration of tens of thousands of wavelength of incident light. The photodiode detector, thus, produces an output electrical current which is a measure of the optical power impinging on the device.

Let $x(t)$ denote the intensity of the transmitted optical signal and let $ry(t)$ be the photodetector current at the receiver, where the constant r is the photodetector responsivity. When the intervening channel has impulse response $h(t)$, $y(t)$ is given by

$$y(t) = \int_{-\infty}^{\infty} x(\tau)h(t-\tau)d(\tau) + n(t) \tag{1}$$

The input $x(t)$ represents power, not amplitude and this leads to two unusual constraints on the transmitted signal, firstly, $x(t)$ must be positive, and secondly, the average amplitude of $x(t)$ is limited. If the average of the transmitted light wave is constrained to a value denoted by P (which satisfies safety regulations), then the input $x(t)$ of the baseband channel must satisfy

$$x(t) \geq 0 \tag{2}$$

$$\lim_{T\to\infty} \frac{1}{2t}\int_{-T}^{T} x(t)dt \leq P \tag{3}$$

The first constraint implies that any modulation scheme for an optical intensity channel must have a DC (Direct Current) component which transmits no information but consumes energy [4] and the second constraint is in marked contrast to conventional electrical channels in which the constraint is on the average squared amplitude of the transmitted signal [5]. The AEL (Allowable Exposure Limit) depends on the wavelength of the optical source, the geometry of the emitter and the intensity of the source. In general, the constraints are placed on both the peak and average optical power emitted by a source. For most practical high frequency modulated sources, the average transmitted power of the modulation scheme is more restrictive than the peak power limitation and sets the AEL for a given geometry and wavelength [6].

The most prominent modulation formats for wireless optical links are binary level PPM (Pulse Position Modulation) and OOK (On-Off Keying).

A. *Pulse Position Modulation*

Most modulation schemes for data transmission on wireless optical channels rely on binary levels to transmit data. The

communication design problem is one of carefully designing a pulse set in order to meet the required amplitude constraints while at the same time ensuring that power and bandwidth efficiency targets are met. Schemes such as OOK and PPM depend on the use of two levels to transmit data. Multilevel modulation schemes can provide better bandwidth and power efficiencies because of their more complex signal constellations. *M*-ary PPM is a fundamentally different modulation scheme that achieves high power efficiency at the expense of reduced bandwidth efficiency [4]. Digital PPM is widely used in intensity-modulated optical communication systems, such as fiber optic and satellite systems, primarily because of its high average-power efficiency [1]. The abundance of bandwidth in these applications makes the poor bandwidth efficiency of PPM of little concern, the FSO environment represents a very similar situation, and PPM with its significantly better power efficiency seems the appropriate choice. In PPM, a *k*-bit source

$$a = (a_1, a_2, \dots\dots, a_k)\varepsilon(0,1)^k \quad (4)$$

is modulated with M-ary PPM, $M = 2^k$, to yield a signal

$$X = (0, \dots\dots, 0,1,0, \dots\dots, 0)\varepsilon(0,1)^M \quad (5)$$

which contains a single one in the position indicated by the binary representation of a. The transmission channel is a binary-input unconstrained-output memory less channel. The coherence length of signal fluctuations is in the range of few milliseconds to tens of milliseconds. One use of the overall PPM-symbol channel consists of *M* serial uses of the binary input channel, and produces the received vector

$$Y = (Y_1, Y_2, \dots\dots, Y_M)\varepsilon Z^k \quad (6)$$

Since PPM uses one pulse per *M* slots, it has a duty cycle of *1/M* and a Peak-to-Average power ratio of *M* [1].

III. Channel Codes

It has been proposed the use of PPM for optical communications. In PPM, a fixed integer $M \geq 2$ is selected, and the transmission interval is divided into consecutive blocks of *M* slots each. In each such block the laser is pulsed in exactly one of the *M* slots at a fixed intensity. Each of these *M* patterns can be regarded as a letter in the sender's alphabet. In coded PPM, the idea is to regard the *M*-letter transmission alphabet as the input alphabet of a discrete memory less channel with $M + 1$ output letters, the $(M + 1)st$ letter is regarded as the erasure symbol.

To achieve performance enhancement, different channel coding strategies maybe combined with PPM. Broadly speaking, the channel codes may be divided into soft decision iterative codes or hard decision codes. Soft decision decoders nominally require slot counts for each slot. The receiver does not make preliminary PPM symbol decisions, but passes on slot counts to the decoder. The soft-decision algorithm is initialized by using the slot counts to determine the probability of each candidate PPM symbol. The receiver for the hard decision decoder is initialized with estimates of each PPM symbol, which may be determined by the receiver, but no explicit slot counts. Hard-decision receiver/decoders are generally less complex than their soft decision counterparts, but have poorer performance. Various choices exist for combining error correction codes with PPM. In [7], a RS (Reed Solomon) code was proposed for error correction on the noiseless Poisson PPM channel. RS performance on a noisy Poisson channel typically remains 3 dB or more away from capacity when conventional hard decision decoding is used.

A number of coding techniques involving convolutional codes have also been proposed. Alternatively, *M*-ary convolutional codes can be used directly with *M*-ary PPM [1]. There have also been proposals to use Trellis codes with pulse position modulation [1]. Since PPM is an orthogonal multipulse modulation scheme, the Euclidean distance between any pair of symbols is the same, and Trellis coded modulation which is designed to maximize the minimum Euclidean distance between allowed signal sequences may provide performance enhancement on multipath ISI (Inter Symbol Interference) effected channels, but it will not be of much benefit in a FSO environment which does not suffer from multipath problems [1].

Turbo codes based on their high coding gains, and their ability to use soft outputs, remain an important contender. In [8] a turbo code was applied to the binary PPM channel, and also a turbo code was applied to *M*-ary PPM.

IV. Conclusion

In this paper a modulation and channel coding for FSO and RF links is presented. The most prominent modulation formats for wireless optical links are binary level PPM and OOK. The most used channel codes are RS and Turbo codes.

My future work will be devoted to hybrid RF/FSO communication systems with soft – switching configuration and I will test different types of channels, modulation, coding and their combination. The results of these different types of transmission systems I will compare and evaluate.

Acknowledgment

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Multi-display environments in natural and ambient user interfaces and their evaluation

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***Abstract*—Work environments with multiple displays connected to a single computer are used to increase the work productivity. Multi-display environment changes the behavior of the computer user, because it affects his/her work space and how (s)he arranges items on displays. This behavior can be observed through the use of special devices, such as an eye-tracker or kinect device. Providing that this behavior is associated with his/her intentions, such as switching focus between items on displays, the computer system can use it for fulfilling his/her needs. Special measures need to be formed for the evaluation of the work productivity of such human-computer interaction. It is essential that these measures evaluate the efficiency of the use of multi-display environments in different domains. Through unobtrusive use of devices for observation of the user, we aim at establishing basic rules for creation of ambient and natural user interface and its evaluation.**

***Keywords*—Ambient user interfaces, human-computer interaction, multi-display environments, observation of the user.**

I. Introduction

Computer systems are present in work environments, in which they make common tasks easier. Multiple displays can be connected to one computer, thus increasing the work space of the computer user. Research by Owens et al. [1] suggests that having multiple displays in the work environment enhances the users' productivity. Human-computer interaction in the multi-display environment changes [2]. It is required for the user interface of the multi-display work environment to be adapted to match the user expectation of the system behavior [3]. Ambient user interfaces are interfaces, in which the information is displayed in the users' periphery, only moving to the center of attention of the system user when desired. Attention of the user is detected through the use of special devices that observe him/her. These devices can identify the point of regard (e.g. point on screen toward which the user is looking), the relative position of the user and the computer in the work environment, the brain waves in users' head or various physical conditions of the system user, such as heartbeat or amount of sweating.

Ambient user interfaces provide the user with comfortable unobtrusive control. Such interfaces are nowadays deployed in ambient intelligence environments. In these environments system automatically reacts on the user actions without direct involvement of him/her. This application eases the execution of his/her task without interfering with his/her standard behavior.

According to the survey made by Sadri [4], ambient intelligence is used in health care, intelligent households, assisted living, shopping, museums, tourism, education. To test the ambient user interfaces, the researcher needs to either inspect them in their environments or construct a laboratory that is designed according to the needs of the targeted domain. Creating a laboratory for testing the ambient interfaces is challenging, because it needs to be adaptable to the needs of any domain. Evaluation of the ambient user interfaces is especially difficult because of the Hawthorne Effect [5] that states that behavior of the experiment participants changes as a consequence to the participants awareness of being studied.

II. Analysis

There are three main focuses in the research of natural and ambient computer system that this paper takes into consideration. First one is the multi-display work environment, which is simple to set-up for different domains and is able to positively affect the productivity of the system user. Second one is the ambient user interface, which reacts to an user action in his/her environment. It is difficult to set-up and evaluate such interface as not every action of the user is intended for the control of the system and sensors embodied in such interface request unhindered access to the user of the interface. Third one is the natural user interface, which provides the user with human-computer interaction that is unobtrusive and intuitive for him/her. Important aspect of such interface is that it would behave according to the users' understanding of the world, so any user should be able to use it when (s)he comes into contact with it.

A. Work environment with multiple monitors

Multiple displays are being introduced into different workplaces with the aim of increasing the productivity of the system user [1]. There are two environments that use multiple displays.

First one is *multi-monitor work environment*, in which multiple monitors, preferably with the same size and resolution, are placed next to each other and serve as one large monitor. It can also be achieved through the use of multiple projectors. This case eliminates the bezels between each screen but it is harder for calibration to create seamless system [6]. Advantage of this work environment is the increased user display space, which can be used for better organization of the work elements. Benefits of the multi-monitor work environment can be achieved through the wide screen environment, in which one screen with the diagonal of at least 29 inches is used.

Putting multiple monitors next to each other requires special mounts and monitor holders.

Second one is *multi-display work environment*. This set-up does not require special mounts for displays. Displays in this environment can be put next to each other or one can be put above the other. Advantage of the multi-display work environment is its simple set-up. Disadvantage of this environment is that switching focus from one display to another is performed with cursor jumps, as these displays can have different sizes and resolutions [3].

Drawback of the larger display space (whether through multi-monitor or multi-display environment) is that the user can lose his attention more easily. Wrong distribution of the work elements can lead to decreased productivity. Larger display space allows its user to display non-work related application, which may act like a distraction from work and even further decrease the users' productivity [2].

In our previous work we inspected the ways of observing a software developer in a multi-display environment [7]. We detected that some observable patterns of behavior, for example rotating the developers head towards the observed display, can be used to perform human-computer interaction.

Kern et al. [8] focused on problem with attention switching in the multi-display work environment. They address this problem with creating a visual reminder - *Gazemark* that serves as a visual placeholder of the last area on the screen, on which the user fixated his look.

Ebert et al. [6] focused on the large display space achieved through the multi-monitor desktop and stereoscopic displays. They created two focus and context screen metaphors that address the problems with multi-monitor systems [9].

First problem is that data displayed on multi-monitor is influenced by the edges of the monitors. Second problem is the loss of data in stereoscopic screens used to display 3D data for viewers.

Because of the continuity of application data displayed on the multi-monitor, spatial relationships are needed to interpret the information correctly. Ebert et al. identify two ways of solving this problem. First one is to use the *offset approach*, which ignores edges and their effect on continuity of the scene. Second one is to project missing image information directly onto the edges of monitors. They accomplished the latter one with placing white cardboard on the edges of monitors and displaying missing image on them with projectors.

Set of measures for the evaluation of a multi screen television was established by Vatavu and Mancas [10]. They created multi-display set-up with multiple projectors that displayed different screens onto wall. This set-up allowed them to test variety of screen resolutions and screen compositions without the use of different sized monitors. For measuring different layouts of screens they used an eye-tracker that tracked the eye-gaze point of the participants. Final set of the objective measures can be used for multi-display work environment and consist of:

- *discovery time* - the time required for the viewer to make a pass over all screens
- *discovery sequence* - the sequence of screens that was traversed by the viewer's eye gaze during the discovery time
- *screen watching time* - percentage of the visual attention to each screen
- *transition count* - the number of the gaze transitions between screens
- *transition speed* - the average eye gaze speed at which the viewers perform transitions between screens
- *eye gaze travel distance* - the total distance traveled by the viewer's eye gaze
- *eye gaze travel speed* - the average speed of the viewer's eye gaze.
- *switch time* - percentage of time during which the viewer's eye gaze travels between screens.

Probst et al. [11] designed a distributed display environment as a response to the prolonged sitting that has increased in the recent years and is connected with increased health-related risks. Some organizations demand its employees to leave their desks for exercising each few hours. In the environment designed by Probst et al. user doesn't leave work for short periods of time for exercise. In this environment the user has two monitors connected to a single workstation and can switch from sedentary to stationary work. This solution is both good for the productivity of the system user and his health. Because of this, the stationary solutions for the workplace need to be included when creating natural and ambient user interfaces.

Another approach to the multi display work environment considers tangible user interfaces. It was examined by Lee et al. [12]. In this approach low cost infrared (IR) tracking was used that allowed the users to directly interact with digital products with touch. IR tangibles allow natural user interactions, as users could control the displayed object with touch. This made the objects on the screen behave similarly to a touch screen device. However this solution can be achieved with the use of touch screens as they are becoming more affordable. Although, this solution can still be useful for high resolution screens and the screens are not getting dirty from the constant touch interaction.

Endert et al. [13] used chair's rotation in an environment with large size monitors and high pixel density to identify the users' activity. In this solution a special device is connected to the chair of the system user. This chair needs to be rotatable on wheels. When user wants to observe part of the display, (s)he rotates him/herself on the chair. As (s)he rotates, the system moves the mouse cursor on the screen according to the chair rotation. Drawback of this solution is the need of a special device connected to the chair. Also it has diminished use in the smaller workstations. The user after rotating the chair still needs to focus look and move the cursor towards the desired destination. Same results can be nowadays achieved through the use of devices that observe the user (kinect, eye-tracker or ultrasound sensor) and are unobtrusive for the user.

B. Ambient user interfaces

Ambient user interfaces surround the user and (s)he can interact with them with the use of input-output devices or with his/her actions. Ambient user interface is aware of him/her and adapts its behavior according to his/her needs, which means that the ambient user interface uses an artificial intelligence. Because of this, ambient user interfaces are called *ambient intelligent*. In this computing paradigm the conventional input and output media no longer exists [4]. Sensors and processors are integrated into everyday objects in order to support the inhabitants. Ambient intelligence system has the following characteristics:

- *Context aware* - it exploits the contextual and situational information.
- *Personalized* - it is personalized to the needs of each individual.
- *Anticipatory* - it anticipates the needs of user without needing mediation
- *Adaptive* - it adapts to the changing needs of individuals
- *Ubiquity* - it is embedded into environment
- *Transparency* - it fades into background of everyday life.

It is already present in some environments and is still under the research focus.

Work of Lee et al. [14] addresses the third dimension of such interface with a head mounted device that calculates the point of regard of the user in space, not only identifying the x and y position of the point of regard, but also the depth depicted by the z position. Kocejko et al. [15] also focused on the head mounted device. They use this device for improving the gaze estimation with the use of the position of the users' head in space. However head mounted solution is obtrusive for the user and is not satisfying the characteristics of the ambient intelligence system.

Giovanni et al. [16] conducted survey of the ambient intelligence in health care. In this environment an ambient intelligence can be used for autonomous and pro-active healthcare services, for example monitoring the health status of older adults or people with chronic diseases and can be assistive for individuals with physical or mental limitations. There are two groups of devices in the health care that monitor the user. First one is *body area network* (BAN) which consist of sensors attached to the clothing or the body. This is an obtrusive approach since the users can feel discomfort caused by these devices. The advantage is that these devices can collect data about the user that are unobservable by remote devices. Second one is *wireless mesh sensor network* (WMSN). This is created by sensors embedded into the environment that monitor the properties of the environment. This approach is unobtrusive and can monitor multiple inhabitants at the same time. However, these sensors can't measure the heartbeat or sweating of the inhabitants.

Use of the ambient intelligence in assisted living for the elderly people was analyzed by multiple researchers. Kleinberger et al. [17] created an assisted living laboratory. In this laboratory they use: *ambient sensors* in switches, blinds and power sockets to track elderly persons' activities, *position tracking solutions* - smart carpet equipped with radio frequency identification and ultrasonic and radio-frequency-based movement sensors in the ceiling, *intelligent walking aid* that recognizes falls and notifies the central assistance system, *vital data monitoring devices* that are worn (bracelets), *autonomous robot transportation platform* - remotely controlled assistant for emergency situations, *interactive TV* and *audio and visual devices* for multimodal interaction with the elderly. Most of these devices can be used in creating an universal ambient user interface. Nehmer et al. [18] created classification scheme for the living assistance domain (view Fig 1).

Shi et al. [19] focused on using the ambient intelligence in the computer enhanced learning. They created *Smart Classroom* - real-time interactive classroom with tele-education experience. Main idea was moving the user interface of a real-time tele-education system into the 3D space of an augmented classroom, so that the teacher could interact with remote students. In this classroom they used location tracking,

	Emergency Treatment Services	Autonomy Enhancement Services	Comfort Services
Indoor Assistance	emergency prediction emergency detection emergency prevention	cooking assistance eating assistance drinking assistance cleaning assistance dressing assistance medication assistance	logistic services services for finding things infotainment services
Outdoor Assistance	emergency prediction emergency detection emergency prevention	shopping assistance travel assistance banking assistance	transportation services orientation services

Fig. 1. Classification scheme for the living assistance domain [18]

microphone array and multimodal interaction technologies. Since many sensors are already present in this environment, it could be further improved with identifying the involvement and the attention of the students in the class.

C. Natural user interfaces

Natural user interface is similar to the ambient user interface. The difference between natural and ambient user interface is that while the user needs to anticipate and learn how to work with an ambient user interface, in natural user interface it comes naturally for him/her, as this environment is structured to behave according to his/her understanding of the world. Natural user interfaces benefit from the gestural interaction.

Norman [20] identifies basics about the natural user interfaces. Problem with interpreting gestures is that they do not leave any record of their path. Gestures are difficult to discover, in contrast with GUIs in which important elements are displayed and easy to discover. Norman states that a lot of research is needed for the natural user interfaces, since the gestures are unconstrained. Metaphors of real use also need to be carefully considered.

Recognizing attention of the people in a natural user interface is particularly important since it can be used for better organization of the interface. Birnholtz et al. [2] investigate the users' awareness beyond the desktop used for face-to-face interaction through computers. They identify three behaviors that are associated with interpreting the user attention, *glancing*, *gazing* and *moving closer to the point of interest*. People quickly assess their environment with glancing. It shows that the person is not focused. If the person starts gazing on something, it means it gained his/her attention. Lastly when person moves closer to some object, it displays his/her interest towards the object. All these can be measured unobtrusively to the user through the use of the special devices, such as kinect and eye-trackers.

III. Summary

As the multi-display environments are becoming popular [9], there is the need of creating the objective measures for the evaluation of such environments. Preferably these measures need to be adjustable for different domains. There are some basic measures set by Vatavu and Mancas [10]. These measures are designed for use with eye-tracker in a simulated workplace. The use of these measures can be redesigned for field tests, with the use of devices that can be transported from place to place. However, the displays in the field test are organized in different ways, so it needs to be taken into consideration before creating the measures.

Measure of the multi-display environments can be achieved through a special laboratory, in which all equipment is adjustable and can be adapted to the needs of the experiment. Since it is used in a laboratory set-up, it can be enhanced with the use of additional devices, such as cameras and microphones, that collect data about the experiment and its participants. Although, laboratory can never fully simulate field tests, since computer systems in real workplace could be outdated and person behave differently when under observation [5].

Sensors and technological devices are being invented rapidly and are more affordable for the wider population. Natural user interface laboratory should be developed for analysis. However, before creating natural user interfaces, it is needed to fully understand the user behavior. This problem is addressed through ambient user interfaces that are allowing research of natural user behavior in his/her environment.

Firstly, an ambient user interface with motion, audio and visual sensors needs to be created. In this environment we can inspect the users' behavior and methods of evaluating such environment. The sensors in the environment need to be hidden, so users would behave naturally. Midas touch is problem connected with the use of users' gaze in human-computer interaction. Solution by Stellmach et al. [21] aims on overcoming the Midas Touch problem with connecting the gaze controlled interaction with the touch-and-tilt device to indicate desired reaction. This approach could be utilized in an ambient interface with gestures.

There are four main challenges for the future research in ambient and natural user interfaces [16]. First one is an artificial intelligence. It is not needed to solve this problem immediately, as the AI that would help the users in the user interface is the last step of creating a natural user interface. Second one is design and human factors. When creating a user interface we need to take into consideration the accessibility of its elements. Longer exposition to the electromagnetic fields form wireless sensors raises concerns about the possible health hazards. Third one is security, since the sensors would collect large amount of data of each person. Fourth one is the social and ethical issue, since the systems are supposed to work automatically for the user.

First interest of our future work is creating measures and evaluating the multi-display environment in different domains, such as classrooms, pharmacies or power plants. Main interest is creating an adaptable environment, which utilizes the ambient user interface and develop objective measures for this interface. These measures should use data from devices, such as kinect, eye-trackers or ultrasonic sensors, to identify and evaluate the actions of the user, for example the time the user needs to perform an action or the movement of the user in the ambient user interface. Last interest is analyzing the different devices that could be used in the ambient and natural user interfaces.

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Multilayer Motion Control System for Mobile Robots with Differential Drive

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***Abstract*—This article presents work done during last year of PHD study, focusing on designed motion control system for mobile robots with differential drive.**

***Keywords*—motion control, mobile robot, differential drive.**

I. Introduction

The main feature of mobile robot of any kind is to move from point A to point B. this may seem as easy task, but when taking the actual position of the robot as feedback of motion control, things can get a little bit complicated. Motion control described in this article can be implemented on almost any type of mobile robot with differential wheeled or tracked chassis.

Such a type of robots are noways widely used in service robotics, as household appliances or for educational purposes. Some of them are for example warehouse mobile robot Kiva, robotic vacuum cleaner Roomba or mobile robot for education Khepera.

II. Previous work

The whole motion consists of multiple control elements, which we divided into several layers, where the outputs from higher layer is input to lower layer. Besides motion control, the mobile robot control system includes software modules such as:

1) hardware Abstraction layer - provides connection between specific electronics and software of the mobile robot,
2) localization / odometry - calculate robots actual position based on data from internal sensors using kinematics of the robot,
3) user program / Communication interface - allows control of the entire mobile robot using communication interface or using functions,
4) multisensor Data Fusion - fuses measured data from multiple sensors into one more precise result,
5) diagnostics - based on the data from sensors and the data from mathematical models determines faults of the sensors and state of the system.

The whole mobile robot control system is shown in Fig. 1.

In the previous articles we presented diagnostics system to detect faults of sensors and actuators and to detect current state of mobile robot. This diagnostics system used mostly hardware redundancy of on-board sensors, that measure the same property using different methods [1]. Data from this sensors are fused together using multisensor data fusion into one more precise and robust result, which is more resistant to individual errors [2].

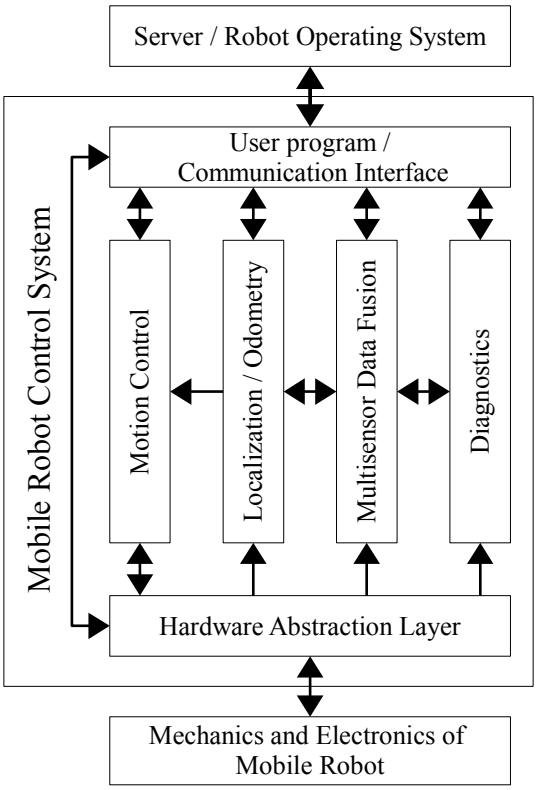

Fig. 1. Robot control block diagram

Localization using camera system to determine absolute position of robot to eliminate cumulative error caused by slippage between wheels and surface was described in [3].

III. Motion control system

The motion control system was separated into four levels. Every level can be controlled using user program or via communication interface. These levels are:

1) wheel speed regulation,
2) robot speed control,
3) motion control to waypoint,
4) bezier curve generation.

Every higher level uses functionality of all lower levels. The dynamics of the mobile robot is counted in restrictions on maximal linear and angular speed, acceleration, deceleration. The motion control system was described in more detail in [4].

A. Wheel speed regulation

This is the most lower layer of motion control system and it is used to handle all the functionality around regulation and control of DC motors, which includes regulating the current flowing trough coil of the motors, regulating speed of the wheels and controlling modes of the motors using H-bridges. to control there are used two PID regulators for each wheel complemented by optional feedforward component to enhance quality of regulation [5].

B. Robot speed control

This layer uses kinematic model of mobile robot, which is used to calculate linear and angular velocities of mobile robot to linear velocities of the individual wheels. It is also used to handles acceleration/deceleration, when the desired speed is set from outside of motion control system.

C. Motion control to waypoint

Motion control layer consists of two parts. One part handles forward/back motion control along the line and the second one rotate mobile robot around the axis. Outputs from this layer are linear and angular velocities, which are used as input to lower layer.

1) Motion control along the line: uses reference waypoint, current position and destination waypoint to control the motion of the robot. First, the line passing trough the waypoints is calculated, then the distance and angle of robot from this line are calculated. Lastly, motion control law, the desired linear and angular velocities are calculated.

When two or more waypoints with the same type follow each other, control automatically switches between them, as the robot approaches individual waypoints, which results in one fluent motion.

2) Rotation around the axis: is used to turn mobile robot to absolute angle or turn about given angle. This motion is executed by setting linear speed is set to zero controlling only angular speed.

D. Bezier Curve Generation

The highest layer is used to generate set of waypoints based on current position, orientation and speed and desired end position, orientation and speed. These generated waypoints are then used as input to lower layer, where they are executed one by one.

E. Case study

Motion control system described above was implemented on MiroSot mobile robot and some sample trajectories were measured to evaluate designed control system. First trajectory shown in Fig. 2 is motion set by individual waypoints and illustrates avoiding an obstacle. The second one shown in Fig. 3 is trajectory generated by Bezier curve. This type of trajectory is used when the mobile robot needs to have certain heading at the end of the motion.

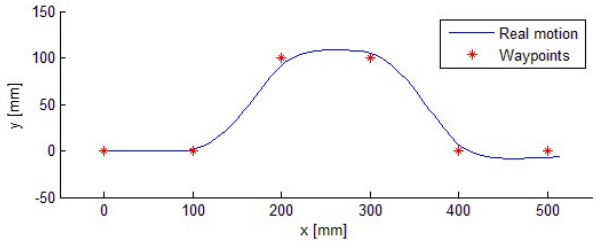

Fig. 2. Motion control trajectory set by individual waypoints

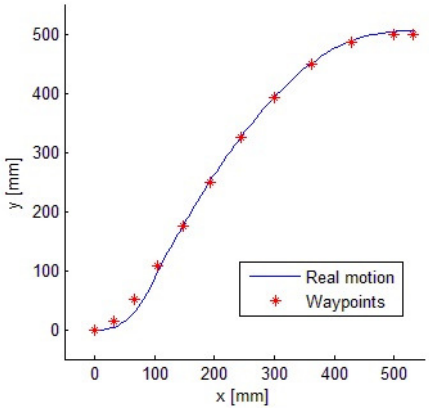

Fig. 3. Motion control trajectory generated using Bezier curve

IV. Future work

In further work we want to combine presented motion control system with diagnostics and multisensor data fusion described in previous articles to achieve more precise motion, with the reduction of errors in localization caused by faults of the sensors or by slippage between wheels and surface.

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Navigation of autonomous vehicles based on Intelligent Sensor Systems

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***Abstract*— Paper presents description of Unmanned ground vehicle and graphical interface. System is based on sensor Kinect and procedures for mapping and localization. Part of this paper is devoted to the design of a physical model of the experimental vehicle for the implementation and verification of mapping and navigation algorithms.**

***Keywords*—Kinect, ROS, mapping, localization, UGV, DSP**

I. Introduction

The current trends of modern robotics tend more to the development of small unmanned autonomous vehicles. These vehicles are capable of self and long-term performance of the tasks set in unfamiliar surroundings without full external operator intervention. Dissertation thesis solves a highly topical issue in the field of modern robotic systems with a focus on the development of an autonomous mobile vehicle using operating systems based on the latest technologies for a more efficient, faster and more reliably to fulfill its goals in unknown environment. The concept of the robotic system in the context of the autonomy of mobile robots includes the areas of knowledge of methods of locating the position of robotic systems, the methods of mapping the unknown space, and algorithms for their intelligent navigation, decision-making and management. Important is the area of knowledge of sensory systems to create maps of unknown environment based of camera systems (machine vision). Machine vision is currently the world's most modern trend towards substitution of expensive sensors operating on the principle of laser or ultrasonic distance measurements. Therefore, the paper uses the Kinect sensor camera system. Kinect is based on the transmission of laser structured light patterns and their deformation when reflected from obstacles, creating depth images associated with classic images from the RGB camera. The use of this sensor is currently a worldwide trend in attention developer of robotic systems. [1][2][3]

II. Unmanned ground vehicle

Many papers verified methods or obtained data only in simulations. [4][5] Therefore, the main goal of the thesis is to build experimental UGV for research purposes. For the implementation and verification of mapping and navigation algorithm has been designed experimental model. The prototype of experimental model is based on the RC car chassis Traxxas Slash 1:10 TQ RTR. The chassis steering is Ackerman type. The intention of Ackermann steering is to avoid the need for tyres to slip sideways when following the path around a curve. The geometrical solution to this is for all wheels have their axles arranged as the radii of circles with a common centre point. As the rear wheels are fixed, this centre point must be on a line extended from the rear axle. This is the main difference between classical robotic type of chassis and this car-like type. Disadvantages are inability to turn in a place and more difficult odometry. According to these disadvantages we need to design and modify control system. Vehicle steering and DC motor are controlled by Digital Signal processor (DSP). DPS also obtain and evaluate data from ultrasound sensors and encoder. Vehicle has a powerful DC motor Titan 550 12T which can easily reach speed around 40km/h. This fact along with overall weight of vehicle led us to conclusion that vehicle need some type of total stop or safety system. We chose two front and two rear ultrasound sensors which control the minimum distance from object. If any object is too near, because of any reason, DPS shuts down DC motor and vehicle stops. DSP also sending data packets to mini-PC which is our main control system. Data packet contains vehicle actual information like speed and heading. Mini-PC is placed on the platform along with batteries and Kinect sensor. (Fig.1)

Fig. 1. UGV

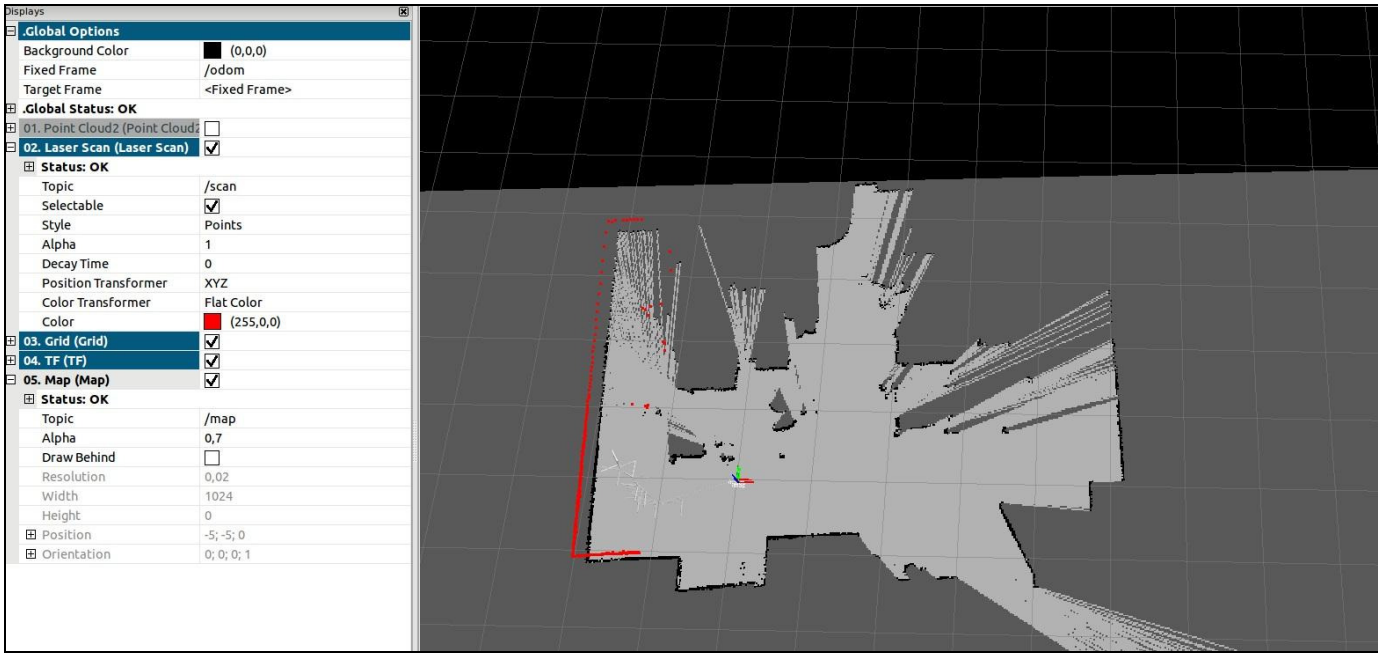

Fig. 2.Visualizationdata in RVIZ

III. Robot Operating System

The Robot Operating System (ROS) is a flexible framework for writing robot software. It is a collection of tools, libraries, and conventions that aim to simplify the task of creating complex and robust robot behavior across a wide variety of robotic platforms.[6] ROS is trend in the field of robotics and automation, which allows to create a complex real-time control system. These systems can manage difficult tasks at the same time. This is the main reason we consider the ROS as our superior control system.

We are using ROS as a tool for evaluating data from Kinect, mapping, localization and visualization of the whole process. The point of this is using existing ROS packages and libraries while we create new package. Advantage of packages in ROS are wide versatility and "black box" principle. Basically, we can create own package on specific robot and then use that package on different robot, for example much bigger. Also system is based on "black box" principle. We do not need to know what is inside in package (equations, calculations, etc.). We need to know inputs (subscribers), outputs (publishers) and parameters of the package.

Therefore, our package for mapping, localization and vehicle control could be applied to any system which complies given specifications.

IV. Graphical User Interface

The graphical user interface (Fig.2), based on data from sensor Kinect, has been created for interaction between the user and mapping as well as localization process. The main task was to create a graphical interface that will display current environment. Also, we need to render and analyze RGBD map of the environment. For this pusrose we used a tool RVIZ. RVIZ is a ROS toolbox for 3D visualization, displaying sensor data and state information from ROS. Using RVIZ, you can visualize a virtual model of the robot. Also, we can display live representations of sensor values coming over ROS topics including camera data, infrared distance measurements, sonar data, 3D model of UGV and more. Our interface shows mapping and localization of UGV. We are using Kinect depth image data to create fake laser scan. This scan is transformed into the map. Map is updated by fake laser scan and odometry at the same time. This approach can eliminate pose and localization errors. Next step is to implement 3D mapping of environment.

V. Conclusion and Further work

The Unmanned Ground Vehicle is capable of mapping and localization in an unknown environment by itself. It can't operate in an outside environment. This disadvantage can't be eliminated by replacing Kinect sensor with Laser scanner. This change will raise the cost of the UGV. For further work, it's recommended to apply 3D reconstruction of the environment. The UGV could then be used for useful purposes. Also, add some optional features into a vehicle or the environment like charging station and detailed telemetry.

Acknowledgment

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Neural networks and their practical applications in speech recognition

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***Abstract*—Proposed work deals with neural networks (NNs) in the automatic speech recognition (ASR) system. There are main practical applications mentioned in this paper. These methods are theoretically described and refer to the practical usage. The goal of the work is to show different practical considerations and explain their usage.**

***Keywords*—speech, batch, reproducibiliy, dropout, bottleneck layer**

I. Introduction

Human speech is the principal medium for transmitting information. Many laboratories are still trying to create a system, which could recognize the speech and transform it into the text. The automatic speech recognition (ASR) system use MFCC features and hidden Markov model (HMM) - Gaussian Mixture model (GMM) [1].

Since the large databases, powerfull systems and better knowledge were obtained, the neural networks (NNs) became a reality [2]. A reaction speed of the neural signal in the human body is 400 km/h.

The NN have many nodes (neurons) which are mutually connected with links (axions) [3]. Neural network model consists of input, hidden and an output layer. The number of hidden layers can be different and it depends on an application. When the number of hidden layers is more than one, we speak about deep structure [4], [5].

The paper is organized as follows: the first section deals with a batch size selection which has minimal variance and their extended version mini batch training converge faster. Further are descriptions of training process reproducibility and network architecture. Next part describes the dropout technique. Neurons need to be less depend on other neurons in the dropout technique. The bottleneck layer has very low number of hidden units and the input information is forcing represent in the lower dimension. The last section deals with future plans.

II. Batch size selection

The easiest batch selection is the whole training set. If a goal is to minimize the empirical loss on the training set, the gradient estimated from the whole training set has a minimal variance. Although a goal is to minimize the expected loss the gradient estimated from whole training set has a smaller variance than a gradient estimated from the subset of the training data.

We can also use the stochastic gradient descent (SGD) [6], which is sometimes referred as online learning in the machine learning literature. SGD actualizes the model parameters based on self-training sample gradients [7], [8]. One sample gradient does not affect the whole training set. This technique is hard to parallelize on the same computer.

The compromise between batch training and SGD training is mini batch training, which computes the gradient based on mini batches of training samples. The gradient estimated from mini batches is unbiased and variance is smaller than in SGD. It can be easy parallelize with other mini batch and converge faster [9], [10].

III. Reproducibility

Training samples are transported to the training process in the random order and model parameters are initialized randomly also, in the DNN training. This observation will raise the interest about the reproducibility of the results of the training. If we want to compare two algorithms or models, we can run the experiments multiple times, each time with new random values. We need to report the average result and the standard deviation. If we capture many conditions, we can get completely the same model and test results when we run the training process twice.

In the large training set is often desirable to stop the training in the middle and then continue with training from the last check-point. Some mechanisms need to be built into the training mechanism to guarantee that restarting from the check-point will give the same results if the training never stopped. An elementary trick is to save all significant information, such as model parameters, current random number, parameter gradient and so on in the check-point file [4].

IV. Network Architecture

The network architecture is one of the main parameters that need to determine. Since each layer can be considered as a feature extractor of the previous layer, the number of neurons at each layer should be large enough to capture the fundamental patterns. This capturing is especially important at several lower layers. The first-layer features are more variable and it requires more neurons to model the patterns as other layers [11].

For the tasks of speech recognition used in Deep Neural Network was introduced, that 5-7 layers with 1000-3000 neurons at each layer worked very well. It is often easier to find

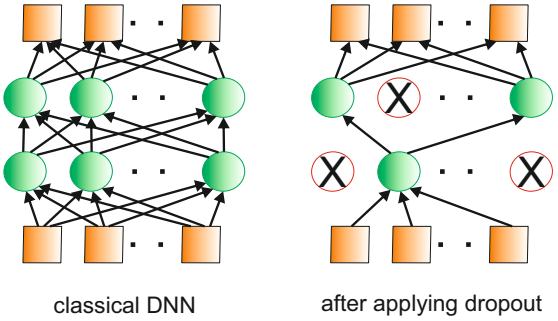

Fig. 1. Dropout technique

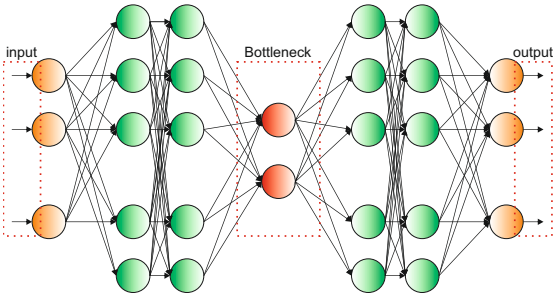

Fig. 2. Bottleneck architecture

wide (more neurons) and deep (more layers) configuration than narrow and shallow one. There are many good local optima that work similarly on a wide and deep model [4], [12].

V. Dropout

Dropout is a well-known technique to control overfitting. The main idea is to eliminate a certain percentage of the neurons in the each hidden layer during training 1. It means that each random combination of remaining neurons need to perform well even without absence of other neurons. The neurons need to be less dependent on other neurons [13].

This technique can be referred as a technique which adds random noise to training data. In DNN, some weights need to be deleted to remove the effect of random noise [14]. Dropout reduces the capacity of DNN and can improve generalization of the resulting model [4], [15].

VI. Bottleneck layer

The features with the narrow profile are conventionally generated from the DNN. One of the layers (especially middle one) has a very low number of neurons when to compare with other layers. This special structure named bottleneck. Generally, the input information is forced to be represented in lower dimension 2. This technique can be referred as an approach of nonlinear dimension reduction [7].

In the recent years was introduced that bottleneck feature increases the performance of the conventional system. Although there were important enhancements reached the performance is still lower than the hybrid system (CD-DNN-HMM) has [10], [16]. NNs with bottleneck layer were applied for a speaker and language recognition [17], [18].

VII. Future work

Based on actual knowledge of neural network system, future work will be oriented on the design of bottleneck layer which should increase the conventional system performance. Our goal is to find an optimal percentage of randomly omitting neurons using dropout technique. The next step will be in design a method that will modify the neural networks by using dropout technique in the training process not once, but multiple times. As third, we want to design a neural network suitable for keyword spotting system where the words are implying danger.

Acknowledgment

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Non-invasive Detection, Localization and Estimation of Breathing Frequency of Static Persons by UWB Radar System

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***Abstract*—Detection and localization of non-moving human targets is becoming crucial in the last years. In contrast to moving targets localization is this task a bit more challenging. The movement of a static targets caused by a respiratory motion is barely observable. In this paper an overview of detection and localization methods will be given. In addition, a few methods for estimation of a monitored target respiratory rate will be outlined.**

***Keywords*—UWB radar, respiratory motion, detection, localization, breathing frequency estimation.**

I. Introduction

Ultra-WideBand (UWB) radars are progressive devices used for various type of nonintrusive people movement monitoring. The term nonintrusive here stands for a fact that a radar can operate without any knowledge of the monitored person. UWB radar can be used for monitoring of elder people [1], moving person monitoring [2] or vital signs monitoring [3]. Special attention is given to the moving targets monitoring due to the increasing terrorist threats in the recent years. UWB signal can penetrate through the obstacles and back [4] so the signal processing methods can detect, localize and track human targets. Nevertheless, these known methods does not operate properly in case of appearance of persons that remain on their place. Static person appears as a clutter in comparison with the moving person and it's much harder to detect. In this paper, an overview of the existing methods for static person detection and localization is given.

For purpose of detection, localization and breathing rate estimation, an UWB radar device can be used with advantage in combination with three antennas into multistatic configuration, which consists of one transmitting (Tx) and two receiving (Rx) antennas. Due to the character of the UWB signal, a through-the-wall measurement can be also performed. In addition, the experimental antenna set can be used [5][6].

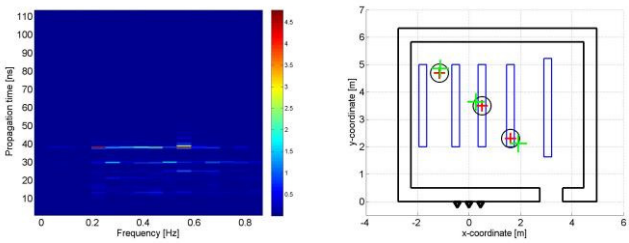
This paper is organized as follows: Section 2 will provide an insight into signal processing methods that deals with static person detection and localization. Section 3 will provide an overview over some methods used for the estimation of the respiratory rate of the static target. In the end, a conclusion will be remarked.

II. Detection and Localization of Static Persons

Detection of the static persons can be maintained as follows. Let's assume the monitored person is situated in front of antennas of a radar. The only movement that is present within the area is the uplift and descend of the monitored person's chest. Amplitude of this movement be easily measured e.g. by a laser telemeter. Each person has its specific chest uplift value, but in common typical values are from 0.2 cm to 0.6 cm [4]. Within a long-term observation, this movement caused by respiratory motion can be qualified as a periodic process with its own frequency. According to [7] this frequency can take values from 0.2 Hz caused by slow, calm breathing up to 0.7 Hz caused by fast, stressful breathing.

A. *Frequency spectrum analysis method*

As it was mentioned before, spectral components belonging to the human respiratory motions can be found within an interval 0.2-0.7 Hz. For estimation of the energy distribution into signal spectrum can be used a spectrogram or a periodogram respectively. In Fig. 1a can be seen energy distribution within a frequency band up to 1 Hz computed by the Welch periodogram method. If such echoes pass through the detection process, a direct calculation localization method [2] can be applied on such signals (Fig. 1b). Usually, detection is provided by Cell Averaging Constant False Alarm Rate (CA-CFAR) or by Order Statistics (OS-CFAR) detector because of their suitability for selected task [8]. A detailed description of this method is beyond this paper. A reader interested in the method functionality can find more information in [9].

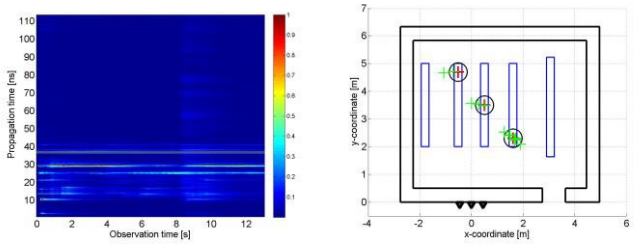


(a) (b)

Fig. 1: Energy distribution onto the signal propagation time computed by Welch periodogram (a) and final localization of the targets (b)

B. *Signal filtration method*

Power estimation of the input signal provides an information about target presence at the certain distance. This can be achieved by the root square of the properly filtered signal. Power estimation can be seen in Fig. 2a, estimated target positions localized by the direct calculation method are depicted in Fig. 2b.



(a) (b)

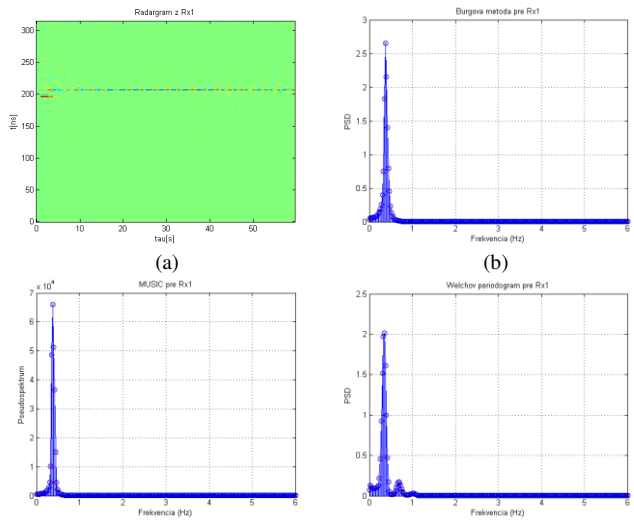
Fig. 2: Estimated power for three present targets (a) and simple localization output (b)

It can be seen from Fig. 2b that this method provides multiple target position estimations. Therefore it could be possible to apply some form of simple tracking algorithm. Nevertheless, this is a subject of our future research.

III. Respiratory motion frequency estimation

Besides static person localization, there is an effort to estimate person's breathing rate. For this purpose can be used following methods: Burg method, MUSIC (Multiple Signal Classification), S-transformation or some form of periodogram (Welch, Lomb etc.). Here, following methods are presented as a result of analysed signal (Fig. 3a):

- Burg method of maximum entropy (Fig. 3b),
- MUSIC method (Fig. 3c),
- Method using Welch periodogram (Fig. 3d).



(a) (b)

(c) (d)

Fig. 3: Input radar signal (a), dominant respiration frequency computed by (b) Burg method, (c) MUSIC method, (d) Welch periodogram

All of the tested methods provide very similar results. Estimation of the person's breathing frequency is quite accurate (around 0.3 Hz). These measurements and signal processing methods are tested in association with our student Jakub Demčák.

IV. Conclusion

This paper provides a rough overview of signal processing methods used at our department to properly treat an UWB radar signals. All methods are intended to use on UWB radar signals that contain a reflections from one or multiple static persons.

For static target localization can be used method using Welch periodogram or method using several filters and simple power estimation. The biggest advantage of the first method is quite good accuracy, because of the averaged result. Therefore occasional errors are easily eliminated. On the other hand, second method provides multiple estimations of the target positions. Our ongoing research consists in matching the most suitable tracking method to achieve even better result than Welch periodogram.

As for the breathing frequency estimation, this is also one of our ongoing research. With the cooperation with our student we are trying to find a robust method with the following parameters:

- low computational complexity,
- acceptable accuracy,
- suitable for real-time application
- integration with the detection and localization methods

Most of the results presented here was or even will be published within a relevant scientific sources.

Acknowledgment

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Open Controllers of Precise Robotic Drives

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***Abstract*—The paper deals with most recent research results and knowledge in the field of open robotic controllers and describes importance to use of this approach in research, development and academic field.**

***Keywords*—HIL simulators, motion controller, robotics, servo control.**

I. Introduction

A standard commercial industrial robot usually does not enable open access into its control system. It presents a kind of black-box where the user cannot change the robot program. Robot can be programmed just with function predefined by its manufacturer. This type of solution guarantees safe and reliable operation which is the most important factor for use in industry. Producers of robots usually offer different tools for offline programming and simulation of an end effector motion. This tools and programming languages are always fixed to use with robots of the given manufacturer only. But on the other side, for development of robot algorithms and also for teaching purposes it is often required that the control algorithms should be known and modifiable. Open control system is also suitable if cooperation of different production robots is required, because they are usually not compatible.

An open control system is required for verification of custom control algorithms in laboratory. It should allow easy modification of control structure, ability for adding axes, possibility for connection of additional components and integrating it to control structure and also monitoring functionalities from high level robotic controller to low level control of servo drives. This article is divided to three general topics - Hardware-in-the-loop robotic simulators, controllers based on open source robotic middleware and authors research in this field.

II. HIL SIMULATORS

In general Hardware In the Loop (HIL) simulation is a method that is used in development and testing of complex real-time embedded systems. In HIL simulation the controlled plant (mechanics, sensors, actuators) are replaced by physical components. It is typical for HIL, that commercially available scientific software is used like MATLAB/Simulink. Recommendation for building a reliable simulation system is in using of customizable industrial components for testing purposes. It guarantees seamless operation on hardware side of simulator.

A. Satellite docking simulator based on hardware-in-the-loop hybrid contact model

Authors of this paper presents a HIL docking simulator concept (Figure 1). Requirement for the docking simulation is that its 6-degree of freedom robots have to mimic the dynamic response of two satellites during contact/docking. To simulate this situation, HIL simulator was build which consists of two robots, controlled in position/impedance structure. This approach enables to evaluate, test and optimise the process of satellite docking. In addition, this paper presents the effect of parameters which are time delay, stiffness, damping and masses of the simulating satellites on the stability of the HIL docking simulator. [1]

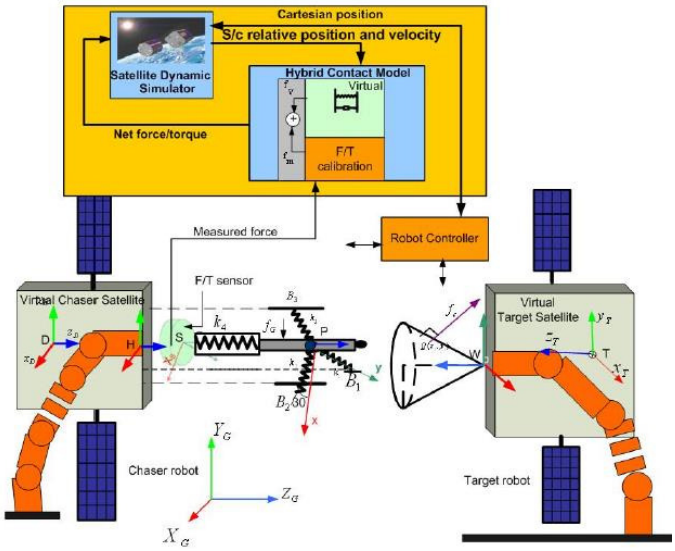

Figure 1 Schematic of the HIL docking simulator

B. Optimizing Industrial Robots for Accurate High-Speed Applications

The research team from Johanes Kepler University of Linz presented their results from research in optimisation of dynamic properties of a Stäubli RX130L type industrial manipulator. Higher level control system was implemented in industrial PC communicating via Powerlink with six ACOPOS servo drives, which power the synchronous motors of the robot (Figure 2). Developed time/energy optimal motion planning strategy, based on optimal exciting trajectories solved by nonlinear optimization techniques was combined with model-based control. Algorithm was verified in HIL simulator based on above mentioned system. [2]

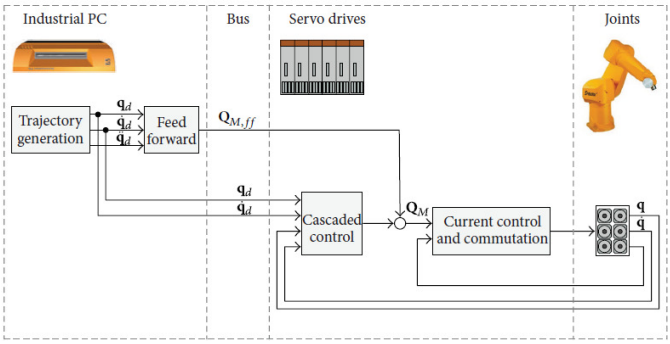

Figure 2 Control system block diagram

C. Design and implementation of a path planning for a high-dynamic handling system

Another project from Linz, based on similar motion control hardware programmed in MATLAB/Simulink designs a software framework used for a high dynamic pick and place handling system. It allows easy programming with simple scripts to easily adapt motion sequences and teach positions. Developed application includes path interpolation algorithm with Bezier-curves for position and orientation of tool center point. [3]

D. Motion Control of Industrial Robots in Operational Space: Analysis and Experiments with the PA10 Arm

In this paper novel robot motion control method was developed based on resolved motion rate control in operational space, combined and compared with conventional hierarchical control in joint space. The stability of this control theory was mathematically verified. Developed strategy was verified in HIL simulator with Mitsubishi PA10-7CE robotic arm in loop. As a control system a conventional PC was used with necessary applications to make it real-time. Control rules were programmed via Visual C++ also as a robot visualisation. Experiments showed good results both in standalone and combined operation mode. [4]

E. Open Software Architecture for Advanced Control of Robotic Manipulators

This work describes an experimental platform that allows the implementation of model-based and sensor-based control algorithms in Stäubli industrial 6-dof robot using a component-based software methodology. Developed system mainly focuses on its modularity with wide range of connectable sensors and another additional components. Series of experiments were carried out to validate the performance of the proposed architecture. This work is heading to develop an open robot control system with implemented impedance control. [5]

F. Real-Time Control in Robotic System

Main goal of this topic was not to build a real time control system, but to make a detailed analysis of robotic real-time controller, which was broken down to atomic tasks and requirements like timing issues or bandwidth problems. Research summarizes requirements to a modern robotic control system and highlights importance of safety, making this system fault-tolerant. A number of results were presented for the control strategy, as well as an implementation on a real robot. [6]

G. An Open-architecture Robot Controller applied to Interaction Tasks

Authors of this project made a control system reconstruction for an old REIS Robotics Rv15 type robot to verify their developed control architecture. This reconstruction was necessary, because an old system had a factory closed software architecture and low computing power for advanced control tasks. Low level control for each joint is deployed on dsPIC30F60110A high end digital signal processorMotor controllers were connected through USB-UART bridge to host computer and CAN communication was also implemented to meet real-time requirements. Additional interaction sensor was added to an end effector to verify implemented impedance force control algorithm. [7]

H. PC Based Control Systems for Compliance Control and Intuitive Programming of Industrial Robots

This article presents similar control method like it was described in previous section. Force and impedance control strategy of robotic arm with force/torque sensor placed on the end effector of robot and also an improved algorithm for sensorless compliance control based on force/torque observer. Each approach was tested on different hardware configuration. Concept with sensor feedback runs on PC with real-time Linux kernel which communicates through ARCNET network card with servo controller of Mitsubishi PA-10 robot. The sensorless approach uses the same computing hardware to control COMAU NS-16 robot. [8]

I. Hardware in the Loop Robot Simulators for On-site and Remote Education in Robotics

In this study, a new approach in HIL simulation was introduced as an education tool in robotics, mechatronics and control. The paper discusses the development and utilization of HIL specifically in the instruction of control design aspects of robotic courses. Two motors driven by high performance DSP boards were used there. One motor represents the joint actuator and the other one is used for the generation of all the torque components affecting that joint for the robot system in consideration. Thus, it is possible to evaluate the overall performance of the robot and its end-effector by combining the data from each simulated joint-associated dynamics pair. The proposed HIL architecture is combined with a client/server software configuration to allow remote connection for students. [9]

J. Design and Simulation of Robot Manipulators using a Modular Hardware-in-the-loop Platform

This research presents a similar approach to design of robotic HIL simulator using load emulation for each joint. Loading and driving motor were coupled together through a torque sensor and loading motor was controlled to generate torque typical for desired application (Figure 3). Various situations could be simulated using this approach and control system can be well tuned for every condition. Developed control system was tested and validated also with real robotic hardware specifically with CRS CataLyst-5 lightweight manipulator. The validation of the RHILS platform was successful, and the platform exhibited similar performance characteristics to the original controller under both normal and aggressive operating conditions. [10]

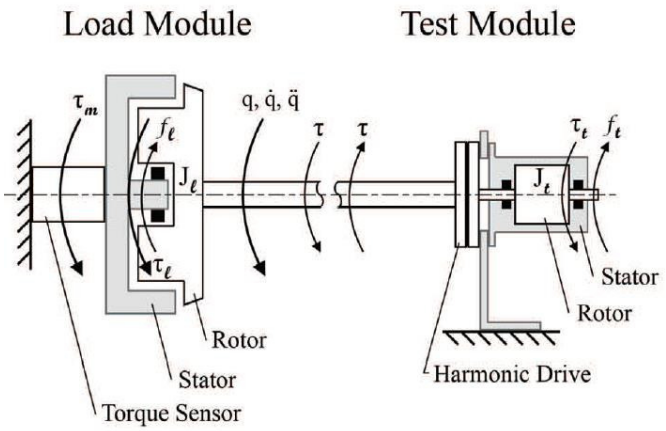

Figure 3 Load and test modules [10]

III. CONTROLLERS BASED ON OPEN SOURCE ROBOTIC MIDLLEWARE

A. Comparison Study of Robotic Middleware for Robotic Applications

This study gives an overview of different actually popular robotic middleware. The document contains descriptions of systems such as Robot Operating System, RT-Middleware, OPRoS and Orocos. Mentioned software was also compared in this report. The comparison was made in different aspects, which are important both from the view of the user and the developer. Comparison results for different aspects are listed in Table 1. [11]

Table 1 Comparison of robotic middleware [11]

	RT-Middleware	ROS	OPRoS	Orocos
Open-source	Yes	Yes	Yes	Yes
Windows	Yes	No	Yes	Yes
Linux	Yes	Yes	Yes	Yes
Composite component	Yes	No	Yes	No
Robot software architecture independent	Yes	Yes	Yes	Yes
Graphical IDE	Yes	No	Yes	No
Simulation environment	OpenHRP, Choreonoid	Stage, Rviz	OPRoS Simulator	No
Real-time	Yes	No	Planned	Yes

B. ROS-I interface for COMAU robots

Beside the community, international manufacturers of industrial robotic systems also noticed a potential of open robotic framework. That is the reason why most of them released an open source code to control their robots. Grouping them together leaded to initiative to make an industrial version of Robot Operating System ROS-I. This article presents a ROS-I interface developed to control Comau manipulators. The developed system lets the user to control both a real robot and its simulated counterpart using the same controller. It allows to use any motion planning library inside ROS instead of using Comaus motion planner. Experiments showed that both the virtual and the real robot performed the same movement during the execution of both assignments. This proves that using the same controller in both simulated and real environment guarantees the same motion interpolation. Experiments were performed on Comau Smart5 SiX industrial manipulator. [12]

C. Connecting ROS to a real-time control framework for embedded computing

As was mentioned in comparison study of robotic middleware ROS don't have hard real-time capabilities. That's the reason why time critical applications like motor control loops shouldn't run on it. Authors of this article made a solution for this problem with keeping complex control algorithms running in ROS on resource rich computer and deploying time critical tasks to embedded real-time computing hardware interconnected by TCP/IP communication. This solution is also suitable for mobile robotics, where power consumption of computing hardware is important. [13]

D. RT-ROS: A real-time ROS architecture on multi-core processors

Another solution to make ROS suitable for real-time control applications is to make it real-time. Authors of this paper separate real-time and non real-time tasks running at the same time on different cores of computer. With this approach they developed a real-time ROS which can communicate with nodes of non RT ROS running on different core through shared memory. This solution reaches low communication times, less than 100 ns between nodes of ROS. The results show that RT-ROS can be utilized for real-time robot control. Developed control system architecture was tested with 6-DOF modular manipulator. It consists of joint modules communicating with controller PC over CAN bus. Also simulation with RVIZ for motion teaching was implemented. Presented results shows, that this innovative solution is a viable way to make ROS as a part of robot controller. [14]

E. An open control system for manipulator robots

In this paper, authors present an implementation of a robot controller using OROCOS. The operating system is Linux with applied RTAI real-time patch. The control system concept is based on a distributed architecture where each processing node is associated to a joint of robot. CAN bus was used for real time communication with sensors and actuators. For testing hardware the Janus robot was used, which is an anthropomorphic two-armed robot, with eight degrees of freedom in each arm, and a stereo vision system. Each joint is driven by DC motors and contains an incremental encoder. Presented results showed usability of OROCOS robotic middleware to build an open source robot control system. [15]

IV. AUTHORS RESEARCH IN THE FIELD OF ROBOTIC CONTROLERS

A. Development of Motion Control of Legs in Six-Legged Robotic Vehicle

This research is focused on development of control structure for driving system of the legs in six-legged robotic vehicle (Figure 4). Joints are driven by hydraulic actuating units with different mechanical structures. For motion control of actuating units a conventional cascade structure was used with inverse

linearization of controlled variables. Control performance was improved by pre-compensation of controlled and observed variables from inverse dynamics model. [16], [17]

Figure 4 Six-legged robotic vehicle [16]

B. HIL Simulator of Drives of an Industrial Robot with 6 DOF

This paper deals with design of HIL simulator of SEF ROBOTER SR25 type 6-DOF industrial manipulator driven by industrial frequency converters of SINAMICS S120 type. The communication was realised by CAN bus with master control system with QNX OS executing control algorithms in real-time. Development of control algorithms and user interface is performed by MATLAB/Simulink, in combination with RT-LAB software support for HIL simulations. Block diagram of a control system is illustrated in Figure 5. Developed control system was verified experimentally and resulting measurements show good agreement with expected results. [18], [19], [20], [21]

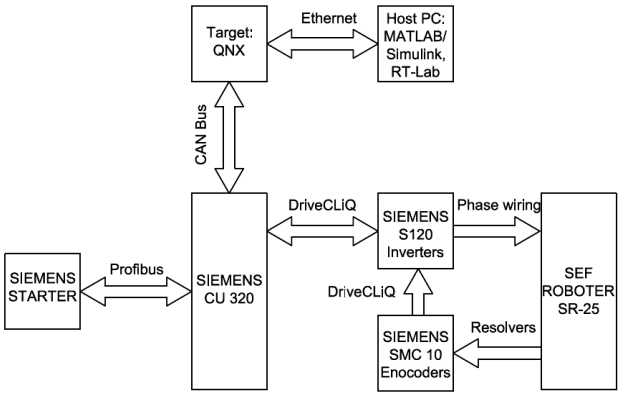

Figure 5 Block diagram of the HIL simulator [18]

V. CONCLUSIONS AND FUTURE WORK

The main goal of this study was to present actual trends in field of robotic control systems. Mainly applications typical for industrial robotics were mentioned, but also several new approaches were presented, which may be usable also in field of service robotics. In future is expected a fusion of several principles based on HIL simulators and robotic middleware to make an easy programmable control system combined with ready for use packages of open source Robotic Operation System.

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PLC based HIL workplace for identification of complex drives control method

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***Abstract*— This paper focuses on developing a universal Hardware-in-the-Loop simulation workplace which is used in education and research in the field of technological dynamic systems modelling and control. The workplace concept is based on generally available and employed hardware (Programmable Logic Controller) and software means (MATLAB), configured to enable work on practically any type of both continuous and discrete system. The workplace is mainly being used for solving tasks related to electric drives, mechatronics, robotics and technological plant control. A case study involving a DC motor drive control is included in the paper.**

***Keywords*—hardware-in-the-loop (HIL), programmable logic controller (PLC), DC motor, dynamic system**

I. Introduction

Owing to their complexity, many educational and research tasks in the field of industrial technological systems require laboratories to include equipment and physical models that would enable execution of various types of verification experiments. Examples of such means are hardware-in-the-loop (HIL) simulations that differ from computer simulation as they involve actual hardware and are not limited with a software-based representation of the system. [1]

There are two main types of hardware used today to make HIL: multi-core CPUs and FPGAs, only a few concepts are built on PLCs [2]-[5].

A new concept of hardware-in-the-loop (HIL) simulation workplace that serves as an effective tool for education and research tasks related to modelling and control of technological dynamic systems is designed and discussed in this paper. The workplace concept is based on generally available and employed hardware (Programmable Logic Controller) and software means (MATLAB), configured to enable work on practically any type of both continuous and discrete systems. Furthermore, this concept, hardware of that is built on PLCs, enables standardized remote access over the internet through tools used in the Windows operating system.

A case study involving a DC drive included in the paper also demonstrates the simplicity and effectiveness of the HIL simulation workplace. [6]

II. HIL simulation workplace design

The basic requirements that need to be met by the HIL simulation workplace, which served as a basis for its basic concept, are as follows:

1. The workplace has to cover the widest possible range of dynamic systems.
2. With regard to the system being modelled it has to have standardized inputs and outputs, i.e. +/-10V, 4-20mA, 24V DC, 230V AC, PWM outputs, fast pulse inputs for incremental sensors, etc.
3. Workplace maintenance has to be as simple as possible and it has to be fast, as during the education process it is not possible to have to wait for several weeks for a repair.

It is with the above requirements in view that the workplace concept illustrated in Fig. 1 was designed.

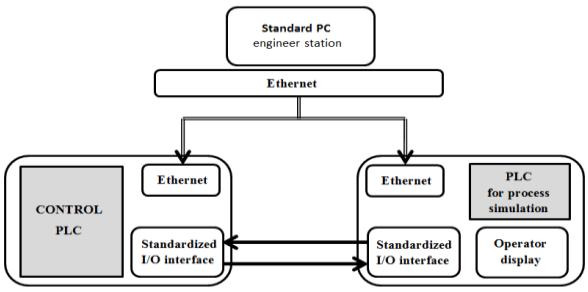

Fig. 1. Basic concept of HIL simulation workplace

In compliance with the concept specified above, an HIL simulation workplace was built having the following parameters:

1. Standard PC i3-2120 CPU 3.3GHz, 4GB RAM with OS Windows 7 Professional. Matlab version R2012a with B&R Automation Studio toolbox for direct transfer of block diagrams from Matlab to the PLC from B@R was installed on the PC. For PLC programming, software package *B@R Automation Studio* version 4.2.
2. PLC for technological process simulation by B@R type PP500 with operator display 5PP520 1214-00 TFT SVGA 12.1″. For more simple process models the PLC enables reaching sample time as short as 1ms.
3. PLC for technological process control by B@R, type X20 CP 1484-1.

III. Case study – HIL simulation of a DC drive control

As an example of the use of the HIL simulation workplace

for educational purposes we present the simulation of control of the angular speed of an electric drive with DC motor.

The DC drive is described by the following state discrete dynamic equations:

$$x_{1k} = x_{1k-1} + \frac{c\phi T}{J} x_{2k-1} - \frac{T}{J} M_z$$

$$x_{2k} = x_{2k-1} + \frac{K_a c\phi T}{T_a} x_{1k-1} - \frac{T}{T_a} x_{2k-1} - \frac{K_a T}{T_a} U \qquad (1)$$

On their basis we created a block diagram of the DC motor in Matlab/Simulink which can be directly converted into the PLC using the Automation Studio Toolbox by B&R installed in Simulink (Fig. 2). In this way, any dynamic system model created in Simulink can be implemented in the relevant PLC without detailed knowledge about its programming environment.

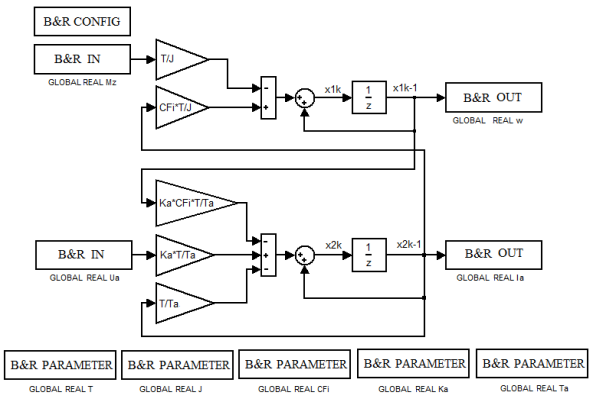

Fig. 2 Block diagram of DC drive in discrete form prepared for conversion into the PLC

For current and speed control of the DC drive we chose a discrete PI controller described by the following equation:

$$u_k = u_{k-1} + q_0 e_k + q_1 e_{k-1} \qquad (2)$$

where u_k and u_{k-1} are the controller output values in the relevant sampling steps, e_k and e_{k-1} are control deviation values (at controller input), and q_0 & q_1 are its parameters. The parameters of DC motor and controllers are specified in the Appendix. The structure of the controllers for current and speed control of the DC drive implemented in the PLC is illustrated in Fig.3.

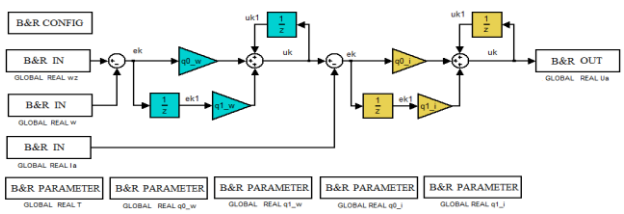

Fig. 3 Block diagram of PI controller for both current and speed loop of the DC drive

Verify the correctness of the solution by comparing the responses of the relevant quantities acquired from the simulation (Fig. 4) and those acquired from the HIL workplace (Fig. 5).

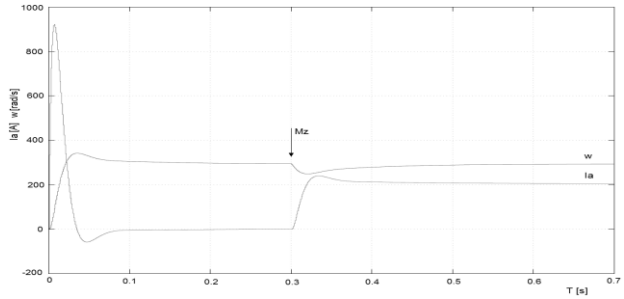

Fig. 4 Responses of drive under control to step change in desired speed (w_{des}=270 rads^{-1}) and load torque (M_z=140 Nm)

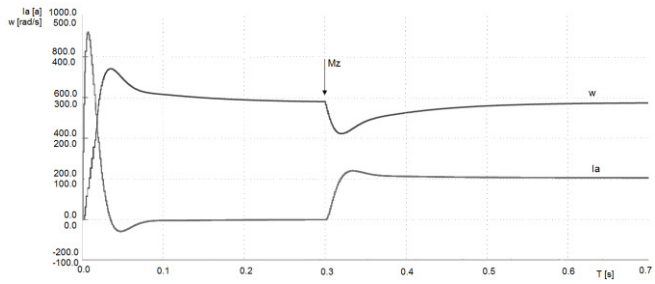

Fig. 5 Responses of controlled drive from HIL simulation workplace to step change of desired speed (w_{des}=270 rads^{-1}) and load torque (M_z=140 Nm)

Comparison of plots of output quantities from Fig. 4 and Fig. 5 shows that the dynamics of DC drive control is in both cases practically the same and therefore the control PLC can be directly interfaced with the real DC drive.

IV. Conclusion

The paper describes the concept and implementation of a universal HIL simulation workplace serving both educational and research purposes in the field of modelling and control of dynamic technological systems. The concept was based on the requirement of the widest possible versatility in exploitation of the workplace, and the requirement of using standardized, generally available equipment for its implementation. The whole procedure of solution of a selected task by means of the HIL workplace is illustrated in the paper on the example of control of a drive with DC motor. The main goal of PhD. study is intelligent methods of complex drives control using method HIL.

Appendix

DC motor: n_n=2800 ot/min^{-1}, Pn=2,3kW, M_n=146 Nm, I_n=12,3 A, J=0,0315 kgm^2, U_{aN}=220V, R_a=1,6 Ω, L_a=8,8 mH, cϕ = 0,7 Vs, K_a=0,625 Ω^{-1}, T_a=0,0055 s, M_z = 140 Nm

Parameters for discrete PI controllers were calculated based on KSO (speed loop) and KOM (current loop) method: current loop: q_{0I}=2, q_{1I}=1,8 speed loop: q_{0w}=5, q_{1w}=4,95

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Parallelization of optimization algorithms for the purpose of usage in cloud robotics

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***Abstract*—Cloud robotics is getting more popular each day. This is the main reason we are developing a cloud support for robots in our lab. This support will consist of calculation power which can spare the resources of robots. We are creating a system, which will be composed of so-called AI-bricks for the purpose of creating a behavior for a robotic platform in a scenario, where robot interacts with a human or with another robot. My goal is to create a brick with population optimization algorithms, which will be able to be used for this purpose. I also tested some approaches for parallelization and built a prototype of a cloud platform which will be using this AI brick. The research done in this area is shown in this paper.**

***Keywords*—cloud robotics, communication technologies, evolutionary algorithms, parallelization.**

I. Introduction

Cloud robotics [1] is a relatively new field which combines robotics and cloud computing. The definition of cloud computing is in [2]. There were multiple systems created which can be named as systems from the field of cloud robotics. Those systems are for instance RoboEarth [3] and DaVinci [4], which are the most popular systems from this area.

When we want to use the cloud for creating a service with some algorithms, we need to think another way as we are not creating the algorithms locally on some computer. We need to apply modifications as for instance parallelization, because without them, there will be no advantage when the algorithm will be used in the cloud. For this, we created techniques which can parallelize algorithms.

As the algorithms from which I am creating the so-called AI bricks, we have selected evolutionary algorithms and particle swarm optimization. In evolutionary algorithms can be two approaches to parallelization used. The first one is the parallelization when using only one algorithm [5]. The second one uses multiple algorithms which can run parallel at the same time and can communicate with each other or can be absolutely independent. We are focusing only on the latter choice when multiple algorithms can run at the same time.

The paper is organized as follows: The second chapter briefly describes the research done previously in the field. Chapter III describes the research done by the author in the actual year. The last chapter is the conclusion, which also describes the future work which we want to accomplish in the next year.

II. Previously solved problems in parallelization and communication methods from the cloud

AI bricks [6] are cloud services applying artificial intelligence methods. Each AI brick can work as a single service which can be used for solving a problem. But they can also be used as a part of a bigger system. Because the AI algorithms are cloud services, a communication method needed to be used. It is because the client (which can be for instance a robot) and the service, or multiple services need to communicate. The communication using WCF [7] was previously created. This method was usable, but we wanted to test also other possibilities.

The next figure shows the parallel approach with multiple evolutionary algorithms.

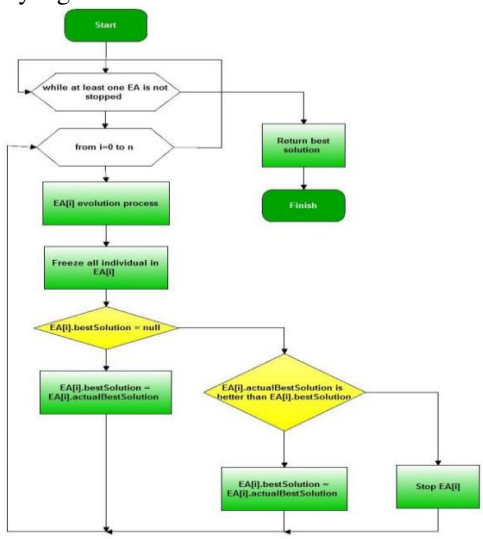

Fig 1: The diagram of the interference of waves based method [8]

In this paper, the same multiple algorithms were used, but the solution was a combination of solution parts separately found with the different algorithms.

III. Newest tested approaches in parallelization and communication methods from the cloud

We tested multiple communication methods for communication with the cloud services. It is because we wanted to know, which one is the best for our purpose to make an AI brick.

First, we tested three methods, which cannot be used for near real-time communication [9]. Those methods were concretely Windows communication foundation (WCF), WEBAPI and OData.

After that, we tested three methods based on websockets. Simple experiments were done with those methods for teleoperating a robot. The results of those experiments were shown in [10].

After the all six methods for communication had been tested, we started to build a teleoperation platform for controlling robots. This system will serve as the main core of a mechanism for learning from teleoperation. This system is named Wizard of Oz (WoOz) [10].

WoOz was tested for controlling multiple robots [11]. For the purpose of testing we used three robots from our lab: the humanoid robots Nao and Hanson, and the Qbo robot. We were also controlling the robot Pepper based in Japan.

The WoOz is based on the WEBAPI technology. This technology is slower than the ones based on websockets. But the biggest advantage was, that a client calling a WEBAPI service is simply applicable to the Linux operating system. This is needed because most of the robots use Linux OS. Another advantage is that it is only called as calling libraries with artificial intelligence methods. So we can just develop a library and make a cloud service. And then we can call the methods via the HTTP protocol.

Beside of the cloud part, we were developing a library which uses nature-inspired optimization methods. For now, it is implementing basic evolutionary algorithms with few operators and methods and the Particle swarm optimization algorithm. It is also implementing the parallelization approach showed in [8], which is distributing each algorithm to another core. The user can tell via parameters of the function how many cores should be used.

This library was used in two types of experiments. In the first experiment, the same approach was used as in [12]. Multiple same algorithms were used, where they are searching for the solution per parts. It was used to create a small complex rule set, where those rules will be able to copy a behavior of a learned neural network. The results showed that the regulator with the ruleset created with the multiple evolutionary algorithms was able to classify correctly 75 % of patterns. It was tested only on a relatively easy task. This result can be better when we will use other technics with various algorithms.

Another approach used multiple particle swarm optimization algorithms. There were 10 algorithms used; all were the same. They were used for finding the minimum in functions from the website [13]. The difference between this and the previous experiments was that here was each algorithm searching a different search space [14]. The experiments showed that this approach was able to find the optimal results after a few cycles.

IV. Conclusion

The paper showed the research done by the main author in the previous year. The research that was mainly focused on parallel usage of multiple optimization algorithms and technologies for communication can be used for the purpose of creating a so-called AI brick. After testing six methods, WEBAPI was chosen as the method which is most usable for this purpose.

This paper also mentioned a teleoperation platform, which was based on the WEBAPI technology. This teleoperation platform was developed in the same way as we are planning to develop AI bricks. Also, some experiments were done with the parallelization using multiple algorithms.

In the future, we want to focus more on the parallelization using multiple algorithms, testing methods for migration, communication between the algorithms and make it a library. From this library will be an AI brick created. The methods will be used for data analysis and learn from teleoperation (from the data obtained from teleoperation).

Acknowledgment

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Powerline ampacity system

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***Abstract*— This paper deals with powerline ampacity systems, specifically depending ambient conditions on transmission capacity of power line. Ambient conditions vary on the hydro meteorological impacts and local impacts. The hydro meteorological impacts include ambient temperature, wind speed and amount of sunlight radiation. Local impacts include location management and level of environmental pollution.**

***Keywords*—power line ampacity system, transmission ability, overhead line, ampacity.**

I. Introduction

Power lines are technological devices that transfer electrical power from primary sources or secondary sources to the point of consumption or to the consumer.

Power lines can be realized as overhead lines or as isolated lines. In terms of implementation, they are preferred overhead lines. The main reasons are lower investment costs and lower operating costs. Another reason is simple maintenance of overhead lines.

We know these distributions systems in Slovak Republic:

Low voltage system: 0,4kV

Medium voltage system: 6kV; 10kV; 22kV; 35kV

High voltage system: 110kV

We know these transmissions systems in Slovak Republic:

High voltage system: 220kV

Ultra high voltage system: 400kV

Extensive development of renewable sources requires expansion of transmission capacity of power lines. Despite the fact that power lines are an integral part of the system but their expansion is in seclusion interests.

For these reasons, it is necessary to seek other means of safeguarding the power transmission system. One possibility is operational methods which we monitor the temperature of the electrical wire and ambient influences. These indicate the current permissible current.

To determine the allowable current of the conductor is necessary to determine all factors influencing temperature of the conductor. Subsequent calculation can be determined at any given time under the conditions of maximum load capacity.

This method uses the current leadership and investment represents only the cost of computing software.

II. The Current Status of the Transmission Capacity of Electrical Lines

Congestion problems of power lines appeared with massive development of renewable sources of high output [1][2]. We mean solar and wind power plants if we talk about renewable sources [3][4]. They are often connected to one end of the power system. Electric power, that they supply is often necessary to transfer over long distances. This leads to overload of local power system [5].

The construction of new transmission lines has been in the past and at present is due to timetable and also a commitment to a huge problem.

- The problem of financing the construction of new lines
- The massive construction of renewable energy sources without respecting energy studies
- Contradiction environmental activists

The problem of the low capacity transmission lines are beginning to be observed not only in emergency situations but also in the normal operation [6] [7] [8].

Size of the transmitted power is defined as follows:

$$S = U \cdot I \tag{1}$$

Where:

S – Apparent power

U – RMS Voltage

I – RMS Current

Thus, the size of the transmitted power can be increased by changing the size of the current, voltage, or both parameters simultaneously.

Methods for increasing the transmission capacity:

- Increase ampacity
- Operational modalities
- Methods of increasing voltage
- Extensive solutions [8]

III. Increase Ampacity

Ampacity is the maximum current that can flow through the conductor, without the damage in the short or long term [8].

This current is primarily derived from the maximum permissible temperature, the determination of which varies depending on ambient conditions, particularly then at ambient temperature and the speed and wind direction [8].

Ampacity is thus dependent on these factors:

- Electrical and mechanical properties of the conductor material

- Thermal insulation properties of the material in cables
- The thermal capacity and conductivity of the guide body and its ability to transfer heat to the surroundings
- Environmental conditions

Conductor temperature also affects the size of the ampacity because it prolongs the wires and bring them closer to the ground and increase resistivity [9].

Since the sag depends on the temperature and is difficult to measure, it focuses research on the possibility of detecting the temperature of the conductors from which it then derives sag.

Due to the quadratic dependence of temperature on the size of the amount of current flowing through you can make a general idea about the differences Ampacity as shown in Fig. 1, when the conductor 400 mm^2 increase permissible operating temperature of 10 °C means an increase Ampacity of about 50 to 100 A.

For most prevalent the conductors ACSR this temperature increase means a change sag of 10-15 cm [10].

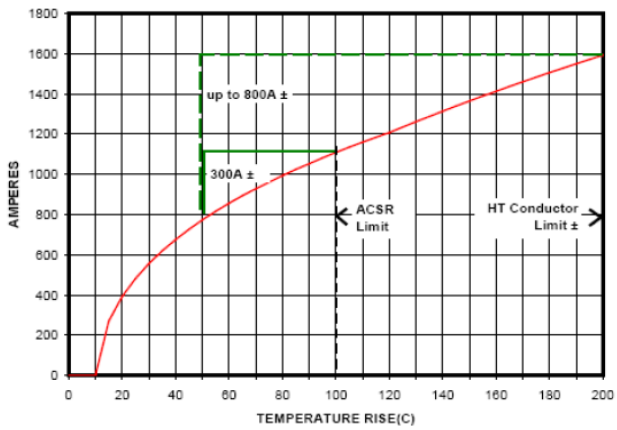

Fig. 1. The dependence of the capacity on the temperature conductors [10]

A. *The methods depend on the conductors*

The first option to increase ampacity is provided maintaining conductors. This method consists in increasing the maximum permissible operating temperature. The most older foreign power lines were rated for an operating temperature of 50°C. The maximum allowable operating temperature of the conductor ACSR is 90-100°C. With this method it is necessary to take into account the increase sag. Therefore, it is necessary to exchange and shortening of the insulator [11].

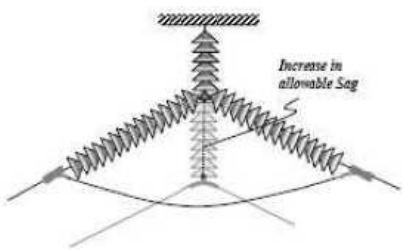

Fig. 2. Replacement of insulators used to increase the height of wires above ground

The second option is replacement conductors. This is an option when the conductors are not adequately dimensioned with respect to the standard. Where we have a reserve in the load bearing structures for the conductors of larger cross section. Despite the high prices occurs to extend the life of power lines. When using a high temperature conductors ampacity can be increased by up to 100%. Of course it is necessary to reckon with the fact that with an increase in temperature of aluminum, increases own resistivity. Among other things, occurring also further the warming due to reactive losses [11] [12] [13].

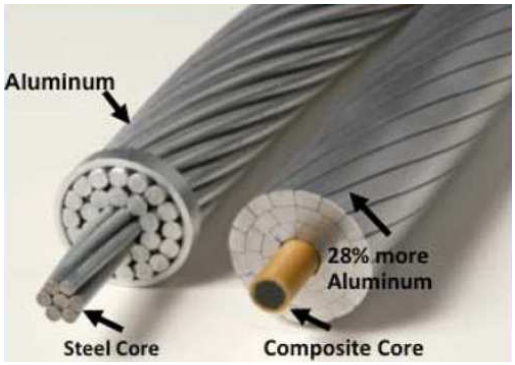

Fig. 3. Comparison of the structure the conductors ACSR and ACCC [13]

IV. OPERATIONAL MODALITIES

This solution consists in the expression of the actual temperature of the electrical conductor and the full exploitation towards the real limits that vary depending on environmental conditions. These are mainly on flow velocity of wind and ambient temperature [14].

Proposal for a new power line is in accordance with standards designed to be safe transmission of electricity even under the worst operating conditions. For these reasons, the management of such capacity is not used [14].

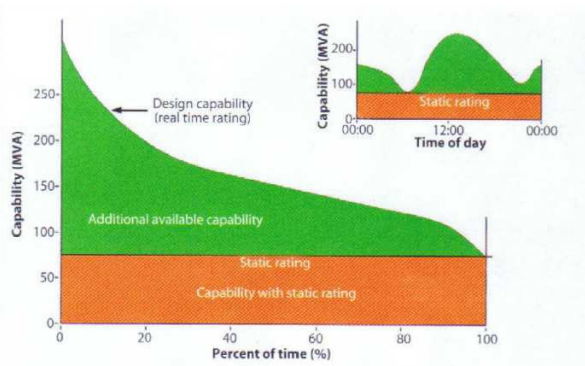

Fig. 4. Static characteristics ampacity for a period of time [14]

A. *Probabilistic methods*

Their principle consists in applying probabilistic models weather conditions in different periods and locations in determining the load limit. The criterion is not the temperature but the maximum allowable sag [14].

We know these probabilities methods:

- The method of crossing the projected temperature
- Determining the absolute probability of failure
- Simulation Methods estimated of security

B. *Real-time monitoring*

Measurement of various quantities related to the current state of the conductors is carried out due to time optimization of Ampacity under given ambient conditions, especially

temperature measurements or sag. With knowledge of the current state of the line, operators can improve planning and management during accidents and emergency situations [14].

That the measurement data used effectively must be immediately after measuring analyze, safely and in time to send to the control center and moreover operators interpret as meaningful information for them, such as e.g. instantaneous reserve.

C. *The temperature measurement of conductors*

Use direct measurement using the measurement systems directly mounted on wire lines at selected locations (local) Fig. 5., or laying the optical fiber directly to the conductors (global) Fig. 6., which allows you to monitor the temperature profile of about every meter up to a distance of several dozen kilometers [15].

Fig. 5. RIBE-Ritherm system [15]

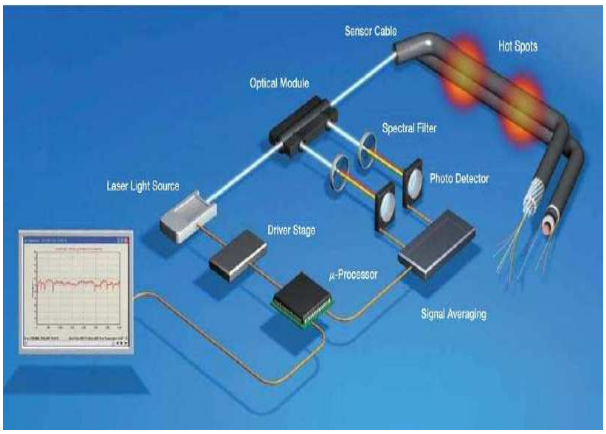

Fig. 6. VALCAP system [15]

D. *Measurement of mechanical tension*

The size of mechanical tension derives from the tension of conductors between the poles and indirectly determines the sag in that section. Sensors are placed between the grounded end of the insulator and an anchor point on the pole [16] [17].

Fig. 7. Location of strain gauges on masts [18]

V. METHODS OF INCREASING VOLTAGE

If the design of poles permits, it is very advantageous to increase the line voltage, and thereby at the same transmit power quadratically reduce losses [18].

With the transition to a higher voltage is beyond an exchange of insulating elements and switching devices are often connected also total replacement of conductors due to the emergence of the corona [19] [20].

A further disadvantages may constitute line redundancy in the voltage level and need long time for reconstruction. Also, problems may arise with height above the ground, which demands with a higher level of voltage is also rising [19] [20].

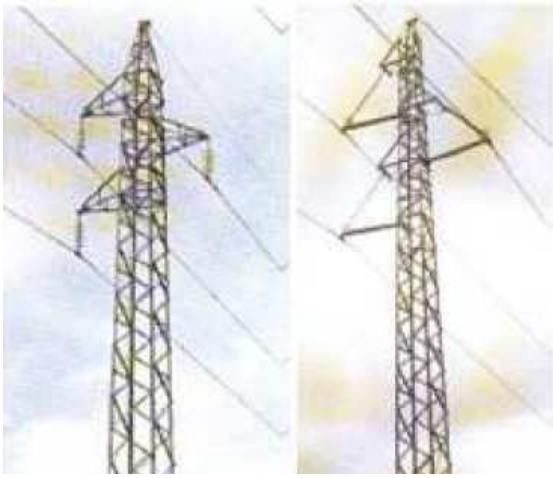

Fig. 7. Changing the line voltage from 66 kV to 220kV

VI. POWERLINE AMPACITY SYSTEM

Conductor ampacity is defined as the maximum permissible load current, which can transmit the conductor without compromising its function. This distortion is mainly caused by exceeding the maximum permissible temperature.

The maximum current that can be transferred over the line, is not a constant value as yet, but is determined for the unsurpassable temperature conductors depending on ambient conditions - particularly ambient temperature and wind flow.

The ampacity depends on:

- electrical and mechanical properties of the conductor material
- thermal insulation properties (the cables)
- ability to dissipate within the conductor generated and received from nearby heat
- ambient weather conditions

It is therefore apparent that the ampacity is mainly influenced by the thermal condition of the conductors, because it determines the extension conductors and therefore sag power line over the terrain.

In determining the maximum transmission capacity we use a method that is based from thermal equilibrium between the conductors and the environment.

At steady state, this equation can be expressed as equality heat gain = heat loss.

The full form of the equation is:

$$P_J + P_M + P_S + P_i = P_C + P_r + P_W \quad (1)$$

Where:
P_J (W) - heat losses in the conductor
P_M (W) - magnetic heating of magnetic field variations AC
P_S (W) - solar radiation
P_i (W) - heating from the corona
P_C (W) - cooling by heat convection – by radiation
P_r (W) - radiant cooling
P_W (W) - cooling from water evaporation

Heating corona P_i, cooling by evaporation of water P_W and heating by changing the magnetic field of alternating current P_M in the equation is usually neglected, from which we get the final equation.

$$P_J + P_S = P_C + P_r \quad (2)$$

In resolving my dissertation work I will be based on this balance equations. It being necessary first to determine the effect of individual components of the equation on the ampacity transmission line. Subsequently combination with each other outside influences determine the overall ampacity of power lines.

We validate the correctness of results in one of the simulation programs to determine the temperature of the conductor at the load current.

Further part of thesis will determine the ability of the transmission lines throughout the day in the selected month of the year. Based on these calculations, we obtain the development and possible current capacity of power lines throughout the day.

A not insignificant part of my dissertation work will be form the calculations of transmission losses. On the basis of the losses it will be possible to determine the optimum and efficient transmission of electricity at a defined current.

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Principles and Applications of Compressed Sensing in Biomedical Signal Acquisition

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***Abstract*—Compressed sensing is an alternative signal acquisition and compression method which allows to sample signals at rate much lower than the Nyquist rate. Simplified sampling tasks and compression of signal can lead to reduction in the power consumption of wireless biomedical sensors attached on or implanted in human body which are used to continuously monitor health functions of patient. This article is a summary of some basic principles and common applications of compressed sensing used in biomedical signal acquisition.**

***Keywords*—Asynchronous sampling, biomedical signals, compressed sensing, data compression.**

I. Introduction

Power consumption is one of the most critical constraints in the field of implantable wireless health monitoring sensors. As the technology of monitoring systems matures, the amount of data they can collect, process, store or transmit keeps increasing. This also leads to growing power requirements which are unacceptable for implantable biomedical applications [1]. The most power consuming block is the transmitter, typically responsible for 60-80% of total sensor's energy usage [2]. Data compression is one of the effective ways to reduce amount of transmitted data. Traditional methods of compression use conventional analog-to-digital converters (ADCs) followed by computationally intensive digital algorithms for data compression [3]. Although these methods of compression are effective, we still need to sample input signal at the Nyquist rate.

Compressed sensing can compress bio-signals with compression factors as large as 10x, which reduces the amount of data transmitted and therefore the total power dissipation of the transmitter. It is an alternative approach to data compression, which takes advantage of the fact that the outputs of many types of sensors are sparse in the time or other convenient (e.g. frequency, wavelet) domain. This allows us to use asynchronous ADCs [1], [4] or random demodulation pre-integration (RMPI) analog-to-information converters (AICs) [5]-[7] and sample the signals in sub-Nyquist rate.

II. Compressed Sensing Background

Important characteristics of a signal, compressed sensing can be applied to, are sparsity and the possibility to obtain the signal with linear combination. Sparsity can be fulfilled for any arbitrary domain, in which the signal of interest can be represented as linear combination [6]. Some biological signals are sparse in wavelet [16] or Gabor (short-time Fourier transform) domain [1]. Electrocardiogram (ECG) signals for example are sparse in wavelet and time domain [1], [2].

Compression is achieved by a simple matrix multiplication

$$\mathbf{x} = \Psi\alpha, \tag{1}$$

where $\mathbf{x}$ is an $N \times 1$ discrete-time signal vector that is K-sparse and compressible in some sparsity basis or frame matrix Ψ (often called a dictionary) of size $N \times N$ where each column is a basis or frame vector ψ_n. By compressible it is meant that the entries of $N \times 1$ expansion coefficient vector α, when sorted from largest to smallest, decay rapidly to zero. By K-sparse signal it is meant, that it can be well approximated using representation consisting of the terms of α with the K largest magnitudes while setting values of the all other terms to zero. According to this definition, signals that have only few nonzero coefficients are compressible as well [7].

The theory introduced in [8], [9] shows that a K-sparse signal compressible in one basis Ψ can be recovered using $M = cK$ linear projections onto a second basis Φ that is incoherent with the first, where c is a constant slightly greater than 1. By incoherent it is meant that the rows of matrix Φ cannot sparsely represent the elements of the sparsity-inducing basis ψ_n and vice versa. The matrix Φ is of size $M \times N$ while $M \ll N$ and consists of random numbers (e.g. Bernoulli, Gaussian, uniform, etc.) [2]. Thus instead of measuring the N-point signal $\mathbf{x}$ directly, we acquire the vector of linear projections $\mathbf{y}$ of size M:

$$\mathbf{y} = \Phi\mathbf{x} = \Phi\Psi\alpha = V\alpha. \tag{2}$$

V is also $M \times N$ matrix and since $M \ll N$, recovery of the signal could not be solved simply by inverting V. *To* reconstruct the original signal in the receiver, we need to solve an underdetermined set of equations, where the number of equations is much less than the number of unknown variables. Due to the given sparsity it can be assumed, that the one solution out of the amount of possible solutions is the right solution, with the sparsest α_0. The recovery of the set of expansion coefficients α can be achieved through minimization of ℓ_0 or ℓ_1 norm. The sparsity K of α_0 is equivalent to ℓ_0 pseudo-norm of α and it is defined as a number of nonzero elements of this vector.

$$\ell_0 : \|\alpha\|_0 := \{n : \alpha_n \neq 0\}. \quad (3)$$

As this definition does not fulfill all norm axioms, it is referred to as pseudo-norm [11] which is used to find the optimal solution.

$$\min\|\alpha\|_0 \text{ such that } V\alpha = \mathbf{y}. \quad (4)$$

But this can only be approached using brute force methods, so it would be preferable to use more general approach and use the ℓ_1 norm. [8]

$$\ell_1 : \|\alpha\|_1 = \sum_{n=1}^{N} |\alpha_n|. \quad (5)$$

The minimization problem then changes into

$$\min\|\alpha\|_1 \text{ such that } V\alpha = \mathbf{y}. \quad (6)$$

This is a convex optimization problem [12] and it guarantees to find a correct optimal solution, if it exists. To minimize ℓ_1 norm classical optimization algorithms can be used.

III. Compressed Sensing Implementations

Mathematical approach on CS differs from the practical implementation in important detail that it considers numeric representations of signal but the real signals are analog quantities. Thus instead of signal vector **x** the measured signal is continuous in time and value and signal sparsity *K* cannot be defined here. In order to apply this approach directly to analog signals, two basic implementations of AICs were developed: RMPI and non-uniform sampling implemented in asynchronous ADCs. These are usually the most discussed CS acquisition system implementations in the literature.

A. Random demodulation pre-integration

In this implementation according to [8], [14] and [15] it is assumed that analog signal $f(t)$ of finite length *T* is composed of a discrete finite number of weighted continuous basis $\psi_n(t)$.

$$f(t) = \sum_{n=1}^{N} \alpha_n \psi_n(t). \quad (7)$$

Then in case where there are a small number of nonzero values of α_n, we may say that analog signal is sparse and compressible. Each of the $\psi_n(t)$ elements may have high bandwidth, but the signal itself has relatively few degrees of freedom.

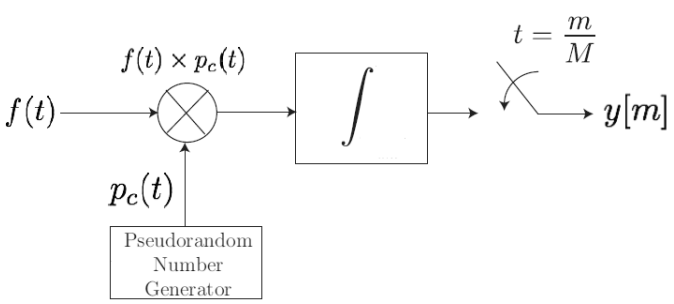

Fig. 1. Pseudo-random demodulation scheme of AIC

Such signal acquisition system consists of three basic components: modulator, filter and uniform sampler. At first analog signal is demodulated by a pseudo-random maximal-length noise sequence containing only ±1's. This sequence is called the chipping sequence $p_c(t)$, and it must alternate between values faster than the Nyquist frequency of input signal. Scheme of such AIC can be seen in Fig.1. The purpose of demodulation is to spread the frequency content of the input signal so that it is not destroyed by the next stage low-pass filter (integrator) which works as the antialiasing filter. Signal is then sampled using standard ADC fulfilling only low demand on sampling rate *M*.

The low-pass filter is used as a simple accumulator that sums the demodulated signal for duration of (1/*M*). The filtered signal $y(t)$ is sampled every (1/*M*) to obtain the measurement vector **y**. After each sample, the low-pass filter is reset. We can describe the output signal as a result of demodulation and convolution

$$\mathbf{y}[m] = \int_{-\infty}^{\infty} f(\tau) p_c(\tau) h(t-\tau) d\tau \Big|_{t=\frac{m}{M}}, \quad (8)$$

where $h(t)$ is the impulse response of low-pass filter. If the input signal (7) is introduced to this equation, we can write

$$\mathbf{y}[m] = \sum_{n=1}^{N} \alpha_n \int_{-\infty}^{\infty} \psi_n(\tau) p_c(\tau) h(t-\tau) d\tau \Big|_{t=\frac{m}{M}}. \quad (9)$$

Now it is possible to obtain values of the ***V*** matrix elements $V_{n,m}$:

$$V_{n,m} = \int_{-\infty}^{\infty} \psi_n(\tau) p_c(\tau) h\left(\frac{m}{M} - \tau\right) d\tau. \quad (10)$$

Advantage of the RMPI method is that it can be used for signals that are sparse in any domain. However, the complex digital post processing tasks (relatively difficult reconstruction of compressed signal) make this system impractical for biomedical and implantable sensing applications.

B. Non-uniform sampling ADCs

When using a non-uniform sampling, the samples of signal are usually taken randomly [17] or asynchronously [1], [4] dependent on the activity of input signal. The sampled signal then consists of samples that are non-uniformly spaced in time. Therefore the average sampling rate of the signal can be much lower than the Nyquist rate.

1) Asynchronous ADCs

Asynchronous ADC according to [1] performs analog to digital information conversion based on deterministic sampling of the input signal based on the activity level of signal. Such conversion is suitable for burst-like signals (e.g. ECG or EMG) sparse in the time domain.

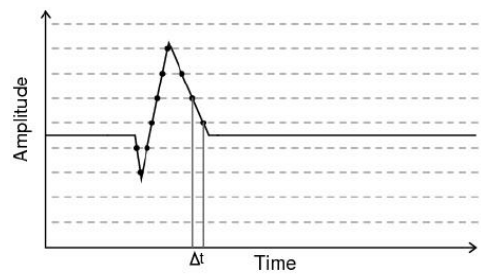

Fig. 2. Example of an asynchronously sampled signal

The principle can be explained using Fig. 2, where an asynchronously sampled signal is shown. The dashed lines in the figure represent 2^M-1 quantization levels, where *M* is the

resolution of ADC. As it can be seen, a sample is taken only when signal crosses one of the quantization levels. In order to record the shape of the signal, there is need to calculate the time interval Δt between samples. The output of ADC then consists of amplitude-time data pairs. These are further processed using asynchronous digital processor or synchronized and processed using conventional synchronous processor [10]. In case of implantable application, synchronization can be performed after the signal is transmitted out of the implant in external receiver to save the power [1].

Practical implementation of the regular asynchronous ADC [1] can be described using Fig. 3. First assume that the counter has just stored the digital value D_{OUT} corresponding to the amplitude of the input signal V_{IN}. This value is used as the input to the first digital-to-analog converter (DAC) and after adding +1*LSB* also as the input to the second DAC, where *LSB* is the least significant bit of the ADC. Output voltages of both DACs are then compared with the input signal amplitude using two comparators. When the input signal amplitude changes by ±*LSB* the value of D_{OUT} stored in counter is incremented or decremented by *LSB* using digital logic. Working principle of the digital logic is clear from Fig. 3. Then the outputs of DACs are updated again as mentioned above according to the new D_{OUT}. The output of the ADC remains at fixed value until there is no change (or change less than ±*LSB*) in the input signal.

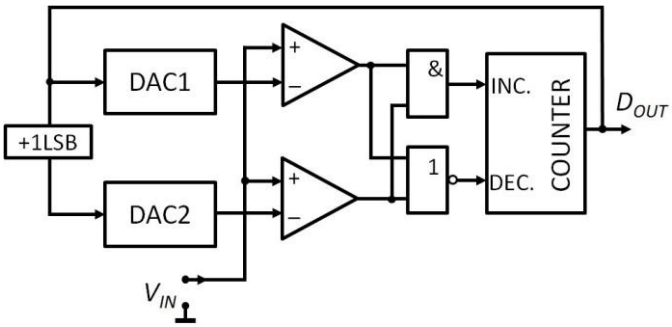

Fig. 3. Architecture of regular asynchronous ADC

This conversion process is free of quantization error because it generates output only when the input signal crosses an analog level defined by the DAC. Nevertheless the ADC does exhibit a quantization error based in time, resulting from the clock jitter in measurement of the level crossing instant. Another error in time is due to the delay in comparator and DAC when making decision. The delay can result in overload distortion for fast changing input signal and the ADC will fail to track such signal.

Typically the DACs in asynchronous ADC utilize quantization levels that are fixed and arbitrarily set to the worst case slope of the input signal. This can result in arbitrarily large number of generated samples. In order to avoid this problem it is possible to increase the size of the quantization levels of DAC or to set the size adaptively as proposed in [4].

Such method provides significant data compression and the signal is easy to recover, because output amplitude-time data pairs can simply consist of only ±1's that represents whether the signal amplitude level is rising or falling and the time difference between the two successive samples.

2) Random sampling ADCs

The input signal is sampled using standard ADC, where an analog register (sample and hold circuit) is used to sample the signal according to random sampling clock and hold it in order to be acquired by ADC driven by a uniform sampling clock [18]. Another approach is to randomly discard samples from uniformly sampled signal. In both cases the time grid of length *N* is defined, whose step length is an interval given by uniform sampling rate of ADC. Such interval defines the maximum frequency component that can be acquired from the signal and the samples exists randomly on integer multiples of this interval. Assume that the randomly sampled signal consists of *M* randomly taken samples within the *N* length time grid. Then the average sampling rate is equal to M / N multiple of the uniform sampling rate of ADC. [17]

According to theory described in section II, we can consider that the analog signal given to the input of ADC is transformed to vector **x** consisting of *N* samples and then reduced to an *M*-size vector **y**, where $M < N$, using linear transform represented by $M \times N$ size matrix Φ obtained from $N \times N$ identity matrix, where only M rows are randomly selected.

Method is suitable for signals that are locally sparse in Fourier domain (short-time Fourier representation), when the signal can be well approximated by few local sinusoids of constant frequency. CS theory says that if there is no noise, multi-tone signals with *k* active frequencies can be recovered exactly using slightly more than *k* samples of the signal.

IV. Practical Applications of CS for Biomedical Signals

CS methods can be used in wide range of applications, usually where the power consumption of transmitter is a critical factor. In case of biomedical signals they are usually used in implementations of body area networks (BAN). BAN is a network of wearable or implantable devices used for continuous remote monitoring of vital parameters of patients suffering from chronic diseases. For example in [20] CS is used in telecardiology sensor network to remotely monitor cardiac condition, where ECG, photoplethysmogram (PPG) and ballistocardiogram (BCG) are acquired and it is shown that wavelet transform using Db2 and Db4 wavelet is the most appropriate for implementation of CS on cardiac signals and that it is possible to reduce the sampling rate of these signals to approximately 1/10.

Rather than using a wavelet basis a dictionary trained with patient-specific ECG signals is used for reconstruction in method discussed in [21]. After the signal is quantized a redundancy removal is provided based on the fact that when a fixed matrix Φ is used during acquisition, consecutive ECG frames yield similar measurement vectors. Therefore, a vector containing the difference between consecutive measurements or the difference between instant measurement and mean measurement is further processed and coded using Huffman encoding.

Another application proposed in [22] shows the possibility of using CS for automatic detection of absence seizures in electroencephalogram (EEG) signals for diagnosis of epileptic patients. It was realized that the compressibility of the EEG signal significantly differs if it is recorded before, after or

during seizure. Thus the compressibility can be used as decision criterion for the automatic detection of seizure and automatic selection of an appropriate compression ratio when transmitting the signal. In this case a Gabor wavelet (Gaussian envelope sinusoids) dictionary was used. However it was found that common (seizure free) neural signals have no good sparse representation in time or any common transformation domain. Because of that, they are often referred to as non-sparse signals. Good recovery quality cannot be achieved here using common CS algorithms. This is usually solved by various dictionary-learning algorithms, for example some approaches were presented in [23], where the block sparse Bayesian learning was proposed for recovering the EEG signal. Similar signal recovery methods are suitable for fetal-ECG signals because these signals are also considered to be non-sparse.

Magnetic resonance imaging (MRI) used for clinical diagnosis of soft tissues is area where the power efficiency is not as critical as the large amount of data that need to be acquired. Thus MRI scanning is very time-consuming and as the scanning time is longer more motion from instruments and patients is recorded leading to image artifacts and distortion. To reduce the scanning time it is possible to use CS as introduced in [24] where a one- or two-dimensional principal component analysis (1D-PCA or 2D-PCA) is used to reconstruct the image from highly (at about 20%) undersampled data. These methods are using a data-adaptive dictionary where the sparsity basis is dynamically adapted according to available database of objects.

Next possible application where it is desirable to shorten the scanning time is computed tomography (CT). In [25] a CS is used for acquisition of CT images leading to reduction the X-ray exposure time. Therefore the radiation dose received by patient is minimized without reducing the image quality.

V. Conclusion

As it was shown, CS is very perspective method for implementation in biomedical signal acquisition because of noticeable power saving or reducing the acquisition time. However, the reconstruction of a signal acquired using such method is relatively complex task and the success of this approach heavily relies on the sparsity of an acquired signal in its representation under the dictionary matrix. Unfortunately, finding an appropriate dictionary matrix for some biomedical signals is very challenging task.

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Proposal of enhanced Hybrid Social Based Routing for MANET (May 2016)

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***Abstract*—In this paper is proposed a routing algorithm for mobile ad-hoc networks - An enhanced Hybrid Social Based Routing algorithm for MANET-DTN (HSBR) as optimal solution for well-connected multi hop mobile networks (MANET) and/or worse connected MANET with small density of the nodes and/or due to mobility fragmented MANET network into two or more sub-networks or islands. This proposed HSBR routing algorithms is fully decentralized combining main features of both Dynamic Source Routing (DSR) and Social Based Opportunistic Routing (SBOR) algorithms. Protocol was simulated and compared with MANET solutions and Delay Tolerant Network (DTN) solutions.**

***Keywords*—MANET routing protocols, DTN routing protocols, Hybrid MANET-DTN routing protocols**

I. Introduction

Transfer of data is important task in our society in every situation. The problems arise, when infrastructure mobile network is unusable (destroyed by natural disaster or the infrastructure does not exist). The Mobile Ad-hoc Network (MANET) can solve this problem thanks routing protocols, such as reactive, proactive or their combination [1][2][3]. Higher mobility and sparse deployment of mobile nodes have direct impact on stability of END-to-END connections between Source – S and Destination - D node during communication. Usage of standard MANET routing protocol is ineffective. Mobility of nodes affords advantage by transport of data thought MANET environment, which is provided by Opportunistic (OPP) Routing Protocols in Delay Tolerant Network (DTN) [4][5][6][7][8][9]. From this reason are protocols, which combined MANET routing and direct transfer between nodes (DEVICE-to-DEVICE) by OPP routing, more effective and is called Hybrid MANET-DTN routing methods [10][11][12][13][14][15][16][17].

Hybrid MANET-DTN routing methods provide transfer of data in well-connected networks, in sparse networks, in the network with high mobility of nodes by END-to-END paths, directly transfer between couple of nodes (DEVICE-to-DEVICE transfer) or using of partial paths locally inside of island, when END-to-END path fails globally.

In this paper is proposed a concept of Hybrid MANET DTN routing mechanism, which is compared with MANET routing solution Dynamic Source Routing – DSR [18] and DTN routing solution based on single copy transfer [6]. These methods was simulated in MATLAB and concluded.

II. Proposal of Enhanced Hybrid Routing Protocol

We tried to compare routing methods, which are usable for different MANET environment. We focused on standard MANET routing protocol DSR [18]. This protocol had to be modified due to integration of DTN mechanism store-carry-forward. The main idea of Hybrid MANET-DTN routing protocol is integration of social information which are spread during finding of path and usage of locally usable partial path to some nodes, which can be helpful for selection of temporary source, or virtual source for future communication.

A. Extension of DSR routing

Some mechanisms of DSR routing protocol [18] had to be extended due to future application for Hybrid solution:

1. Route request (RREQ) was extended about the destination's additional message (social based inter-node relation information);
2. Probabilities of message delivery was calculated based on user profile table (consist of personal and contact profile);
3. Detection and usage of the last node (in connection with S) on disconnected path was perceived as virtual source (V_S);
4. Two main mechanism for DSR finding of path – Route discovery and Route maintenance had to be adopted.

B. Inclusion of opportunistic routing

This mechanism provided transfer of data between devices directly (DEVICE-to-DEVICE transfer) in situations, when MANET mechanism crashed. Opportunistic routing worked based on single copy forwarding and calculation of probability of delivery worked based on social relation among nodes – SBOR routing).

C. Hybrid Social based Routing

Proposal of enhanced Hybrid Social Based Routing (HSBR) combine mechanisms of DSR routing protocol with Opportunistic routing protocol in order to maintain communication. This protocol represented well solution for sparse and/or dense network with or without END-to-END connections. It worked very well for different velocities.

HSBR operated with social information stored in personal and contact profiles. Calculation of probability of delivery was calculated based on method of profiles comparison.

III. Simulations and Results

Proposal of HSBR was simulated and verified in software Matlab together with two other types of routing protocols: HSBR, SBOR and DSR. Parameters for simulations are set in the TABLE 1.

TABLE 1 Set values of Variables for simulations

Variable	Value
Area [m]	1000x1000
Number of nodes	100
Radio range [m]	130
Number of transmitted message	5
Limited number of attempts to send the message	200
Number of simulations repetitions	100
Velocity	
-slow walking	1,4 m/s
-fast walking	2,8 m/s
-running/cycling	5,6 m/s
-driving in a city	11,2 m/s
-driving out of a city	22,4 m/s

The main result of simulations (Fig. 1) was success of all packet delivery of one message compared with average delay of delivery for given packets for different level of velocity.

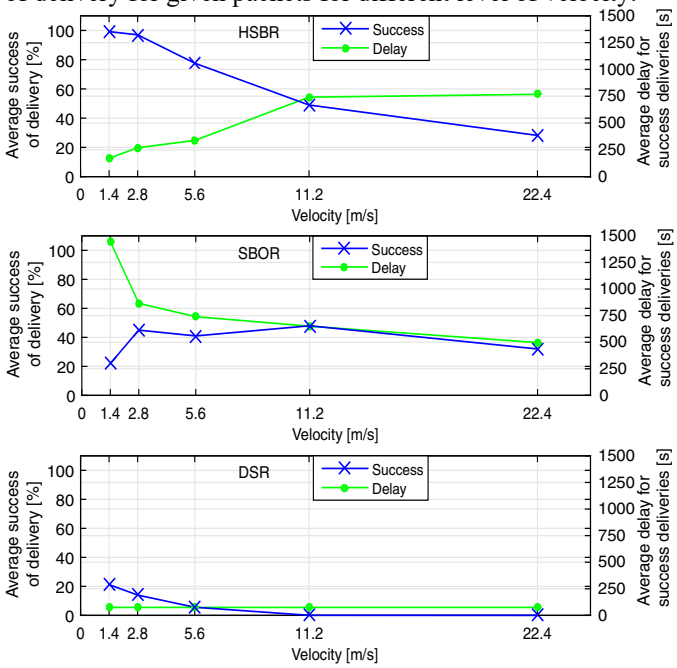

Fig. 1 Success of delivery and average delay (only success deliveries) for Hybrid Social Based Routing (HSBR), Opportunistic Routing (SBOR) and DSR routing protocol

The same movement was used for every protocol, so we compared functionality of protocol in the same situations.

Hybrid protocol got the highest success for the lowest velocity level, where was delay the lowest. Success got decreasing and delay increasing character because of velocity.

Opportunistic protocol got different result for lower velocity level than HSBR and similar for higher velocity.

DSR protocol got very low success of full packet delivery due to start deployment of mobile nodes, where S and D were in different subnetworks and END-to-END path could not be establish by process of finding path.

Hybrid routing protocol was usable for different environment and got the best results from all compared protocols. It is the possible way how to keep communication in areas without infrastructure where requirement to delivery of message is higher than short delivery time.

IV. Future Work

In the future, we want to focus on mobility models for mobile devices, because it is important by social routing decisions. Than we want to study routing methods and topology control in field of MANET with technology of cognitive radio. This technology is helpful for effective scanning and sharing spectrum and allocation of communication channel for devices by more physical sources.

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Proposal of modification of postage stamp method

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***Abstract*- This paper deals with my work over last year. Current use valuation strategy, i.e. postage stamp method is analyzed and is proposed modification. This method is called Preselection. Modification Preselection takes into consideration next dimension videlicet distance in zone form. Analyzed are two approaches to this modification, on basis of geographical division, or km zones. The results are compared with the currently used method postage stamp.**

***Keywords*— modification km; modification region; postage stamp; preselection.**

I. Introduction

Ensuring stable economic growth and competitiveness in advanced world economies has led to incorporation of thoughts unbundling into legislation individual countries. For this reason in power engineering to restructuring of vertical integrated systems on the partial horizontally integrated system. Key issues in restructuring power engineering are issues of congestion and stability of transmission system. The issue of transmission belongs to the regulated parts of electricity market, as is necessary to ensure non-discriminatory access and fair distribution of costs among various transactions provided by an independent system operator. This issue has led first to the establishment of a valuation strategy, which is based on directly flow from valuation of vertically integrated system, it is a method postage stamp. [1] [2] [3] This method assigns transmission costs only on the size of the transmitted power and does not take into account transmission distance or impact of each transaction to the transmission system. From reason remove weakness have put into practice methods MW-km, contract path method and in stage of mathematical-physical model of energy flows, were designed different modifications of these methods, as well as new pricing strategy as method of distribution coefficients, method unused transmission capacity, Bialek trace method and Kirschner trace method [4].

II. Proposals modified method postage stamp

In my papers, I focused on issue of pricing in relatively simple transmission systems, such is the Slovak transmission system Fig.1. In this transmission system, where we consider a valuation strategy, which takes into account physical flows power in transmission system, it is necessary to carry out mathematical-physical model of system, whose complexity is directly proportional to accuracy of calculation of flows in transmission system. However, if it is a relatively simple transmission system, which I have dealt in my works is benefit of such a comprehensive pricing strategy is very questionable. In small transmissions system are flows of energy through each node within transmission system relatively easily quantifiable and predictable.

Fig. 1 Transmission system of Slovak republic [5]

For this reason, I focused in my works on modifying currently used method postage stamp, so that I am in valuating took into account distance. However this distance is not given exactly, as in case method MW-km, but is considered zonal. Pricing based on idea call charging used in past in telecommunications, and therefore calls in city or intercity, whether transaction is within zone or across multiple zones. For this reason I call this modification of method postage stamp as preselect. For definition of zones is can be accessed in two ways, and the breakdown by geographical region or by bands of km. In my works, I take into account both alternatives. Each approach has its advantages and disadvantages. In event of division on geographic region are problematic transactions on the border of region. In case transmission system of Slovak republic, I considered three regions and those are West, Central and East. In case km zones, it is necessary to know exact km distance between point of power injection and point of power delivery. In this case, I suggested km zones, which correspond with geographic regions and are three zones: up to 150km, 150-250km and over 250km. These calculations not include costs caused by transit flows carried out through territory of Slovak republic within interconnected transmission systems UCTE, because these are valuated differently. [6]

Table I. The resulting charges method postage stamp and proposed modified methods

Method Postage Stamp								
Name	**Quantity**	**Unit**	**Name**	**Quantity**	**Unit**	**Name**	**Quantity**	**Unit**
Total transmitted power	17649	GWh/year	The total operating cost of the system	60729569,99	€	Fee for transmission	3,44	€/ MWh
Modifications - regions								
Region	**Quantity**	**Unit**	**Between regions**	**Quantity**	**Unit.**	**Via three regions**	**Quantity**	**Unit**
Fee region Eastern	0,99	€/ MWh	The fee for the transmission East -Central	1,94	€/ MWh	The fee for the transmission East –Central -West	3,44	€/ MWh
Fee region Center	0,95	€/ MWh	The fee for the transmission West -Central	2,45	€/ MWh			
Fee region West	1,5	€/ MWh						
Modifications - km								
Into 150km	**Quantity**	**Unit**	**From 150 to 250km**	**Quantity**	**Unit**	**Above 250km**	**Quantity**	**Unit**
Fee for transmission	1,03 €	€/ MWh	Fee for transmission	1,2	€/ MWh	Fee for transmission	1,55	€/ MWh

III. Results

Based on information available in the annual report of SEPS a.s., [7] which operates transmission system of Slovak republic were calculated transmission costs of one MW of electricity, which was calculated using method postage stamp to the value 3,44€/ MWh. Results are shown in Table I. In case, if we are considering a regional approach, so visible benefits of this approach within region, where price is one third until half against postage stamp price. More significant is benefits for proposal in km zones, but price is directly proportional to reallocation of transactions within km zones. In these transactions it is considered, that 20 percent of transactions in transmission system is up to 150km, 35 percent of transaction is in range of 150-250km and 45 percent of transaction is over 250 km. On basis of this division of transactions, it can be concluded, that proposed modifications have their contribution for valuation of transmission, and proposed valuation strategy compensates disadvantages of method postage stamp. [8][9] This proposed approach to valuation in small systems can take your application into place.

IV. Future work

My future work will focus on issue of valuation of transmission based on marginal price difference due to congestion in transmission system. This is method of LMP, FTR and congestion management.

Acknowledgment

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Pulsed heating as a method of modifying the magnetic properties of amorphous material FINEMET - type

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***Abstract*— In this paper, the novel method for modification of the magnetic properties of amorphous material FINEMET-type is presented. Specifically, the research is focused on the pulse annealing of such material that is in the shape of amorphous ribbons. Further, the magnetic properties of samples were measured under influence of uniaxial mechanical stress. Heat treatment under mechanical stress allows formation of induced magnetic anisotropy, leading to improvement of magnetic properties.**

***Keywords* — amorphous ribbon - FINEMET, pulse heating, measurement of magnetic properties, magnetostriction, uniaxial mechanical stress.**

I. Introduction

Nano-crystallization of amorphous FINEMET creates materials, which have a wide range of applications due to their high magnetic softness. The disadvantage of these alloys is their brittleness. This makes them not suitable for application where shocks or vibrations are present, for example, in automotive or aviation industry. Therefore, our research is focused on improvement of their magnetic properties while keeping the amorphous state of the material. Exceptional magnetic softness (very low H_c), reduced hysteresis losses, modified shape of the magnetization curve can be achieved in these alloys using pulse annealing. Using this kind of treatment it is possible to preserve their mechanical properties, in contrast to the traditional heat treatment, which is used on a large scale in manufacturing nano-crystalline alloys [1, 2].

II. Overview last year:

One of the tasks was to improve the apparatus for measuring of other physical quantities during the pulse. These were the voltage on the sample, the current flowing through of sample and the relevant temperature for the given number of periods. From these of quantities were subsequently calculated additional physical quantities such as resistance, power and total supplied energy. The reason for this measurement was to better define the impulse. The following experimental set-up (see Fig. 1) depicts the apparatus for impulse heating and its connection with the existing the apparatus for measuring the magnetic properties.

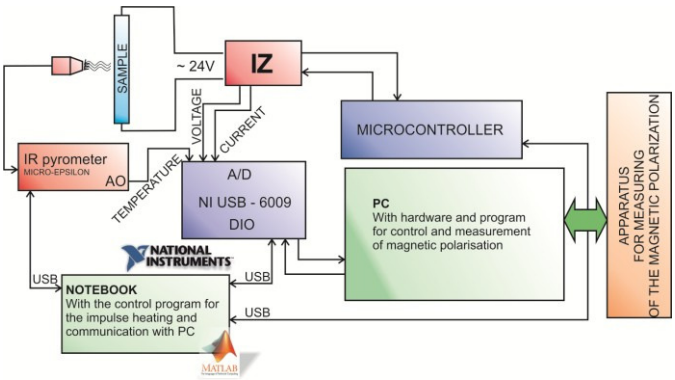

Fig. 1. Experimental set-up for impulse heating.

In the Fig. 2 is plotted progress of single parameters during the impulse.

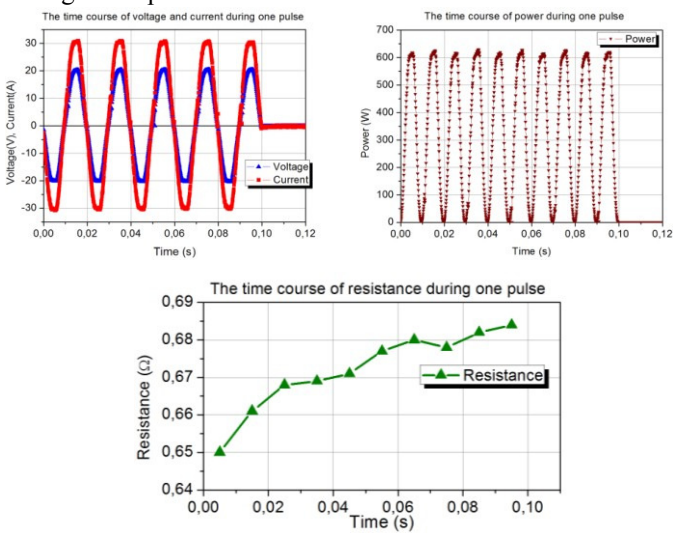

Fig. 2. Progress of selected parameters during the impulse.

In the next step, magnetostriction, our sample was measured as another parameter of magnetic properties. It was measured in the laboratory of PF-UPJŠ using Narita method. Magnetostriction is given by the following equation:

$$\lambda_S = \frac{1}{3} \cdot J_S \cdot \frac{\Delta H}{\Delta \sigma} \qquad (1)$$

Where J_S is saturation magnetization, $\Delta\sigma$ is the change of mechanical stress and ΔH is a corresponding change in the magnetic field. Ratio $\frac{\Delta H}{\Delta \sigma}$ is a slope fitting line of the curve.

The calculated value of magnetostriction is 21.13×10^{-6} for our sample.

III. Results achieved in this year:

Another task was to improve the apparatus for uniaxial mechanical stress. This device enables applying mechanical stress to the sample during the pulse. Heat treatment under mechanical stress allows formation of induced magnetic anisotropy, direction of which, depending on the magnetostriction, is in the direction of the magnetic field (mechanical stress), or perpendicular to this direction. This can change magnetic anisotropy constant, which has significant influence on magnetic properties of the sample. Block diagram of this device in fig. 3.

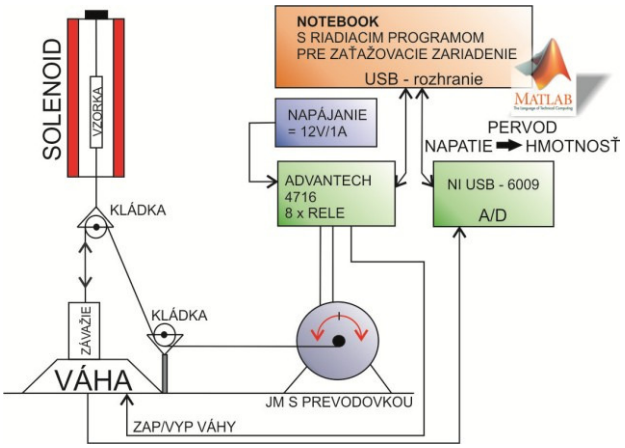

Fig. 3: Block diagram of the device for application uniaxial mechanical stress during impulse heating.

In the next figure (fig. 4) are plotted the dependencies of coercivity of samples (H_c) on the number of applied pulses. The picture shows three dependencies: Dependency on the pure pulse heating, dependency on the pulsed heating applied simultaneously with application of a magnetic field (H = 2000 A/m) in the direction of the axis of the sample, and lastly the dependency on the pulsed heating applied simultaneously with application of mechanical stress (σ = 2.27 MPa) in the axial direction of the sample. The sharp decreasing in coercivity after applying of the first pulse can be explained by a significant reduction in internal stresses which were introduced into the material during the manufacturing process. This effect is more significant for the case of the pulse heating with the simultaneous application of mechanical stress. It is believed that in addition to relieving occurs the rearrangement of atoms at a short distance what leads to an induced anisotropy, resulting in further reduction in the coercivity of the material [3].

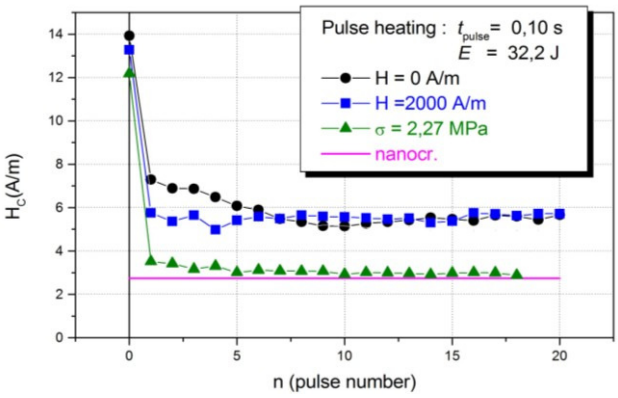

Fig. 4. The influence of pulse heating on the coercivity of FINEMET at the different conditions of processing.

IV. Results

Results presentations and publications previous year:

- Active participation in the conference SCYR 2015: Experimental Measurements and Results Obtained during 3th Year of my Postgraduate Study /*L. Hubač*
- Published paper in proceedings: Nové zariadenie na impulzný ohrev feromagnetických amorfných zliatin v podobe pások / *Lukáš Hubač, Ladislav Novák,* In: Electrical Engineering and Informatics 6 : Proceedings of the Faculty of Electrical Engineering and Informatics of the Technical University of Košice.
- Active participation in the conference Magnetic Measurement 2015: IMPULSE ANNEALING AS POSSIBILITY OF MODIFICATION OF MAGNETIC PROPERTIES OF AMORPHOUS METALLIC ALLOYS / *Jozef Kováč, Ladislav Novák, Lukáš Hubač,* In: Journal of Electrical Engineering, 2015
- Paper was published in Current Contents journal ACTA PHYSICA POLONICA - A: Pulse heat treatment of FINEMET alloys under tension / *Antal Lovas, Lukáš Hubač, Ladislav Novák*

V. Conclusion

Using pulse heating was achieved a significant improvement of the magnetic properties of the FINEMET material. Thus, the short heating time is sufficient to induce diffusion of atoms over short distances, leading to relieving internal stresses and also to elicit induced anisotropy. This short heating time is nevertheless insufficient for the diffusion of atoms over a long distance, leading to the formation of FeSi clusters or crystallites, causing embrittlement.

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Real-Time Localisation of Moving Persons in 3D Space

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***Abstract*—This paper describes recent advance in research of real-time 3D localisation and tracking of moving persons. The major contribution presented in this paper is development of a complete system for through-wall localisation of persons in 3D space by means of short-range ultra wideband (UWB) radar measurements. For that purpose we will introduce a simple 3D localization approach developed for ultra wideband (UWB) radar equipped with 1 transmitting and 4 receiving antennas. The proposed method is based on the approximation of 3D localization problem by two 2D localization problems. The decreasing of a computational complexity as well as opportunity to use existing procedures and methodologies developed for 2D target localization are among its main benets**

***Keywords*—UWB radar, localisation, 3D, real-time**

I. Introduction

Presently, we recognize two typical scenario types which represent the need for detection and localisation of persons hidden behind walls, obstacles or otherwise obscured. First group of scenarios are military and security operations in which it is required to detect unauthorised entry to secured areas, or to detect, localise and determine the number of perpetrators of the crime or their victims. Second group of scenarios is aimed towards life rescue in emergency situations such as earthquakes or building fires in which the goal is to estimate the location of motionless survivors to increase the effectiveness of search and rescue operations.

Among existing techniques used in described situations are thermovision cameras, cameras with long optical fibers that are injected into the holes or fissures in the collapsed buildings, acustic systems detecting sounds produced by survivors, search dogs that mark a place where they smell human beings. The use of short-range UWB radar with ability to detect motion was proposed as a complementary or alternative solution to these existing techniques.

The proposed system for human beings detection and localization consists of laptop computer and UWB radar with one transmitting and minimum of two (for 2D target tracking) or three (for 3D target tracking) receiving antennas. Transmitting antenna emits electromagnetic waves to monitored area and receiving antennas capture reflections of electromagnetic waves from objects in this area. Information about presence and position of persons is determined from the measured data by means of signal processing methods. Such system has a potential of increasing the effectiveness of life saving operations, which motivates me to work on the topics related to the improvement of its reliability.

II. Proposed simple 3D localization method

As it was mentioned in the introduction, the localization method simplification is achieved through the use of radar antenna system consisting of 1 Tx and 4 Rx. Here, we have chosen "+"-shaped lay-out of the radar antenna system with Tx in the central point and Rx in the corners. In such a way, we obtained 3 antennas in the plane [x,y] (horizontal placement) and 3 antennas in the plane [y,z] (vertical placement). One Tx and two Rx is the minimal number of antennas for TOA based target localization in 2D space. Such antenna arrangement allows to solve a simpler 2D version of the problem for $N = 2$:

$$d_i = \sqrt{x^2 + y^2} + \sqrt{(x - x_i)^2 + (y - y_i)^2}, \quad i = 1, 2 \quad (1)$$

instead of the set of 4 simultaneous equations. Of course, to obtain 3D target location, (1) needs to be computed for both planes [x,y] and [y,z]. Let T'=[x',y'] and T"=[y",z"] be the estimated target position in the plane [x,y] and [y,z], respectively. Then the final position of target in 3D space is estimated as:

$$T^* = [x^*, y^*, z^*] = \left[x', \frac{y' + y''}{2}, z''\right]. \quad (2)$$

The computation complexity of ellipsoid intersections is decreased to the complexity of computation of two intersections of ellipses and consequential average of their y-coordinate.

The motivation for the proposed localization approach was also the fact that we were able to immediately use our 2D signal processing procedure for people detection, localization and tracking [1]. This procedure enables to track multiple persons moving even behind obstacles (e.g. walls). Besides the final stages of target localization and tracking, it includes the processing stages such as background subtraction, target detection, TOA estimation and wall effect compensation. The procedure is implemented also in an experimental display unit for see-through-wall UWB sensor systems working with one transmitting and two receiving channels. The display unit embodies the signal acquisition, the described processing procedure and interactive graphical user interface enabling to detect, localize and track people in real-time [2].

III. UWB radar systems

The acronym UWB refers to a technology which make use of signals occupying a very large bandwidth of frequency spectrum. The Federal Communications Commission (FCC) defines a UWB device as any device where the fractional

bandwidth B_f is greater than 0.2 or which occupies the absolute bandwidth B greater than 0.5 GHz. The fractional and absolute bandwidth is defined as follows:

$$B_f = \frac{2(f_u - f_l)}{f_u + f_l}, \quad (3)$$

$$B = f_u - f_l, \quad (4)$$

where f_u and f_l are the upper and lower cut-off frequencies of the emission point $L_{cut-off} = -10$ dBm.

UWB radar systems emitting signals occupying a frequency band $DC - 5GHz$ can be used for through-obstacle person localisation, with advantage, because electromagnetic waves with such frequencies propagate through most common building materials with acceptable attenuation, whereas higher frequencies are significantly attenuated.

IV. Real-time localisation in 3D space

The display unit of the localisation system was is based on the UWB Radar Imaging Unit software, which was developed at Department of Electronics and Multimedia Communications (TUKE) for target localisation in 2D space. Communication between the sensor and dedicated computer is done over USB connection, the appropriate drivers and software utilities were provided by the sensor manufacturer - the ILMSENS company. The time critical algorithms, such as TOA estimation or MTT (Multiple Target Tracking), which implements gate checkers and multiple Kalman filters, were programmed in C programming language. These routines were then imported to LabVIEW development environment which we used as a framework for development of the display unit. LabVIEW provides necessary tools to visually represent data by use waveform graphs, radargram charts (customized radargram for detection algorithm is shown in Fig. 1), XY graphs (used in localisation in 2D space) and variety of 3D graphs. The stem graph type is shown in Fig. 2. The tests of the display unit shown the capability of processing the data measured from four receiving channels and displaying the results of the target position at the rate of nearly 24 display updates per second (which corresponds to frame rate of standard movie formats).

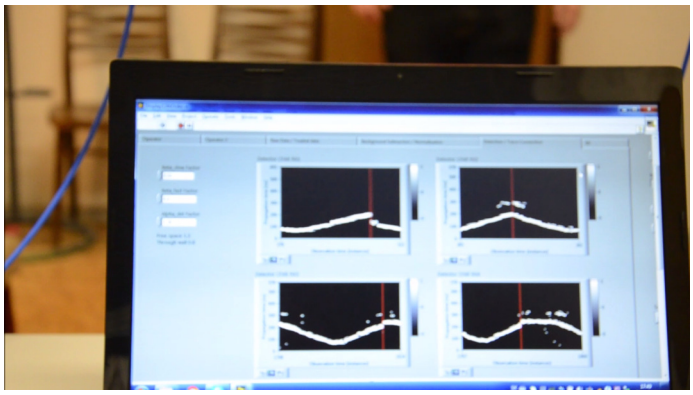

Fig. 1. Detector radargram charts on the screen of the display unit clearly show the presence of a moving target.

V. Conclusion and future work

Increasing computing power in laptop computers creates a great window of opportunity for development of systems for through-wall tracking of uncooperative targets. By utilising better performing computers, we are able to implement more computationally demanding algorithms while processing raw radar data from more receiving channels. This paper describes our approach to the problem of 3D localisation of moving targets and shows the viability of the system. We would like to continue the research on the extended antenna array layouts, localisation and tracking signal processing methods.

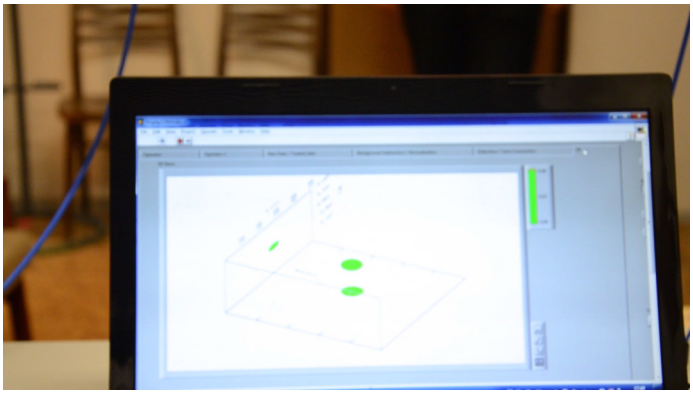

Fig. 2. Target position displayed on stem graph. Target is projected to XY and YZ planes for easier interpretation of its position.

Acknowledgment

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Recent Developments in Depth Imaging and Sensor Fusions: A Review

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***Abstract*—The aim of the following study is to provide a short review on recent developments in the area of computer vision. Based on previous analysis, the area is divided in two waves: depth imaging and sensor fusions. The first wave is approached by object recognition and depth maps, both highlighting most common issues addressed by researchers. On the other hand, the second wave is approached by sensors as means of obtaining environment data and their fusions, currently popular issues of recent hardwave contributions. While electronics engineers contribute to development of advanced but expensive sensors, computer scientists focus on combining data of multiple cheaper solutions what makes their products available for the wider public. The summary ends with a short proposal of an analytical evaluation experiment with three low-cost sensors.**

***Keywords*—Depth maps, environment analysis, gesture recognition, Kinect, Leap Motion, sensor fusion.**

I. Introduction

Depth imaging has been growing at a fast pace along with the field of computer vision. It is an interesting topic for scientists as well as general society, since it offers a range of practical application in geology (seismic mapping), robotics (robot's vision), 3D modeling (from forensic or archeologic site reconstruction through building mapping to something as trivial as a little figurine model of a person), gaming (avatars in games), medicine (design of a prosthesis).

Many contributions have been published recently and this area of science has got even more attention upon the arrival of motion sensors. Science community soon realised some of such sensors can be a cheap substitute for expensive and huge depth imaging equipment. Studies on depth imaging have experienced a great growth in quantity, obviously bringing quality too. Clearly, a lot of problems or challenging issues have been overcome or are still under development. Some of them are mentioned in the following sections.

II. Current Status

As in most fast-developing fields, computer vision can be divided in two waves: hardware and software, both depending on each other, however, being developed separately by lots of research groups worldwide. Generally, hardware represents means of obtaining information from the environment, e.g. RGB-D cameras or motion sensors, while software includes theories and techniques of processing these data.

Most corrent studies deal with depth imaging, which can be further divided in two crucial issues: object recognition and depth maps. Arrival of Microsoft Kinect has recently popularized another area: sensor fusions.

A. Common Sensors

Currently, depth sensors draw their attention mostly as computer controllers. RGB cameras featured with depth sensor (RGB-D cameras) represent powerful devices with known limits. On the other hand, there are promising technologies for an indoor sensing (so-called indoor radar systems).

1) Intel RealSense:

There are two versions of how this camera is produced: integrated and extern version. Integrated version is embedded in notebooks and all in one devices. Camera is part of new tablets as well. Possibilities of the camera provide video chat, gesture control and scanning environment through RGB and depth sensor. The camera works on 60 fps in an infrared mode.

Recently, Intel RealSense was successfully utilized within the study published in [1]. The study describes creation of a real-time 3D computer game based on an augmented reality. The game implements 3D reconstruction and tracking using the Intel RealSense camera system.

2) Duo 3D:

There are 3 models of cameras by Duo3D: Duo MLX, MC and M version. That is, there are three different solutions of design and options of use. Duo 3D are ultra-compact imaging sensors. They are intended for use in industry, research and integration. With these cameras it is possible to get a low level access and control, what is a great attribute. This camera represents clever equipment because of its small size and wide capabilities [2].

3) Leap Motion:

The Leap Motion Controller can be categorized into optical tracking systems based on stereovision. The device has been developed for depth sensing, however, it does not provide neither RGB camera nor microphone. The sensor is focused on highly efficient hand tracking and gesture recognition, although it is not focused on sensing skeleton or face tracking. Leap Motion hardware consists of a pair of stereo infrared cameras and illumination LEDs. A variety of studies have involved Leap Motion sensors, studying 3D gestures or pointing tasks.

Many studies focus on 3D gesture evaluation, revealing high user preference for free hand interaction successfully tracked by the Leap Motion Controller. Similar study is presented in [2], conducted on user-elicited fine resolution finger and hand pose gestures for controlling the interactive TV. Authors of both studies claim the sensor highly contributes to the affordable desktop free-hand motion sensing devices, providing an extensive evaluation of the sensor.

The evaluation consisted of both static and dynamic measurements, resulting in an interesting conclusion that the controller may be used as a suitable replacement for other high-precision optical motion capturing systems in a limited space. However, the authors also claim that in its current state, Leap Motion should not be used as a replacement for professional tracking systems, primarily due to its rather limited sensor space and inconsistent sampling frequency.

4) Fotonic:

Fotonic is a specific high performance depth sensor in robust outdoor design. The most beneficiary property is low motion artifacts, and high frame rate, making it very suitable for tracking moving objects. Time of flight technology can be explained as radar operating with light. This technology allows to calculate exact distance with high accuracy.

Fotonic sensor includes 48 LED and gorilla glass. Moreover, it is interchangeable [3]. The sensor uses ARM powerful processor and it is compatible with Linux platform as well. Maximum frame rate of the sensor is 52 fps. The sensor has been used in [4] within a simultaneous measuring as a demonstration of dynamic sensing ability of the FBG (Fiber Bragg Grating) displacement sensor.

5) Ultra Wideband (UWB):

UWB is an information carrying medium used in conventional radio communication technologies. Signals are defined as signals that have large bandwidth or a large absolute bandwidth [5]. It is a promising technology for indoor localization. Ultra wide band technology is mostly used in medical engineering and computer science. Federal Communications Commission and European Telecommunication Standards Institute allocated 7,500 MHz of spectrum for unlicensed use of Ultra wide band equipment from 500 MHz to 10 GHz bandwidth. Since the earliest regulations, the radio technology and regulations have converged into a narrow band regulation. UWB signal transmission was a contrary to the progress possible due to regulations.

Due to highly intense pulse, UWB is mostly used in medical area for patient motion monitoring. Small distance and high data rate communication function of UWB allow gathering and exchanging a large quantity of data. Devices are able to sense for a long time thanks to low energy requirement. Moreover, the capability of non-invasive sensing of vital parameters, such as respiration system of human body [5], may be helpful in medical engineering as well.

In sensor networks, there are two types of nodes called Full Function Device (FFD) and Reduced Function Device (RFD). FFD is commonly known as a "coordinator" adequate to its ability to perform the above functions. UWB is very similar to ultrasound. Major difference between UWB and ultrasonic is their usable distance. Attribute of UWB sensor is that it can penetrate through walls, since it uses RF pulses and it has a high gain [5].

B. Object Recognition

Traditionally, the success of visual recognition has been limited to specific cases, e.g. faces or handwritten characters. Recent trends include large-scale recognition (hundreds of thousands of categories), real-world object recognition (hundreds of households objects) or human poses from depth images (see sec. II-C). Since body parts independently vote for the presence of a person, most techniques are based on scrolling fixed-size windows over different scale space positions of particular images in order to classify the window areas, e.g. [6] collapse the 3D scan into a virtual 2D slice to find salient vertical objects above ground and classify a person by a set of SVM classified features. Similarly, authors of [7] detect people by processing vertical objects and considering a set of geometrical and statistical features based on a fixed pedestrian model.

Most publications take inspiration from the Histogram of Oriented Gradients (HOG) detector in order to design a robust method for recognition of people in dense depth data, also called as Histogram of Oriented Depths (HOD) [8]. In general, HOD locally encodes the direction of depth changes and relies on depth-informed scale-space search leading to a 3-fold acceleration of the detection process.

While most of such works require a ground plane assumption, authors of [9] overcome this limitation through a voting technique which builds upon classified parts and a top-down verification procedure. This way, the system may learn almost optimal set of features while dealing with sparsely sampled and articulated objects. Other works address the problem of multi-modal people detection [10], e.g. trainable 2D range data and camera systems, stereo systems to combine image data, disparity maps and optical flow or using intensity images and a low-resolution time-of-flight cameras.

Most recent studies have drawn their attention to recognition of moving object [11] or object detection as well as tracking from the perspective of a moving observer [12]. In such a setting, it is not necessary that every object is recognized in every video frame. Rather, the number of recognition queries quickly become the main cost factor. Thus, it is necessary to lower this number as possible while the system covers every relevant scene object by at least one query.

Since gestures represent a new paradigm for users to interact with mobile devices, applications do not need to design and implement custom-tailored solutions. As authors of [13] point, low streaming bit rates (coupled with the need for guaranteed reliability), low streaming delays, and multiple concurrent broadcast sessions (when multiple users are involved) have brought a brand new yet practical challenges that need to be addressed with a new transport solution.

C. Depth Maps

Depth map is an image that contains information about distance of objects or general surfaces on the scene, all from the viewpoint of the scanning sensor. Particular points or areas on the image are represented by different lightness or colour, depending from the sensor distance. In general, closer areas are usually represented by dark to black colour, sometimes by red colour. Further areas are visually displayed by lighter colours, often by blue (see Fig. 1).

Authors of [14] claim that depth maps can be obtained in two ways: Calculation of light flight time which is emitted and captured by the sensor. The other one is through examination of pattern displayed in time the infrared pattern is projected. With this way of depth map construction, so-called noises come into view. They arise from depth holes and inconsistent depth values what can lower the quality of acquired depth maps.

According to [15], there are multiple kinds of noise:

- Arised from the sensor distance — The object may be too far or too close to the scanning device.

- Arised from the imaging geometry — Due to wrong angle and the screening of one object by the other one, light holes or shadows may be formed. Moreover, shadows can occur if the scanner cannot recognise the object edges properly.
- Arised from the surface of the scanned object — Specular surface noises may be formed if the emitted scanner light reflects from the scanned object. On the contrary, there are non-specular surface noises when the object is transparent. Then, the light penetrates through the object and scans the object from the back of the scanned object. Too rough objects may cause noises as well.

Fig. 1 depicts an example of RGB and depth images captured by Kinect in [15]. Part (a) outputs the scene as an RGB image. Part (b) includes depth data rendered as an 8-bit grey-scale image with nearer depth values mapped to lower intensities. Then, depth image in (c) shows too near objects in blue, too far objects in red and unknown depths in green colour. Unknown depth are usually caused by highly specular objects.

(a) (b) (c)

Fig. 1: Example of RGB and depth images

The authors of [16] provide an interesting analysis of the depth mapping. They performed an experiment with a sensor, studying circumstances that may affect the accuracy of the depth mapping. They confirm that the accuracy is decreasing with an increasing distance from the sensor at the same time as it is decreased by the low resolution of the depth measurements.

On the other hand, the authors of [17] tried to come up with more efficient way to aquire depth maps. They provided a method of filtering depth maps through Kinect sensor, while they were utilizing information about motion and colour attributes of every scanned object.

D. Sensor Fusions

With depth imaging, sensor fusions have got into forefront, since they are capable of collecting large amounts of data from the environment, processed into a form which is more acceptable for users. This is because unlike cameras, which scan the colours of the surroundings, sensors collect depth data, which is then evaluated by fusion software to 3D models or graphs.

A good example of this technique is the Kinect sensor, which applies the fusion of RGB camera and depth scanner to represent parts of a human body by its joints, such as head, neck, shoulders or arms. The joints are described by their 3D coordinates. The sensor scans them all in real time, per-pixel for every single body part, not the whole body as a 3D object, bringing more fluent interactivity as well as a better gaming experience.

Similarly, Liu et al. propose in [18] to divide the problem to more phases in order to manage the 3D reconstruction of an object for a greater accuracy. In particular, they came up with a four-phase method. First, they scan the object multiple times with the sensor to get the depth maps from every side. Then they calculate the confidence values of each of the depth maps, searching for the most optimal values. In the third stage, they remove some outcomes which are outside of the confidence area to optimize the depth maps even more. Lastly, they try to fill the noisy holes to make a clear fusion of the depth maps. This way, the product will be a way more accurate than regular scanning of the object with one sensor.

On the contrary, authors of [19] have used Kinect to bring a real-time 3D reconstruction. They use all the live data available from the sensor managing to make a global object by tracking the 6 degrees-of-freedom pose of the sensor with a 30 Hz frame-rate. Since it does not use RGB camera, only the depth sensor, it can fully operate even in darker conditions.

Another contribution is described in [20], analysing SLAM (Simultaneous Localization and Mapping) method for different applications like non-Euclidian spaces or 3D orientations. Through the SLAM techniques, the authors also described camera calibration. Furthermore, they even immerse into robotics, describing sensor fusion in accelerometer or stereo calibration.

In [21], the authors provide a survey on usability of Kinect RGB-D sensor for close range 3D modeling. They bring a basic characteristics of the sensor with all its pros and cons, moreover, they compare the second version of Kinect to the first as well. There is also a work of Odowichuk et al. [22] about using Kinect in the music industry. Explaining how radiodrum 3D input with the computer software work together, they discuss the development of the sensoric approach to modern music.

III. Summary

Alongside with 3D reconstruction of the objects, sensors can also be used as a vision substitutes for robots or people. One can even say this would be an upgrade of human eyes. Detection of various objects (mainly people) is a fundamental problem of any intelligent system.

Most works use cameras and 2D or 3D range finders for this task. Unlike common cameras, which only scan the colours, depth sensors use the depth data for seeing through objects or behind the corners. Another feature can be an RGB-D camera with GPS or pressure. This may improve the navigation or bring augmented reality to cellphones. Many systems can benefit from these features, however, in order to protect the privacy, nonmaterial shields covering the buildings can be an interesting stream of studies.

The literature we studied pointed out several problems and issues regarding mainly low-cost sensors. One issue is creation of depth maps when detecting objects present in the analysed environment. Here, another issue apperas: the noise. This is due to distance, geometry and object surface. Some studies suggest geometric calibration as well as depth calibration [21]. Other studies focused on gestures, highlighting Hidden Markov Model and Artificial Neural Networks as two effective methods in dealing with this issue [13].

On the other hand, low-cost sensors use RGB-D methods complemented by probability computations [2]. In addition to gesture recognition, recognition of their context is a more tedious task, e.g. gesture meaning or direction of a pointing finger. However, this problem belongs rather to the area of artificial intelligence than to a computer science.

Among all low-cost sensors, Kinect is the one which enjoys its massive popularity among end-users as well as researchers. While first contributions were focused on Kinect hacking, currently most studies are of evaluating or comparative character. Although many studies mention a lot of problems related to imperfection of Kinect, much less of them suggest proper solutions or even classify particular problems. However, those studies that are dedicated to improvement of Kinect data processing, are the biggest contribution. E.g. [15] classifies noises in Kinect depth images. Moreover, it carefully analyses noise causes as well as their preventions and partial solutions.

Kinect is not a single sensor but a fusion of sensors. Since the idea of sensor fusion is not widespread yet, we believe our future work might bring an interesting contribution.

Currently, healthcare benefits probably the most from the results of the mentioned studies. Common users benefit mostly from gesture recognition. However, not all aspects which are of interest to active researchers are useful to common users or programmers. Engineering aspects of techniques are mostly emphasized in books, omitting vast theories that do not have sufficient practical applications as the time. The most popular one are [23] from 2012 and [24] from 2014, computer-vision book focused on sensor utilization.

As another part of the analysis, three devices are planned to be tested: MS Kinect v2, Leap Motion and Myo Armband.

The first two use depth imaging in order to scan particular gestures. Kinect uses RGB-D camera to track body joints, while Leap Motion uses only a depth sensor, scanning only human hands. On the contrary, as the name suggests a kind of arm band, Armband uses muscle tracking in order to recognise each performed gesture. The goal of this experiment will be to perform an analysis of particular devices recognising different gestures, which will result in a comparision of these 3 approaches to determine, which device is suitable for different types of gesticulation.

Currently, there are many different sensors offering different approaches and applications. Scientists as well as manufacturers have come with various excellent sensors so far, e.g. Fotonic or UWB, however, their costs discourage common users from using them. On the other hand, there are various low-cost sensors that can provide sufficient data about the environment.

In our opinion, this creates an interesting opportunity for computer scientists. If we are able to make a fusion of such low-cost sensors and if we are able to process their data through an adequate computer application, then we can provide a smart low-cost system for environment analysis as well as its protection, available for common users. Here, low-cost is the most important characteristics, since it allows to perform simple changes in the used sensor as well as in the computer application.

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Reinforcement Learning in Robot's Behavior Adaptation

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***Abstract*—The paper gives an overview of our approach to adapt the robot's behavior in social human-robot interaction. It discusses reinforcement learning for obtaining the given goal. We also present a cloud-based interface for social robotics, which serves for teleoperation during various human-robot interaction scenarios. As a conclusion we summarize the work done in the last year and the next steps of our research.**

***Keywords*—social robotics, cloud computing, reinforcement learning, Wizard of Oz**

I. Introduction

One of the major challenges of today's research in human-robot interaction (HRI) is to prepare robots for long-term HRI. Research experiments in this field have moved from laboratories to different real-world environments, e.g.: supporting young patients in hospitals as they learn to manage a lifelong metabolic disorder (diabetes), motivating physical exercise for older adults, autism therapy and others.

From the perspective of human-centered robotics, robots need to react appropriately to human expectations and behavior. This paper discusses a system for social robots that is able to learn how to choose the proper behavior in human-robot interaction.

We designed a Wizard of Oz interface [1], which is used by a human observing the experiment to control the robot. We also implemented an interactive reinforcement learning (RL) algorithm, which adopts the Wizard's knowledge. We believe that this approach increases the machine intelligent quotient, based on the three-dimensional model of machine intelligence, where the controllability for complicated dynamics includes the behavior of the robot [2].

II. Design of the Wizard of Oz Interface

Our main goal was to create a modular system which can be used in different HRI scenarios. Moreover, it can serve as a common platform for researchers. Since it is cloud-based, it is always online and after connecting the robot to the system the users are ready to go.

The system consists of the following parts [3] [4]:

1. Motion library – it contains the behaviors specific for the given scenario. This part of the system is dynamic and can be changed according to the given experiment. The system also provides a short animation of every behavior to the user.
2. Motivational behaviors library – the platform also comes with a database of emotional expressions based on Plutchik's emotional model (joy, anticipation, anger, disgust, sadness, surprise, fear, trust).

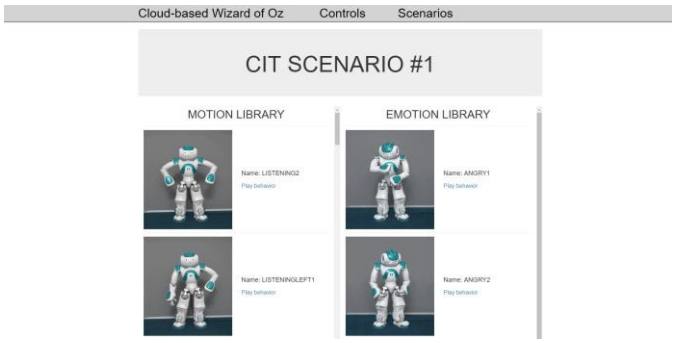

Fig. 1. Wizard of Oz interface for a laboratory scenario using our cloud-based system

III. Interactive Reinforcement Learning for Robot Learning

In our pilot study exploring RL in social HRI we used socially guided machine learning. It reframes the machine learning problem as an interaction between the human and the machine. In the case of supervised learning, a human provides input to the machine learning algorithm which performs its task and gives output. Opposite to this is the setting of a social learning system, where the machine learning provides output but it also interacts with the human teacher. Such a system is designed to efficiently learn from people with no experience in machine learning.

This approach was successfully used in different interactive scenarios. Knox and Stones in [5] used human reward to solve typical reinforcement learning problems. In [6] interactive RL was used to teach a NAO robot to sort objects. Mitsunaga et al. [7] implemented a policy gradient reinforcement learning algorithm to adapt the robot's behavior during the interaction with a human partner. However, none of these studies was focusing on learning from the human operator. The first mention of such an approach was in [8].

In our scenario the robot greeted and told news to the subject from various information sources, e.g. politics, economics, sports, etc. The goal of this short interaction was

to make the subject happy.

To reach the goal we used interactive Q-learning which is a modified version of a commonly used RL algorithm [9] (see Fig. 2). According to the definition of an RL problem we distinguished three states of the subject: sad, unknown and happy. To keep the interactions as short as possible, the robot greeted, told a weather prediction and news.

1: s_t = last state, a = action, r = reward, α = learning rate, γ = discount factor
2: **while** subject not happy **do**:
3: $\alpha = \varepsilon$-greedy action selection
4: execute a, sense new state s_{t+1}
5: sense reward r
6: update Q-value:
$Q[s_t,a] = Q[s_t,a] + \alpha(r + \gamma(\max Q[s_{t+1},a] - Q[s_t,a]$
7: $s_t = s_{t+1}$
8: **end while**

Fig. 2. The interactive Q-learning algorithm

During the learning process the subjects (in this case the authors) were scanned by a Kinect sensor and the following data were recorded:

1. Length of the interaction – whether the robot impressed the user enough to finish the session
2. Attention detection - whether the user was engaged
3. Emotion detection – based on facial expressions we detected whether the subject was happy or sad. When none of these was recognized, the user's state was labeled as unknown.

Based on these data we defined the following reward function:

$$r = \textit{happy states/second} + \textit{engaged states/second}$$

The "happy states" and "engaged states" represents the number how many times the sensor detected happiness and engagement of the human partner during one second. Since the Kinect sends 30 frames per second, the total amount of the reward for one second is 60.

On Fig. 2 an example of a learning process is shown, where the red lines are representing the robot's interventions. One can see, that e.g. the intervention in the 7th second of the interaction didn't make the subject happy so the reinforcement was minimal. On the other hand the interventions in seconds 31 and 36 got the biggest reward, which means that the human partner was engaged and happy at the same time (see also Fig. 4).

Fig. 3. Example of a learning process

As it was mentioned before, the emotional states and the engagement of the subject were determined using the Kinect sensor. On Fig. 4 the data for calculating the reinforcement are shown.

Fig. 4. Happiness and engagement of the subject during a session

IV. Conclusion

During the last year we designed and implemented a cloud-based Wizard of Oz interface which can be used for various scenarios and offers a database for robot behaviors. We also implemented an interactive reinforcement learning method which can be used for robot learning during the interaction with humans.

The next steps include the extension of the current Wizard of Oz system by a learning algorithm, so the learning can take place in the cloud environment. We also plan to extend our approach by utilizing an artificial neural network for predicting the reinforcement. In addition to this we will implement the interactive version of other reinforcement learning approaches, such as SARSA and test those on a subject model created by Senft et al. [10].

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Research of electrophysical properties of paper insulation impregnated by natural ester

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***Abstract*— This paper offers information about research of oil-paper insulation system. Insulation system is one of the most important part of electrical devices. It is very important to understand electrical and dielectric properties of insulation system. The insulation system of many type of electrical equipment is mainly composed by the insulating oil and paper. Oil impregnated insulation paper is used in transformers for many years. Conventional mineral oil is some possibility of environmental pollution and fire with explosion. But natural ester insulating oils are non-toxic, more biodegradable and less flammable than a mineral oil. Therefore conventional mineral oil is being replaced with natural ester insulating oils. The next aim of this paper is research of influence of accelerated ageing on the oil impregnated paper.**

***Keywords*— mineral oil, natural ester, thermal stress, ageing.**

I. Introduction

In a liquid-filled transformer, the insulating liquid plays an important function by providing both the electrical insulation (in combination with a solid such as cellulose) and the means of transferring the thermal losses to the cooling system. The insulating liquid can also provide important and easily obtainable information for use in diagnosing the health of a transformer [1]. For the reliable operation of high voltage power transformers, it is essential that the cellulose insulation structures used in their construction are completely oil impregnated. The oil impregnation procedure is important to ensure that no cavities are left inside the cellulose insulation and thereby dangerous partial discharges are avoided [2]. For more than one hundred years, the majority of liquid-immersed transformers have been filled with mineral oil. The significant use of this petroleum-based product has been justified until now by its wide availability, its good properties, its good combination with cellulose and its low cost. However, with environmental issues now becoming extremely important, the use of a product with a high fire point temperature and high biodegradability is becoming extremely attractive [3]. Natural esters are produced from vegetable oils, which are manufactured from plant crops. They offer the advantage of a high fire-point as well as good biodegradability, but all types of natural esters suffer from not being as oxidation stable as other types of insulating liquids. Although natural ester fluids can be produced from a wide variety of crop oils, natural esters for electrical applications are most commonly produced from soya, rapeseed and sunflower oil. This is due to factors such as availability, cost and performance characteristics [3]. Therefore, my research is focused on electrical properties of natural esters and the option to use of these liquid dielectrics in electrical equipment.

II. Recent Research

Research of electrical and dielectric properties of oil paper insulation is the aim of many scientific collective. Properties such as breakdown voltage, dissipation factor, relative permittivity belong between the basic of diagnostic variables.

Current research of this area compares the electric and dielectric properties of mineral oil paper insulation and rapeseed oil paper insulation. The results [4] shown that rapeseed oil paper insulation has a higher permittivity as a mineral oil paper insulation. Dissipation factor has a similar behavior for a both insulation systems. Temperature is one of the factors which has strong influence on condition of oil paper insulation.

III. My Research

Because of insulation system of oil- paper is composite from liquid part and solid part, my current research is focused on these parts together.

My research was focused only on the oil-paper insulation system. Properties as relative permittivity, dissipation factor, and electric breakdown voltage were analyzed. The results [5] shown that, both insulation systems have similar dependence of dissipation factor on frequency. Dissipation factor exponentially decreasing as the frequency is increasing. Rapeseed oil paper insulation has a higher value of dissipation factor than mineral oil paper insulation. The breakdown voltage of natural esters is higher than breakdown voltage of mineral oil. The average value of breakdown voltage for rapeseed oil paper insulation is 19.3 kV and for mineral oil paper insulation is this value 18.3 kV. As well as the breakdown voltage, the electrical breakdown strength of rapeseed oil paper insulation has higher value for E_p than mineral oil paper insulation. The average value of E_p for rapeseed oil paper insulation is 53.61kV/mm and for mineral oil paper insulation is 50.84kV/mm.

The aim of my next work was analyze of properties such as relative permittivity and dissipation factor of oil paper insulation depending on frequency and voltage. In this experiment were used two types of mineral oil and two types of natural esters with combination of paper. From the results [6] we can make following conclusions. Insulation paper impregnated by rapeseed oil has the highest value of relative permittivity in throughout frequency range. Insulation paper impregnated by sunflower oil and insulation paper impregnated by mineral oil Nynas-Lyra X have very similar waveforms of relative permittivity in frequency range from 10 Hz to 2 MHz. Waveforms of dissipation factor decreases exponentially for all specimens of oil paper insulation. The highest value of dissipation factor was measured at insulation paper impregnated by rapeseed oil. Significant difference of dissipation factor is among specimens in the frequency range from 10 Hz to 0.1 MHz. This difference is not such significant at higher frequencies, and at higher frequencies the dissipation factor starts increasing. Frequency has strong influence on changes of relative permittivity, whilst influence of applied voltage has not such significant. The same conclusions apply for dissipation factor. Voltage dependence of relative permittivity is constant or the changes are not such significant as at frequency.

Temperature has great influence on condition of insulation system and it causes accelerated ageing of this system. Electrophysical properties as relative permittivity, AC breakdown voltage and polarization index of insulation oil paper before and after thermal ageing were measured. From the results we can make following conclusions. AC breakdown voltage of rapeseed oil paper is higher than AC breakdown voltage of mineral oil paper in each case. The value of relative permittivity is decreasing after each thermal stresses. Decreasing of relative permittivity is caused by evaporation of moisture from oil paper. Relative permittivity of mineral oil paper is increasing if voltage is increased in each of cases. The resistance of mineral oil paper insulation is higher than resistance of rapeseed oil paper insulation.

The last experiment describes the similar electrophysical properties as above, but there were used mineral oil, synthetic oil and natural ester as a one part of oil paper insulation. The temperature of accelerated ageing test was 90°C and there was chosen two different intervals of ageing. The first measurement was realized with new samples, the second one of measurement was realized after 500 hours ageing and the third one of measurement was realized after 750 hours ageing. Properties such as relative permittivity, dissipation factor and the breakdown voltage were described and analyzed.

The last part of my research during the PhD study was focused to long time thermal ageing of insulation materials. The different types of insulation oils, and paper was used for prepper the specimens. The ageing time was determined from 0 hour to 1500 hours. All results from this part as well as all result since 1 year study are written in my dissertation. My publication activities contain one contribution during the big international conference ISH 2015, 23-28 august in Pilsen. The second publication was published in conference proceeding from international conference Elektroenergetika 2015 , 16-18 September in Stará Lesná High Tatras.

Another direction of research in the area of impregnated paper was mixture of mineral oil and natural esters as a liquid part of oil-paper insulation. In this case were used linssed oil and sadfflower oil which were mixed with mineral oil ITO X with difference ratio. The same properties as were described above, were studied and analyzed.

CONCLUSION

The aim of this paper was compare the dielectric properties of commonly used transformer oil with natural ester and synthetic ester in combination with transformer paper From experiment can be visible the natural ester as possible substitution of mineral oil, but many researches rebut this fact. Therefore, the research of natural ester oil paper insulation is very important.

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Research on the impact of a combination of renewable energy sources in distribution networks

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***Abstract*— The issue of mutual impact between various forms of renewable energy sources is answered by a controlled interaction of a defined number of these sources – a "virtual pwer plant". In the context of distribution paths of electric energy (electric grid) towards the end user, application of information technology results in an intelligent power network, a „smart grid". In the case of considering a particular project, it is useful to use methods for modelling the combination of renewable sources in order to cover the power load diagram, in cnsideration with the defined criteria for quality indicators of power distribution.**

***Keywords*— unpredictable, renewable source, intelligent network, virtual power plant, load diagram, electric disribution quality**

I. INTRODUCTION

In accordance with directive no. 2009/28/ES concerning the use of alternative energy sources, along with changes to, additions, and subsequent repealing of directives 2001/77/ES and 2003/30/ES, the use of alternative sources throughout the EU has been on the increase. Between the 28 member states, as of late 2012, the share of alternative energy sources (AES) has risen to 14.4%, compared to 8.3% recorded in 2004.

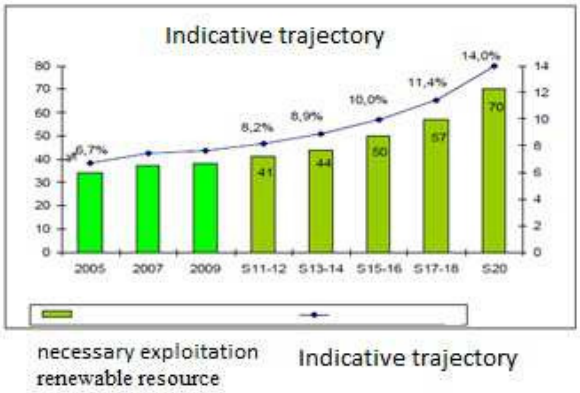

Fig. 1. The share of renewable resource energy in the gross final power consumption in Slovakia

The main reason for the increase in AES support is the effort to fulfill the „Europe 2020" strategy, in which five important, ambitious goals, concerning i.a. the areas of climatology and energetics, have been set for completion before the year 2020. In the field of power generation, the member states have pledged to increase the share of AES on the final gross energy consumption, the goal being 20% by 2020. [5]

The above mentioned findings point to a rapid increase in AES power generation, as well as a swelling of AES source installations. Currently, the AES based power plants number in the hundreds. Even on the scale of a single local distribution network – VSD a.s., approximately 820 sources are located. [6]

It is therefore logical for the AES developers, as well as power distributors to future-proof ant optimize the intersecting influences of these power sources and networks. This means deepening the mutual technical and economical cooperation. Currently, the power distributor (PD) is required to purchase all of the energy produced by alternative sources. The PD also has to deal with the task of releasing the purchased energy according to the power load diagram. The load diagram itself is defined by the actual power consumption. The process of AES power purchase is accomplished under the defined legislature of the environment. [2, 3, 4] The basic provisions under law 251/2012 concerning electric energy declare the following:

Electric power system is a centrally controlled network of interconnected power plants, electric distribution elements and appliences, with the purpose of supplying electricity to the society. [1]

Distribution matrix is a system of interconnected power lines of voltages up to 110 kV along with electromagnetic devices required for power distribution along a specific area. Devices required to provide measurements, protection, direction, shielding, information and telecommunication for the power system are a part of it as well. [2]

Renewable sources of energy are non-fossil energy sources, which have a constantly renewed energy potential, powered either by natural processes or human activity. These include:

1. hydroelectric energy
2. solar energy
3. wind energy
4. geothermal energy
5. biomass including all products of its processing

6. biogas, landfill gas, gas from water treatment facilities
7. biomethane
8. aerothermal energy
9. hydrothermal energy

b) Electricity from renewable sources is any electricity generated power generating devices that only use renewable energy sources, or electricity created in shares that correspond with necessary amounts of energy generated via renewable sources. Electricity produced from hydroelectric pumping storage is not considered to be AES.

c) to be considered a AES producer, one must produce electricity from renewable sources. [3]

The theme of this particular work is the optimization of relationships between various AES providers, their distribution operators, and end users. The grid operation is characterized by the daily load diagram (DLD), as well as quality pointers of electricity distribution. [5]

II. RENEWABLE SOURCES, CURRENT STATUS AS RELATED TO ELECTRIC GRIDS

From the viewpoint of operating an energy network, solar and wind power is considered as highly unstable, with high fluctuations in power generation. For this reason, they have long been branded as, so called, unstable renewable sources in the field of power production. [4]

The classic conceptualization of a power grid system depends on the current state, where several major power sources exist (each generating dozens to hundreds of MW) For economical reasons, these centralized sources tend to have as high an installed per-unit output as possible. Transformation of very high voltage (transmission, 110kV/22kV) and low voltage (distribution), is ordered hierarchically. Energy flows are definitive – from concentrated sources to end users. The amount of production is determined by consumption. Renewable sources generally take form of a large number of relatively small electricity sources (on the scale of kW up to 1 MW). They are defined as **dispersed, distributed or decentralized energy production.** These networks generally operate in a high or low voltage environment. In the sense of curren legislature, all energy produced by renewable sources must be purchased. In a given network, low consumption may lead to an overabundance of energy – the energy flow may change into a non-hierarchical flow, from a lower voltage network into a higher one. Production in centralized facilities must accomodate not only actual consumption, but also the production from the renewable sources.

The issues concerning dispersed sources in use in a distribution network have been relevant since the first implementation of these sources. The importance of this problem rises along with the number of active AES. The integration of AES into distribution networks is a specific point of interest of the dedicated work group CIREZ. In principle, it is concerned with the conditions for connecting AES into distribution networks, with focus on feedback of given sources at the point of connection to the network. For example, this includes the question of voltage quality in high and low voltage networks with a high penetration of alternative sources. It's also concerned with the performance of AES in normal operation, and especially in failure states. [7, 8, 9, 19, 11]

The problem of AES dispersed within the network is the transport of electricity to the end user. Transfer is in principle connected with energy losses. Optimally, the energy should be used at the very place where it's being genrated. Thus, energy consumption near the point of origin should have the highest priority.

Compared to a situation with a small number of dispersed sources within the network (numbering in the dozens in the past), the management of hundreds of dispersed sources within a localized network by a single provider has much hihger requirements on both the transfer management and actual distribution in real time. [5] The characteristics of highly dispersed AES, their integration and cooperation with the grid, require an adrequate technological backing – requirements of long distance measurements, remote control, data transfer and processing. We are, in effect describing the so-called intelligent network - a „Smart Grid".

III. SMART GRID

Intelligent networks (Smart Grids) combine the traditional technologies with innovative digital solutions. Thanks to a more effective exchange of information, the flexibility of electric grid management rises. From the perspective of integrated combined AES systems, this represents an effective method of their management. [10] One of the latest implementations of intelligent grids is the integration of individual AES energy production units into the grid. The support of AES follows the environmental goals set by the European Commission.

The use of innovative digital technology will allow for the monitoring of a whole grid along with electricity flow regulation. The prevention of blackouts will be improved, resulting in a more dependable power supply. Intelligent grids are the answer for the current questions concerning the management of distribution networks. Distribution grids have an option of becoming a modern provider of specific services in the field of electricity generation, transport and supply.

The consumer is no longer a passive participant in the grid. The system evolves over time, based ton relevant needs. Energy flows are definitive and transparent. Customers actively enter the energy market and utilize it efficiently. Customers are able to utilize the **Demand Side Management (DSM)** tools. DSM is a strategy utilized by electric companies, offering measures in the area of load management, cost and tariff management, customer support, financial stimulus programs, municipality support programs, development and testing of various products. The goal of DSM is to seek further ways to improve energy effectiveness for the custome, as well as improving the supply services. One condition for the implementation of DSM is a mechanism of its financial support. DSM is relevant when the marginal costs of creating new power plants are higher than average expeditures.

As stated in the introduction, an integral part of the grid is the consumption side - the receiving device on the customer

side. In this context, devices that increase energy effectivenes on the end user's side may as well be considered intelligent grid components. These may include surge protectors, inverters and back-up power banks.

The devices used are known in principle, but are used on a higher technical level, on the basis of new technology and electric control components – DVRs (Dynamic Voltage Restorers), distribution static condensers, static devices implementing uninterruptible power systems (UPS), "on-line" power supplies with a single or double conversion, and UPS systems featuring „delta" conversion and rotational energy banks with flywheels for uninterrupted electricity supply.

One beneficial solution in the grid-user relationship is the so-called „netmetering". It's a very transparent and efficient method for the government to support small scale energy producers – especially homeowners and consumers who want to be energetically self-sufficient. The principle behind this model is simple: A supplier who generates electricity for their own use transfers the energy surplus into the grid without the right to financially gain from this production. The are, however, entitled to cost-free consumation of an equal amount of electricity from the grid in a determined time. The consumer uses the grid as a sort of „power bank" – they can extract whatever energy they previously put into it. In case they produce less energy than they consume, they buy the needed electricity from the grid like a regular customer.

Intelligent grids increase service quality. It is expected that

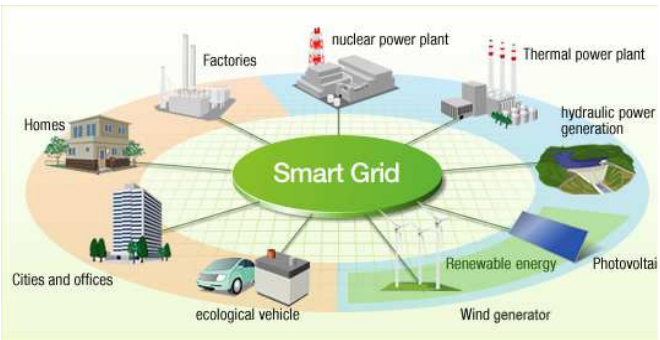

Fig. 2. Smart Grid Shematic

the costs of operation will decrease while the competetiveness of grid operators will increase. Further benefits are expected for the environmental sustainability and the whole system. Distribution grids cease to be a passive component between energy source and destination. In the near future, electric grids will allow for an efficient way of energy exchange with minimal greenhouse gas emmissions, increased electromobility and transformation of cities into new, modern districts with minimal negative environmental impact.

Based on the findings above, it is possible to claim that the research into introduction of AES into distribution grids leads to the concept that presents itself as the so-called virtual power plant. It deals with the coordination of individual sources in relation to the grid operators and electricity providers. Thusly joined, AES can be in the ownership of a single provider or have thair relationships defined by a contract.

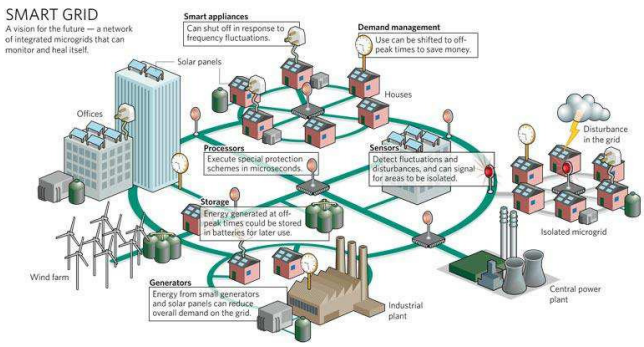

Fig. 3. Smart Grid with Virtual Power Plant

IV. VIRTUAL POWER PLANT

In principle, a **virtual power plant** consists of a central controlling unit, multiple power plants (directly connected to the grid from various points across the country) and a number of electricity consumers. The dispatching center of the virtual

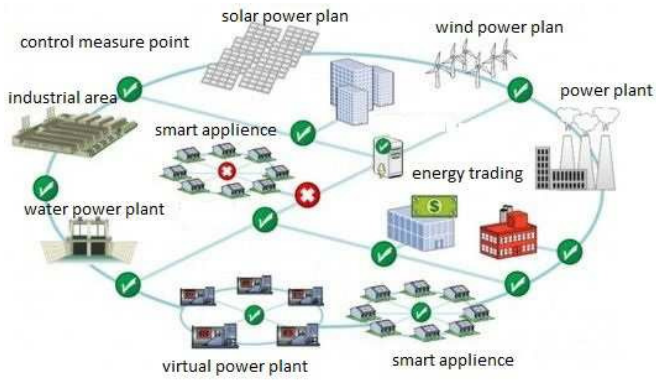

Fig. 4. Smart Grid with Virtual Power Plant

power plant is directly connected to the controlling units of the physical sources, as well as to the TSO (Transmission System Operator). An unlimited number of power plants can be joined, regardless of their size, location or primary energy source.

The controlling unit of the devices (Smart Unit), which is connected to the virtual plant, transmits production and operation data to the central. At the same time, it gathers instructions from the central, based on the specific demands from the electricity market.

Virtual power plants are unique in the fact that they can also participate in the support of the grid any hour, any day of the year without disruption. This system is useful for:

- secondary regulation as requested by system operator
- portfolio management on the customer side
- production of thermal and electric energy based on demand
- production, regulation and distribution of electricity 24/7

V. CONCLUSION

Renewable energy sources are currently an integral part of the power distribution networks. The primary regime of grid production is determined by power collection – its scale, structure, temporal fluctuations. Grid load is characterized by

its load diagram. The task of cooperation between sources of various characteristics and spatial structure is, as specified in chapter II., solvable via the implementation of technical solutions that are characteristic of an intelligent „smart grid“. Focusing solely on the source elements of the grid, the term „virtual power plant“ becomes the key concept. Using it, it is possible to optimize the cooperation of various sources of renewable energy, as well as their interaction with the whole grid.

The topic of „smart grids“ is currently quite popular in the media. Several renowned companies, such as ABB, Siemens, Landys&Gyr [14, 15, 16], already offer complete, readily applicable solutions. Equally, the suggested models concerning virtual power plants are offered as applicable solutions. These cases directly reflect a situation where the purchase of AES into the grid is no longer practiced, so the producers will have to apply their product on a free market on a commercial basis. One practical solution is represented by the „SEAS – Váh Cascade virtual block” project. [10]

Possible drawbacks of further innovative developments of Smart Grid and virtual power plant technologies are not seen in the technological area, since that consists mainly of applicated programming equipment and infrastructure placement (measurements, communication), but rather in the legislature. An interesting concept arises – a „virtual end user“ with assigned attributes similar to a virtual power plant. In this case, it is possible to use DSM and technical solutions in order to provide high quality energy management on the user side, optimizing the use of a virtual power plant on the scale of a local (virtual) distribution network. The proposed research potential lies with the development of specialized software for a particular applications or projects, as well as modelling the load diagram of a distribution network of various renewable sources, in accordance with a set of criteria for electricity distribution quality.

In the following time period, we will focus our research on:

-defining technical parameters of individual grid components (in the area of electric sources, distribution and AES) required for the optimization of their performance during operation and failure states

-stating the requirements for a multiple criteria based optimization, taking into account the legal environment of the electricity producing free market

-modelling the grid component cooperation, defining the requirements data transfer and programming support.

ACKNOWLEDGMENT

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Robust Language Modeling in Automatic Speech Recognition System in Slovak

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***Abstract*— This paper summarizes the work of student for his four year of the post gradual study. It aims on improving the automatic speech recognition systems by creating more robust language models. Our goal is to outperform the conventional language models that are used in the current system for automatic speech recognition in Slovak language.**

***Keywords*—language modeling, latent Dirichlet allocation, latent semantic indexing, text categorization**

I. Introduction

In our four year study, we mostly focus on creating robust language models for automatic speech recognition (ASR) in Slovak language. We wanted to improve our large vocabulary continuous speech recognition system (LVCSR), which is part of the successful Slovak automatic transcription and dictation system for the judicial domain [1].

The robustness in language modeling can be understood in many ways. We can create better language models by incorporating new techniques and algorithms for training and adapting language models. Our convenient language model in ASR is smoothed by the Witten-Bell algorithm. It is trained on 24 subcorpora and adapted by the linear interpolation to the domain that will be used, mostly from judicial or parliamentary domain. Several problems can raise up, when we will not have enough text data for adaptation purposes. But the increasing number of the text documents gathered from the Internet can help us to overcome this problem. But the question is then how to effectively categorize this text data from Internet. And this can be the next area of how to create more robust language model. We can organize text corpora in better way, using clustering or text classification algorithm. Training language models on organized text corpora can improve the robustness of whole ASR system by creating domain oriented language models.

This paper is organized as follows. Section II briefly overview the whole work of student on his postgraduate study with his most interesting results in the area of text categorization and language modeling in ASR in Slovak language. Last chapter describe possible future work in the area of language modeling and recommend several ways for potential followers in the area of language modeling.

II. Results

This chapter summarizes the obtained results that were published in several indexed journals or international conferences.

A. Language models comparison

In our first experiment with improving robustness of language models in ASR, we have focused on comparison of several advanced language modeling techniques that were published in several major speech conferences in the world. The preliminary experimental results have showed that our convenient language model smoothed by the Witten-Bell algorithm produce still the best performance according to the model perplexity and recognition accuracy [2]. We have decided then to focus on text categorization and language model adaptation as a way to improving the robustness of language modeling in ASR.

B. Clustering of Slovak text documents

Our research in text categorization have begun by clustering small training corpora of Slovak text documents from Wikipedia. The obtained result were used for choosing the best term weighting schemes, similarity measures and clustering techniques that can be possibly used for clustering all collected Slovak text data. We have found out that Term Frequency Inverse Document Frequency (TFIDF) together with Pearson correlation index or cosine similarity provide the best results in clustering Slovak text documents with k-means or hierarchical agglomerative clustering algorithms [3], [4], [5]. We wanted to use these techniques in clustering the whole collected corpora, but the memory and computing requirements were very high, so we had to found some better and effective way how to categorize more than 6,5 millions of Slovak documents.

C. Text categorization of Slovak text documents

In paper [6], we have proposed technique for text categorization with keywords to the in-domain and out-of-domain data for better domain-specific language modeling and speech recognition. We have designed an algorithm that extracted a list of 5 210 key phrases length from 1 to 4 words from morphologically annotated judicial corpora. The processed documents and the list of key phrases was transformed to the vector space model (VSM) with TFIDF weighting schemes. Then we have measured the similarity between our list and processed documents. If the measure was

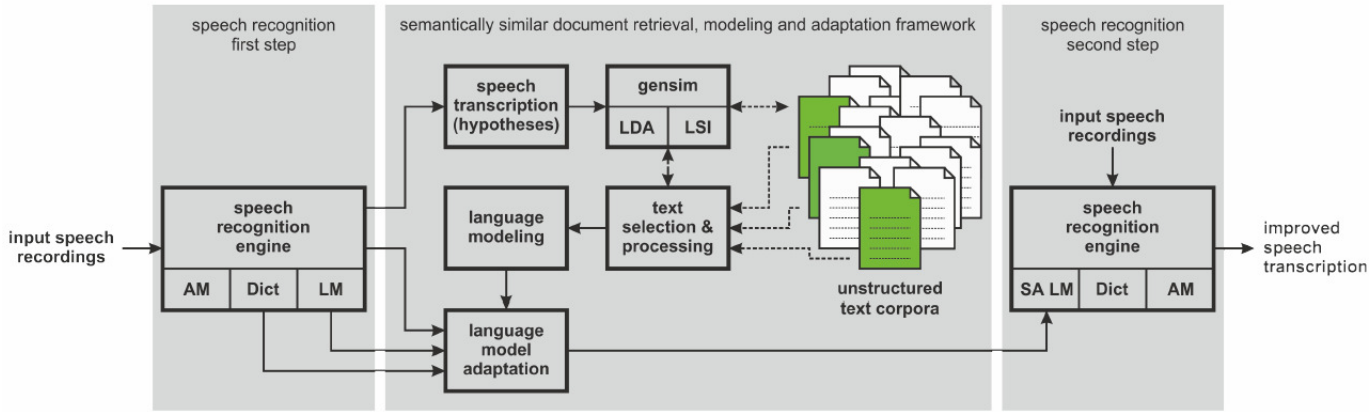

Fig. 1. Semantically similar document retrieval and language model adaptation framework

higher than threshold, which was based on the calculation of median of a sequence of coefficients, than the documents was categorize to the in-domain corpus. The experiment results of the language modeling and adaptation to the judicial domain show significant improvement in the model perplexity about 19% and decreasing of the word error rate (WER) of the Slovak transcription and dictation system about 5.54% relatively.

Another automatic text categorization system based on latent Dirichlet allocation (LDA) was proposed in [7]. We have divided initial text corpora into 2, 5, 10, 20 or 100 subcorpora with various iterations of LDA. Language models were built on these subcorpora and adapted with linear interpolation to judicial domain. The experiment showed that text categorization using LDA outperform not only baseline language model, but also categorization with keywords. The perplexity was reduced about 12.3% and WER about 7.26% relatively.

D. Semantically similar document retrieval framework for language model adaptation

The obtained results and knowledge from the previous researches have led us to create framework for retrieving semantically similar document as a tool for language model adaptation. The proposed framework is illustrated in Fig. 1 and it is going to be published in [8]. We have used this framework for retrieving semantically similar subset of unknown text documents for speaker for adjusting parameters of an existing well-trained language model to a specific speaker style. We have used latent semantic indexing or latent Dirichlet allocation for retrieving the subset of semantically similar documents. The hypotheses from the first step of ASR system is used to retrieve enough amount of text document from the indexed corpora using Python library Gensim [9]. The retrieved documents are used as an adaptation corpora. Preliminary results have showed slight improvement in ASR system in fully automatic subtitling of parliament speech, broadcast news TV shows and TED talks.

III. Future work

For potential researchers that will maybe follow presented work we have several advice. We recommend to experimentally investigate the usage of recurrent neural networks for language modeling in ASR in Slovak language and incorporate the Kaldi toolkit for speech recognition system [10]. It could outperform our convenient setup for ASR in Slovak language.

In the area of text categorization and semantic similar document retrieval we recommend to improve our proposed system by adding the new words from adaptation data to the speech recognition dictionary during language model adaptation that could improve the accuracy of the ASR system.

Acknowledgment

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Searching for Malware Markers: Packing and Harmless Software

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***Abstract*—Harmless software is rarely included into malware research, its role is often to serve as a testing set for monitoring detection rates of new detection engines. However, even safe programs have high potential for malware research if careful observations of their properties and behaviour are made and the results are compared with features of malicious software. The following text is a brief report of research activity and observations employing harmless software in order to identify key features for distinguishing malware from safe software.**

***Keywords*—Malware behaviour, malware packing, bytes distribution, malware analysis, Docker, application container.**

I. Introduction

A shift from syntactic - structural malware analysis towards semantic - behavioural malware analysis is apparent among malware researchers. Since syntactic form of malicious programs is mutable and unpredictable, researchers incline to behaviour or other aspects which are less prone to obfuscation. Despite this trend there is no comprehensive description of features which take part in formation of malicious features in software. Current malware models are mostly oriented on proliferation or mutation in general, however, these do not suffice for practical usage (malware detection, mitigation, defence, etc.) and for further research purposes. Though several typical malware features are described among researchers, e.g. obscuring program's functionality through packing, their usability and reliability are not verified.

II. The research problem and its initial status

Based on research from the past year, a question arises whether assumptions about typical malware behaviour my be incorrect in some situations. The fact is that these special cases have not been sufficiently explored yet.

Another issue is significance of harmless software in the research of malicious behaviour. Many researches use harmless software only as a resource for demonstrating high detection rate of presented detection engine. Selection of harmless samples may considerably influence detection rates. Many times programs which are installed on the system by default are used as a control group in published researches. While these do not lead to false-positive results, they do not form a proper representative set of harmless software, since many different software products are available and some of them may even resemble malware in some of their features. However, research studies comparing malware behaviour and properties with harmless software are not known.

III. Progress in the research area

Our research was dealing with reliability of features which are considered as typical signs of malicious software. Special attention was given to packing, which employs compression for reduction of program's size, combined with encryption to obstruct program's reverse-engineering, signature-based detection and static analysis [1]. Unfortunately, software packers are popular among malware writers [2].

A series of experiments [3] were performed on a set of 100 samples - system administration tools and utilities, used e.g. for tasks management, deleting temporary files, broken links removal, memory optimization, files encryption. These programs were harmless, what was checked with anti-virus (AV) scanners, and were selected because of their behaviour's potential similarity with categories of malware operations, summarised in last year's literature review [4].

Analysis revealed that among 100 samples only 19 were not packed by any known packing tool. The other 81 samples were packed by 15 different packers, e.g. UPX which is preferred by numerous computer viruses [5], PECompact, PecBundle, INNO, ASPack, PE-Patch. Many samples were modified with several packers simultaneously - multiple layers of packing were applied.

Detecting a packer which is often employed by malware does not necessarily mean that the sample is malicious. A closer look at distribution of bytes in analysed samples uncovered further differences between samples. Distribution of bytes in basic applications that are not packed, compressed or encrypted, is typically uneven, it exhibits several fluctuations which are well visible. On the contrary, minimal or no fluctuations (uniformly distributed bytes) are considered as anomalies and suggest that the sample was modified with a packer, encryption or compression engine. Fig. 1 contains graphs of bytes distribution from several samples. Specifically samples 1, 2, 4 and 6 represent typical packed programs.

Distributions of bytes obtained from samples by analytic tool Charcount [1] were divided into 5 categories[2] based on intensity of fluctuations in distribution. Categories 1 and 2 represent samples with uniform or almost uniform bytes distribution and are related to usage of packers. On the other hand, category 5 represents samples with numerous significant fluctuations typical for normal programs. Although only 19

[1]http://aluigi.altervista.org/mytoolz/charcount.zip
[2]Details about categories and criteria of sample's placement into particular category are described in the article [3].

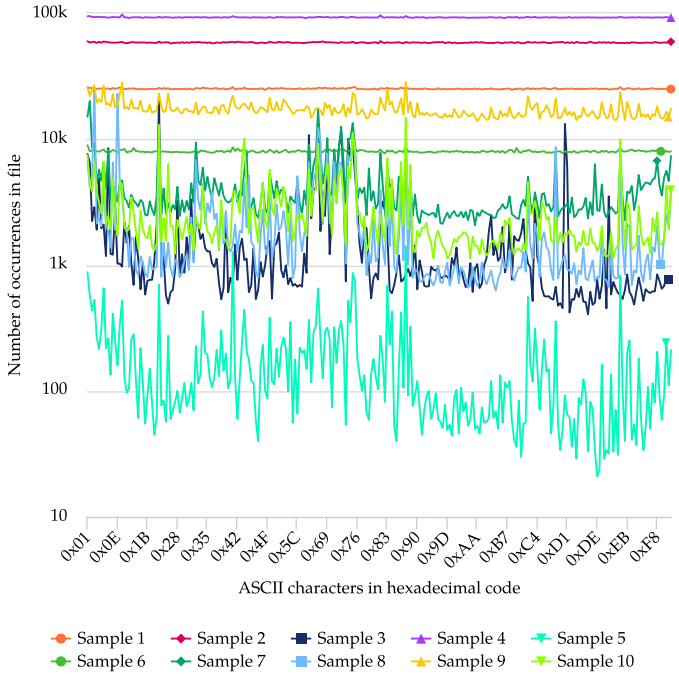

Fig. 1. Distribution of bytes for 10 selected samples from analysed set. They illustrate difference between uniform (in this context anomalous) bytes distribution and distribution with high fluctuations.

samples were not packed according to the first analysis above, 60 samples indicate bytes distribution of normal (not packed) programs (Fig. 2).

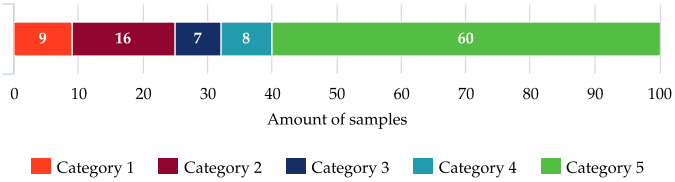

Fig. 2. Number of samples in categories of bytes distribution.

More detailed look into a PE file[3] can uncover which section of the file is packed, if any. Analytic tool Bytehist[4] creates several images with histograms of bytes usages. The first corresponds to the sample as a whole file. In case of a PE file the other histograms correspond to its sections, typically `.text`, `.bss`, `.rdata`, `.data`, `.idata`, `.reloc`. If Bytehist detects some content even after the last section, it is presented as a section `.rest`. Examination of results from Bytehist showed that only 12 of 100 samples contained no data after the last ordinary section. For the rest of samples, the amount of bytes in `.rest` varied. Histograms of sections also indicate percentage of the original program's size contained in the section. Only 19 samples contained `.rest` section under 50% of the program's size and 90% or more of program's bytes was present in more than a half of samples. This unusual distribution of bytes across sections, or rather behind common sections, is suspicious. Furthermore, if section `.rest` exhibits uniform distribution, it suggests some hidden feature in the sample. Only 3 programs indicated data in section `.rest` with uneven distribution.

[3]**P**ortable **E**xecutable file is generally standard binary file format for an application or DLL on Windows operating system.

[4]https://www.cert.at/downloads/software/bytehist_en.html

Examining behaviour of a program which is packed requires dynamic analysis - execution of the program. For security reasons, analysis of malware behaviour is often performed in a virtual environment or a sandbox. A problem may arise when some kinds of malware are able to detect this uncommon environment, as mentioned in last year's literature review [4].

Research of this problem showed that current solutions are not yet able to avoid environment detection, and the best choice for capturing as many malware activities as possible is usage of a physical computer system separated for the purpose of malware analysis. This carries a risk that the system may get infected with examined malware, which would require complete restoration of the system every time it happens. Application containers which are currently gaining popularity could reduce problems associated with physical analytic environments. Recent experience with Docker containers for secure testing of students' assignments was very positive [6]. Docker also drew attention of malware research community [7] so its usage is considered in the future.

IV. Conclusion and Plans for the Future

Harmless and malicious software evidently share suspicious features like packing, program's code in unusual .rest section and uniform distribution of bytes. This leads to a conclusion that assumptions about typical malware features are not always reliable. In case of packing, it should not be considered an indicator of maliciousness, since it is linked with both malicious and harmless software. Unless the purpose of packing the sample is known, solid conclusions can not be made.

Next steps of the research comprise experiments with application container Docker for the purpose of secure software dynamic analysis. Another categories of behaviour will be examined with system monitoring tools, e.g. operations related to file system: files created, altered, deleted or moved at the time of malicious and also harmless programs' execution.

At this time, a large database of properties and behaviour, extracted from known malware, is collected through online analytic services. Gathered information will form an overview of the most notable malware features, guide future in-depth analysis and direct research of potential *malware markers*. The goal is to create a set (or various sets) of such markers and use them as a basis for formulation of malware models.

Acknowledgement

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Secure User Authentication in web Applications

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***Abstract* — This article is dedicated to a brief introduction to creating a secure user authentication in web applications. In the first part of this article, there will be introduced most common attacks on the web system, which may occur. Some of them may be easily avoided, others may be still dangerous. In the latter part, we will discuss about passwords, which are the essential part of the user authentication. And lastly, there will be proposed solutions for some miscellaneous, like account recovery, long term authentication, etc.**

I. Introduction

A common problem while developing a web based applications is to implement safe user authentication and access controls, which are basically sign-up and log-in forms. They may seem to be simple in theory, but engineering one that meets all application security standards can be really hard to accomplish, since attackers tend to be very creative in finding ways to overcome security measurements.

Without proper security level, authentication systems may are very fragile and therefore the whole application and its content can be compromised by a single attack. However, for every possible attack, there is an effective solution to achieve a more resilient and secure application.

Also the internet community needs to be taught the dangers of possible attacks, because their accounts or privacy may be compromised if they lack knowledge, or just act irresponsibly on the internet (i.e. having a weak password).

II. Possible attacks

With growing internet population, we must face increasingly more different attacks and methods of compromising our web applications. Hackers are usually motivated by grudge or complaint against the site, or the owners themselves. They also try to overcome a website's defenses for commercial or political reasons, or just try to obtain potentially valuable user information for their own profit.

A. SQL Injection (SQLi)

Injection vulnerabilities are major source of concern for web and application developers which store usable information in local database. An attacker can make a string using specific SQL commands, which can be used to gain access to the database, mainly due to the predictable nature of these types of applications. The string can be entered in input fields such as login forms, search boxes and even directly into a url to negate simple client-side security measures on the page itself [1][2].

B. DoS/DDoS

Denial of Service (DoS) is an attack, when the attacker attempts to prevent legitimate users from using services, or accessing information. It can be accomplished by "flooding" a network with information, so that legitimate requests cannot be processed.

There is a variation of DoS called Distributed Denial of Service (DDoS). The main difference is that some other computers are infected first with virus, which does DoS attacks to the target system. DDoS can be more powerful than DoS, if distributed in wide range of systems [1][2].

There are 3 main varieties of DDoS attacks:

- Protocol Attacks – packets attempt to consume server or network resources.
- Volume Attacks – attacker tries to overwhelm bandwidth on a targeted site.
- Application Layer Attacks – requests are made with the intention of crashing the web server by overwhelming the application layer.

C. Brute Force

Using a brute force attack may not be time efficient, but it is still used to access control of sites that are not well protected against it. Basically, it is an attack which uses specialized scripts that continuously try different inputs (for example username and password combinations) until a positive response is received from the server (for example user authenticated). This can be a brief attack which uses only most common passwords, or long-term targeted attack composed of lists of millions of passwords to try. More sophisticated brute force attacks use specially crafted dictionaries, which can work on users with weak passwords [1][2][3].

D. Cross Site Scripting (XSS)

Cross Site Scripting (XSS) is when an attacker injects untrusted snippets of Javascript into web application without validation. Then, this Javascript is executed by the victim who is visiting infected site. This way the attacker can completely alter the content of the site for own purposes – for example sending user credentials to another server [1][2][3].

There are three primary types of XSS:

- DOM based XSS – no HTTP request is required, because the script is injected as a result of modifying the DOM of the target site in the

client side code in the victim's browser and then executed.

- Reflected XSS – An attacker sends the victim a link to the target application. The link has a script embedded within, which executes while visiting the target site.
- Stored XSS – An attacker is able to plant a persistent script in the target website which will execute when anyone visits it.

E. Man-in-the-Middle

Man-in-the-Middle attack is based on intercepting a communication between two systems and then, by using a various techniques, splitting the original TCP connection into two separate connections, one between the attacker and the victim, the other one between the attacker and the server. While this connection is intercepted, the attacker acts as a proxy and is able to read, insert and modify the data in the communication between the client and the server [1][2][3].

MITM attack can be very effective when using the HTTP protocol due to the fact, that the data transferred are all ASCII based.

This attack can be also performed over a HTTPS connection by using similar technique. The only difference is in establishing two independent SSL/TLS sessions, or one SSL/TLS session with the server and one unprotected session with the client. The browser warns the user that the digital certificate is not valid, but the user may ignore the warning, because s/he doesn't understand the possible threat and by doing that, allows MITM attack to be possible.

This attack can be prevented by using HTTP Strict Transport Security (HSTS) policy, which protects HTTPS websites against downgrade attacks and cookie hijacking. The only condition is that the MITM attack is not happening during the first communication between the server and the client.

III. BACKGROUND OF SSL/TLS

SSL/TLS (Secure Socket Layer/Transport Layer Security) are protocols used by web applications and they provide secure session key establishment, symmetric key based traffic confidentiality and public key certificate based authentication. The protocols are mainly relied on by most commerce applications, which need to use strong security protocol [4][5].

The protocols are mostly referred to as interchangeable, but the truth is that the latest version of SSL 3.0 is the predecessor of TLS 1.0. While SSL is now considered completely insecure, especially after the POODLE and BEAST attack development, it is still used by some servers to provide "secure web sites". On the other side, TLS 1.2 can prevent those attacks and is considered the best security protocol for web sites, so far. It is believed that it will be replaced by the next version of the protocol (TLS 1.3), but it is still in the process of development (as of January 2016, it is a working draft).

On the other hand, both methods ensure that your data is encrypted when it is transmitted over the Internet. They also both assure you that the server you are communicating with is the server you intend to contact and not some "middle man eavesdropper". They are able to do it, because servers with SSL/TLS support must have certificates issued to them by a trusted third party, otherwise the user will be alerted that the server cannot be trusted and may be a serious risk. This may occur if the certificate is not trusted, or the server does not match the domain name. The certificates verify that the domain name they are issued for really belongs to the server [6][7][8].

Connection through there two protocols can be established in two different ways [6]:

- Implicit (by protocol) – the connection begins with insecure request to the server and then it is switched to secure connection, after the successful handshake between the client and the server. If for any reason the handshake is not successful, the connection is severed.
- Explicit (by port) – Using a specific port means, that the secure connection should be used. The server is waiting to establish a secure connection and then process some requests, if the used port is configured.

IV. PASSWORDS

Most authentication services use a string of characters as a secret password to verify user identity. People used passwords from ancient times and its complexity has improved over time, but some people still use simple phrases as passwords, because they are easier to remember. Using simple passwords can be a huge security risk, because it can be easily guessed. As a response, most authentication services have implemented a password policy, which enforces using strong passwords. Another interesting approach is using a single sign-on [9].

A. Policies

Password policy is an essential part of user account protection [10][11][12]. Good password policy should cover:

- Minimum password length: It should be 8 or more characters, but some services may require more characters. There is no ideal length of the password. In general, the longer the password is, the harder is to guess the password. Some servers may restrict the maximum length of the password for legacy support, but it is not recommended to limit the maximum password length.
- Maximum password age: Some services may set an expiration date on passwords, so the user is forced to change the password. While this may be good in cases that the password was somehow stolen and the attacker is then granted unlimited access to the system, users tend to choose weaker passwords or abbreviations of the original password, if the maximum password age is set too low.

- Minimum password age: This is not widely used feature, but it prevents users from bypassing the maximum password age policy by not allowing the user to change password for some period of time after it has been changed.
- Password history: Sometimes, the service may prevent the user to reuse some old passwords to increase the system security. While this may seem like a good idea, people tend to choose weaker passwords, or to write them down, if they are prohibited to use set of passwords they have remembered.
- Password complexity: Apart from basic password policies, the most commonly used policy is enforcing password to meet some complexity level. One example of complexity can be:
    - Password should be at least 8 characters long.
    - Password cannot fully or partially contain the user name, email, birthdate, telephone numbers, license plate numbers, or other common numbers or phrases.
    - Password should consist of at least three of the four available character types: lowercase letters, uppercase letters, symbols and numbers.
    - Password should not contain any phrase from the password blacklist, which is basically a list of weak commonly used passwords (for example qwerty123).

B. Hashing

Passwords are stored on the server for the need for comparison with the user input. Storing passwords in the plain text form proved to be a huge security risk, because anyone can simply hijack the database and gain access to user accounts. This is why people have developed specially crafted encryption methods for passwords, which do not allow the process to be inverted [13][14].

1) Functions

Ideally, the hash function should have four properties [15][16]:

- The computation is quick for any given value.
- It is impossible to generate the original message from the hash value.
- Only a small change to the message can cause a huge difference in the hash value. This is called the avalanche effect.
- There cannot be one hash value generated for different messages.

While the hashing functions are often referred to as password hashing functions, they can also be used for different purposes (for example indexing).

2) Algorithms

There are many different algorithms, which can be used for password encryption. With the growing computing power, people are forced to design stronger encryption algorithms, which cannot be easily broken. Some of the algorithms that have also been broken in theory or in weakened state are considered not safe anymore, because they can be a possible threat [15][16][17].

In general, it is recommended to not use old and fragile algorithms, but instead to replace them with their newer versions with stronger keys, or with different algorithms (for example whirlpool).

3) Salt and Pepper

Salt is a random, evenly distributed, high entropy value, which is added to the password before hashing, to increase the security. It is widely used with common secure algorithms and stored on the server side along with the hash [17].

The pepper is something similar to the salt, but it is not stored in the database, but rather hard coded in the server side scripting code. Someone may think it is logical that pepper increases the security in case the database gets stolen, but the truth is that its cons outweigh the pros. Main problems with the pepper are:

- Feeding one hash into another can be dangerous.
- It is working against the design of hashing functions.
- It is not maintainable.
- It is required to use some custom cryptographic function.

V. Long-Term Persistent Authentication

Many sites use a “remember me” button, which is convenient if the user visits the site often and is on a secure private device. But designing one is not easy. It should not just a simple cookie, which stores user credentials, because it can be easily forged [14].

The cookie should instead contain a unique token, which is generated for the current session. The token should be stored in the database on the server, alongside with the expiration time and date. This way it is nearly impossible to forge the token, if the expiration time is set right.

Also the designer of the application should be aware of the timing leak behavior of the database, which can lead to security flaws. It is recommended to the lookup in the database in the constant time to prevent this behavior.

VI. Account Recovery

Another aspect of the whole system authentication is the account recovery. While some developers see this feature as a possible backdoor threat, most developers implement this feature. If the use of this feature is inevitable, the developer should follow these rules:

- Never use any security questions. Most people just use a simple answer, which can be looked up, or just simply guessed, because it tends to be way weaker than the password.
- It is recommended to use real time generated tokens for the password recovery instead of security questions. The tokens should be sent via secure mail protocol.
- Always limit the token lifespan, so the attacker will be unable to use brute force attack.

- Also never send the old password to the user (you should not be able to do this, if you are hashing passwords).

VII. Possible improvements

While it is generally advised to use existing authentication systems, which have been proven to be secure, one might be able to design their own authentication system, but it needs to be tested against possible threads. Not just in theory, because it may fail to be safe in real environment.

Hackers have proven to be more creative than safety analytics and that is why most security measurements and improvements are just a response to attacks that have been successfully done. But apart from that, security analytics are designing new methods to render their systems more secure.

Hashing functions are getting improved from time to time, which is essential part of the computer evolution. There is still some space to create a new cryptographic algorithm that can be tested against collisions and also against possible attacks. Also hashing functions which use these algorithms can be improved, to be more secure with the increased computational power available.

Also attack detection can be good asset to fight against attacks. Currently there is limited attack detection capability on servers, mainly because of the unpredictable nature of the attacks. For example one cannot distinguish DDoS attack and multiple legitimate users trying to reach the server. They both cause high traffic load which may cause the site inaccessibility. Good attack detection can limit the attack damage it may cause, or completely render it useless.

This can be accomplished, if we could distinguish legitimate users from the attackers. The attackers cannot be tracked from IP addresses, because most of them use different methods to hide their real address, or just use other computers infected with virus to do the job for them.

Some countries have proposed that the internet should not be anonymous, because of the criminals, but most of their citizens are against the proposal, because they do not want the authorities to know what they are doing on the internet, even if they are not doing anything illegal. And also the proposal is against the right to privacy.

Other improvements can be made at the protocol level. Man in the middle attack is still a threat and currently there is no protocol which can completely prevent that to happen. It could be an improvement, if SSL/TLS is enforced via built in lists in browsers, so that it will be unable to drop the HTTPS to HTTP and prevent session hijacking or intercepting the communication even on the first attempt to connect to the server. The question is how hard it will be for the attacker to compromise the list on the client side. Also the server needs to be protected against possible malware that may reside on the client side.

VIII. Closing thoughts

In the real world, there is no possible way to achieve having totally secure system. Every system that can be accessed by someone can be hacked; it is just a matter of time and technology. While this may discourage some people, others may seem this as a challenge and try to find additional methods for protecting their system. Currently there are some known flaws and attacks that cannot be prevented, but they may be just a history with each new improvement in the internet security.

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Simulation of DC-DC Converter with fuzzy logic control of output voltage

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***Abstract*— The paper presents an output voltage control method for full bridge DC-DC converter with controlled output rectifier and an active snubber on the secondary side. Due to complicated mathematical model of presented converter and its non-linearity, fuzzy logic control for control output voltage of converter was choosen. The paper deals with simulation of fuzzy logic controller for DC-DC converter in MATLAB and contains its comparison to classical PI control. The mutual comparison shows that fuzzy logic control is more robust and achieves faster transient response.**

***Keywords*—DC-DC converter, Fuzzy Logic Control, MATLAB, Soft-Switching**

I. Introduction

DC-DC converters are included among the most commonly used power electronic converters because of their high efficiency and flexibly adjustable output voltage. In recent decades intensive research is made in the application of soft switching DC-DC converters, which can reduce the switching losses and hence increase the switching frequency of the inverter (switching losses are directly proportional to the switching frequency), in order to reducing weight, volume and cost of converter [1]. These converters are also used in electronic devices with an emphasis on the stability of the output voltage even with input voltage and load variation. This causes the requirement to develop advanced control methods to meet the demand placed on the DC-DC converters. To resolve this problem, there have been developed many techniques with different advantages and disadvantages arising from their operating principle.

Conventionally voltage control mode or current control mode techniques are used for control of DC-DC converters. The advantages of such methods include fixed switching frequency and zero steady state error of the desired voltage. In contrast, the disadvantages can include their degraded transient response at load change and parameters variation. To eliminate these drawbacks slide mode control techniques were created, which are robust to load variation. The main weaknesses of these methods include a variable switching frequency during load changes and power supply of converter, leading to complications in the design of output filters. The various disadvantages of the most commonly used methods of control led to intensive research to newer methods such as predictive control or using methods of artificial intelligence in the control of DC-DC converters [4].

Fuzzy control is currently one of the most perspective methods of artificial intelligence applied for control tasks, and also has been successfully applied in the control of power electronics [3]. The main advantage of fuzzy control over traditional control techniques is that FLC should be used to control system without knowing their model and to work with uncertain inputs. Moreover, the fuzzy control is suitable for the control of nonlinear systems, and is characterized by a high robustness.

In [2] is a comparison of PID control compared to fuzzy PID controller in buck and boost DC-DC converters. Experimental results have shown that both types of control are stable in the steady state and reached required values. The transition response appeared better properties of fuzzy controllers to achieve smaller overshoot during load changes and minor oscillations in some tests for other achieve similar results as PID control.

The paper presents a simulation results for control output voltage of the DC-DC converter with controlled output rectifier and secondary turn-off snubber, for PI control compared to PID fuzzy logic control.

II. Overall Simulation Scheme

The simulation model for the designed DC-DC converter has been in created MATLAB Simulink for control of the output voltage with short-circuit protection. The structure is shown in Fig. 1.

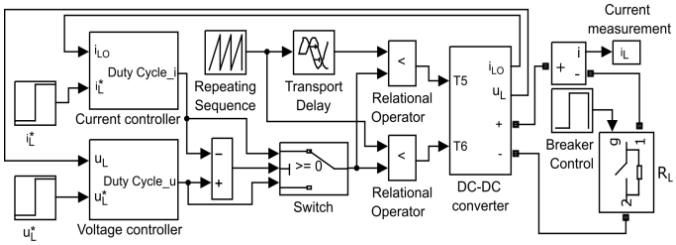

Fig. 1. Overall simulation scheme of DC-DC converter

On the left side of the simulation model are placed current and voltage controllers, which control output variable based on measured current before inductance i_{LO} and output voltage of converter u_L and actual voltage set point U_L^* and current limiter setpoint I_L^*. The controllers are arranged in parallel

structure and their output is duty cycle of rectifier transistors T_5, T_6. Current limiting is provided by switching logic. There is applied a rule that controller with smaller control move (desired duty cycle) is switched to pulse width modulator. The switching of transistor T_5 is shifted by half of the period. In the central part of the model is shown the switch that on the basis of a differential output current and voltage controller switches the desired output controller for PWM generation. The PWM generator consists of comparing the reference signal with the output of the regulator.

III. DC-DC CONVERTER

The internal structure of subsystem DC-DC converter from Fig. 1 is shown in Fig. 2. The subsystem was created with Simscape Power System library of MATLAB Simulink.

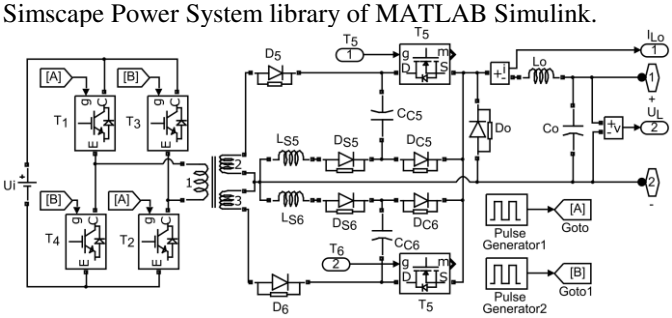

Fig. 2. Model of DC-DC converter

DC-DC converter shown in Fig.2 consists of full bridge inverter, transformer, controlled output rectifier, an output LC filter and secondary energy recovery turn-off snubber.

The inverter consists of IGBT transistor's T_1-T_4, which are creating high frequency voltage transmitted to rectifier by step-down planar transformer. The controller rectifier consist of MOSFET transistors T_5, T_6 with diodes D_5, D_6, which is connected to output filter consisting of L_0 and C_0 serves for smoothing the output rectified voltage.

The secondary energy recovery turn-off snubber consist of diodes D_{S5}, D_{C5}, D_{S6}, D_{C6} capacitors C_{C5}, C_{C6} and inductances L_{S5} , L_{S6}, which minimizes the turn-off switching losses of the rectifier transistors [1], [5].

IV. VOLTAGE FUZZY LOGIC CONTROLLER

Figure 3. shows a structure of the voltage fuzzy logic controller. The fuzzy logic controller (FLC block) has two inputs, the error e and change error Δe. The error is the difference between set point voltage u_L^* and actual voltage u_L. This value is processed by "Data processing block", which contains data filtering and averaging value of 4 difference samples. The change of error is computed like difference between two samples of the error. Both inputs are normalized and limited to interval {-1, 1}. Output of FLC is normalized change Δu, which represents the change of duty cycle for transistor of rectifier [4].

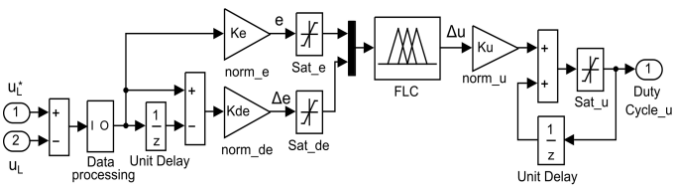

Fig. 3. Voltage FLC controller structure

The output of FLC controller is duty cycle, which has limited integrated change of duty cycle Δu. The limiter is set to max value 0,85.

The proposed fuzzy logic controller is a Mandami type with the max-min compositional rule of inference. For FLC are defined 26 rules based on the author experience. The fuzzy sets have triangular shape and are evenly distributed upon universum [4].

V. SIMULATION RESULTS

The simulation was performed according scheme in Fig. 1 for load variation from 10 Ω to 0.01 Ω (0.01 Ω load represent short circuit), where the output of current controller is toggled for control of duty cycle of rectifier transistor. The input voltage was set to 325 V, the switching frequency was set to 100 kHz, and output voltage was set to 45 V.

Comparison of PI control and FL control was made. A simulation shows that the FLC achieved a better transient response, reaching the required value more quickly in a small overshoot of the output voltage.

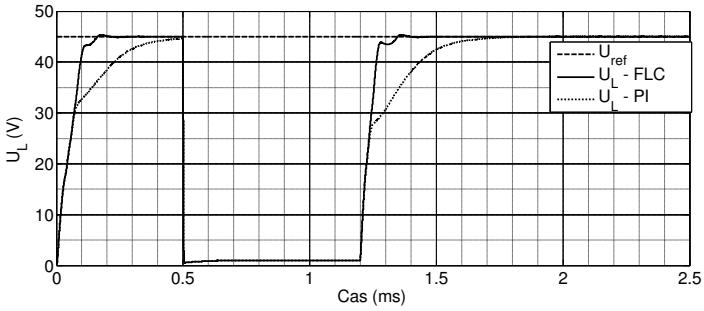

Fig. 4. Voltage FLC controller structure

VI. CONCLUSION

The paper presents simulation verification of designed FLC for output voltage of converter in load variation, which is compared to previously designed voltage PI controller. The simulation results show that fuzzy logic controller is able to achieve better transient response of DC-DC converter.

The future work will be focused on the implementation of proposed control technique in digital signal processor and its optimization.

ACKNOWLEDGMENT

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Simulation of pv-battery hybrid system

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***Abstract*—This paper deals about sizing of hybrid renewable source application to supply power for public lighting system .for entire village without connection to the electrical grid. Such hybrid renewable power systems are suitable in remote area where grid connection is unavailable or connection to grid is expensive. Hybrid system in this paper consists from photovoltaic power plant and large battery bank to storage electricity. Battery bank is supposed to be large because time when electricity is needed is completely different from time when photovoltaic power plant produce power from sun..**

***Keywords*— PV; Battery; Homer; Simulation; Hybrid system; Renewable energy.**

I. Introduction

Hybrid Renewable Energy Systems (HRES) is composed of one renewable and one conventional energy source or more than one renewable with or without conventional energy sources, that works in stand alone or grid connected mode. HRES is becoming popular for stand-alone power generation in isolated sites due to the advances in renewable energy technologies and power electronic converters which are used to convert the unregulated power generated from renewable sources into useful power at the load end. The important feature of HRES is to combine two or more renewable power generation technologies to make best use of their operating characteristics and to obtain efficiencies higher than that could be obtained from a single power source. Hybrid systems can address limitations in terms of fuel flexibility, efficiency, reliability, emissions and economics [1].

A. Solar Energy

Solar energy is the most promising of the renewable energy sources in view of its apparent unlimited potential. The sun radiates its energy at the rate of about 3.8 x 10^{23} kW per second. Most of this energy is transmitted radially as electromagnetic radiation which comes to about 1.5kW/m^2 at the boundary of the atmosphere. After traversing the atmosphere, a square meter of the earth's surface can receive as much as 1kW of solar power, averaging to about 0.5 over all hours of daylight. Studies relevant to the availability of the solar energy resource in Slovakia have indicated its viability for practical use.

In solar photovoltaic applications, the solar radiation is converted directly into electricity. The most common method of doing this is by the use of silicon solar cells. The power generating unit is the solar module which consists of several solar cells electrically linked together on a base plate. On the whole the major components of a photovoltaic system include the arrays which consist of the photovoltaic conversion devices, their interconnections and support, power conditioning equipment that convert the dc to ac and provides regulated outputs of voltage and current; controller, which automatically manages the operation of the total system; as well as the optional storage for stand alone (non-grid) systems [2].

B. HOMER

HOMER (Hybrid Optimisation Model for Electric Renewables) another time-step simulation program developed by NREL(National renewable energy laboratory) adds optimization to basic simulation capability. It simulates the annual performance of many different system configurations for a specified set of energy sources to find a configuration that satisfies technical constraints at the lowest life-cycle cost. It is also possible for the user to define sensitivities (e.g. different mean values for solar irradiation, wind or power consumption) to narrow the range of results. The outcome of the simulation is a list of the possible systems in order of life-cycle costs. A graph depicts the various ranges of the most cost-effective systems over the given operating period, based on the selected criteria. Detailed results can be output for each of the individual simulated systems (graphs, tables, scatter plot, print-out)[3],[4],[5].

II. Hybrid system parameters

A. Load profile

Lighting systems of public lighting comprises a total of 640 pieces of lighting equipment. Power consumption of 18,18kW system is calculated with losses. Losses of this system is about 10% of whole consumption. Overall, the lighting major, minor roads and paths used three types of lamps. They are Archilede S power consumption with 36W, and Archilede E with 27W, CARIBONI LEVANTE SMALL 24W. Overview of luminaires and representation can be seen in the the following Tab.1.

Tab. 1 Types of used lamps

Type of lamp	Input power	Number of pieces
Archilede S	36W	80
Archilede N	27W	150
Cariboni	24W	180

Typical daily energy consumption can be seen on Fig. 1

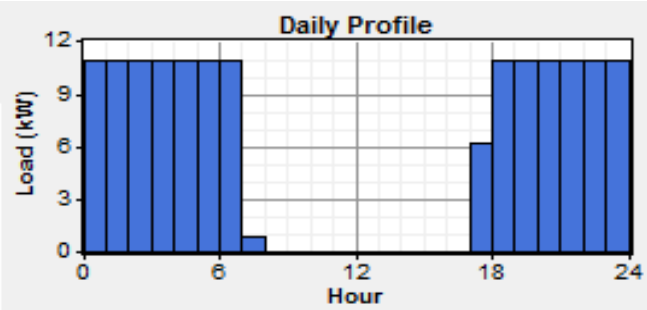

Fig. 1. Hourly load profile

B. Solar resource data

Budimir's monthly solar radiation values are obtained with HOMER from NASA. For coordinates in HOMER, 49°19′ N latitude and 21°9′E longitude are used. This is the coordinates of Centre of Budimir. HOMER syntheses solar radiation values for each 8760 h of the year by using Graham algorithm. This algorithm produces realistic hourly data, and it is easy to use because it requires only the latitude and the monthly averages of solar irradiation. The synthetic data displays realistic day-to-day and hour-to-hour patterns. If one hour is cloudy, there is a relatively high likelihood that the next hour will also be cloudy. Similarly, one cloudy day is likely to be followed by another cloudy day. The synthetic data is created with certain statistical properties that reflect global averages. So data generated for a particular location will not perfectly replicate the characteristics of the real solar resource. But tests show that synthetic solar data produce virtually the same simulation results as real data. Monthly average values of solar data are shown in Fig. 2.

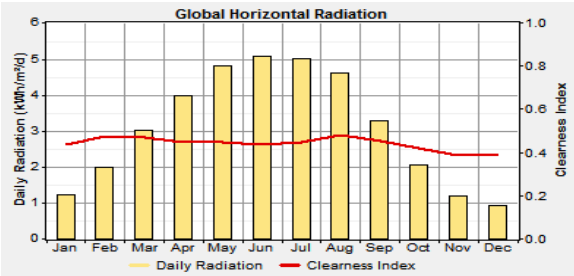

Fig. 2. Solar radiation a clearness index profile for Budimir

III. Hybrid Simulation System

After the system components and the equations, modeling and simulations of the micro power system is carried out. HOMER, optimization model is used to simulate the system. Large number of options are available for different sizes of the components used, components to be added to the system which make sense, cost functions of components used in the system. HOMER's optimization and sensitivity analysis algorithms evaluated the possibility of system configuration.

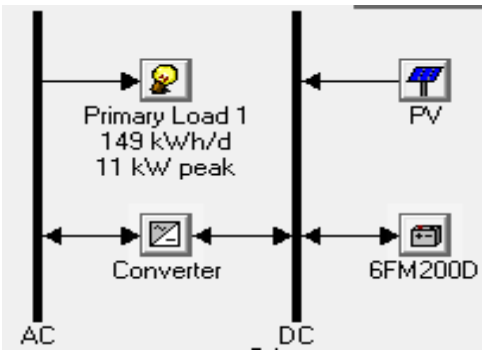

Fig. 3. PV-Battery hybrid generation system

A. Simulation result

Fig. 4.shows sizing of the hybrid PV-battery system who works off-grid and covers whole load of public lightning system without intermission in power supply. System costs from photovoltaic plant with size 100kW 180 batteries and converter with size 12 kW.

Fig. 5. shows the monthly production from sources PV

PV (kW)	6FM200D	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage
100	180	12	$ 143,668	2,040	$ 169,746	0.276	1.00	0.13

Fig. 4. Hybrid generation system

source production per year is 118393 kWh and Year production of whole hybrid system is 118393 kWh.

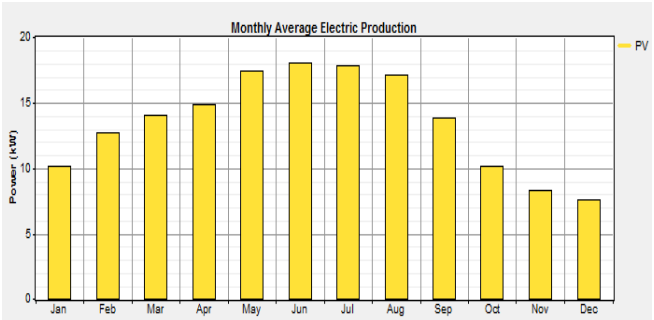

Fig. 5. Monthly average production in PV-Battery system

B. Sumary of problems and next direction

Problems in sizing optimization of hybrid systems are with choosing right mix of renewable sources to best cover load of system for lowest price of whole hybrid system.

Next direction of my work is designing hybrid systems connected to grid and analyze benefits of this connection and behavior of hybrid system connected to the grid.

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Structure and description of the scenes of virtual reality

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***Abstract*—If we have content for virtual world and we want to implement in to virtual reality system we need to know how to build structure of scene. How to define properties, parameters and relations not only for these objects but also for no graphical data. Based on these data we can describe ways how are objects visualized in the VR world, their behavior, interaction with user and interaction with each other as well.**

***Keywords*— virtual reality, structure of scene, implementation to virtual world, properties of objects.**

I. Introduction

Based on previous works [10][11][12] where we have described forms and ways how to create virtual reality system (VRS) as well as the contents of virtual reality world. We have defined hardware and software interface of VRS and basic parameters and characteristics of the 3d models such as wireframe model, surface models, volumetric models and techniques and procedures such as box/subdivision modeling, spline modeling, digital sculpting, NURBS. But if we want to implement content into the virtual system we need to examine and define the additional properties, parameters and relations not only for these objects. Based on these data we can further describe ways how the objects are visualized in the VR world, their behavior, interaction with user and interaction with each other as well. All these aspects form the structure of virtual reality scenes. Appropriately and well designed properties and relations affect how immersive virtual reality will be for users. All this is related to our current work, which is definition of 3D content in the 3D CAVE.

II. Problematics

The main problem is the correct implementation of objects in the virtual world. For this purpose we need to realize everything that the term virtual system includes and from which parts it consists.

As we assume the virtual world as an object oriented system, we were based on the premise that everything in the VR system is the object, even VR system itself. Each object of the virtual world has its own hierarchy.[1][2][3][4] As a very first step we can take into account a hierarchy that consists only from **representation** and **behaviour**. The behaviour describes the logic of object and representation is presented as frameworks divided to different subsystems of virtual reality. We determined local and global properties for each framework. Local properties are required only for a particular framework while global properties are shared across full spectrum of frameworks because they are important for the logic of object. (Fig. 1) We assume lots of simple and also very complex relationships between different objects. These relationships represent processes (or instructions), which can affect these objects and change their properties or states (locally or globally). While the hierarchy shown in the figure represents the categorization of VR world from a data flow perspective, using these relations (operations, instructions) categorization of VR world can be defined in procedural perspective.

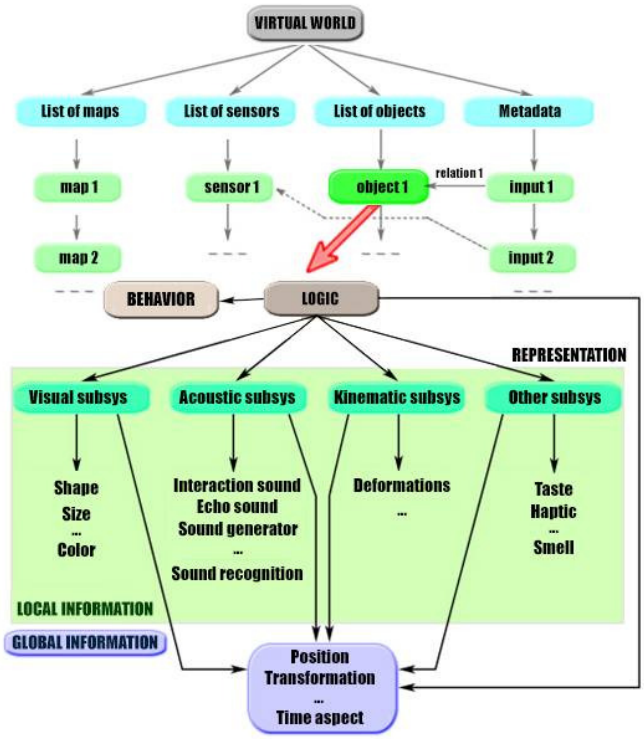

Fig. 1. Interconnection between core and subsystems of VR system[1][2][9]

Following the earlier part, the implementation model is the important part of representation of the virtual world. It is

especially important for the representation of the object (scene / world) that other parts of the system exploit efficiently.

In terms of the purpose and membership to particular subsystem, we divided the objects into the following groups: geometric, light, sound, physical and auxiliary and others.

The geometric objects are those objects which are within the scope of the visualization framework. We defined the basic parameters such as **shape**, **position**, **rotation**, **size** and **colour**. Although these characteristics describe the geometry, say nothing about composition, designation and about its properties. We can describe only its shape. For this reason we need to consider other qualities such as determination of the surface and appearance. The surface of real objects differs in many parameters. It may be wrinkled, structured, transparent or glossy. When we defined only the colour of the object, it was represented as polygons, where each peak was determined by colour, and then the surface was dyed by interpolation of colors. The colour has no such information value itself and therefore we want to implement a new object - **material**. For this new material we can determine the other properties that have a great impact on trustworthy projection of the object in the virtual world. Tracking behaviour of the objects of real world we determined 3 properties which can ensure proper visualization.

Texture – carrier of visual information about structure of the object, a set of colours and the rules of their use.
Reflection **-** the ability to display their surroundings
Transparency **-** the ability to transmit light rays

These properties were sufficient only until the moment when we got closer to the subject. A closer look reveals subtle details in the spatial structure of the object's surface. For a better visual experience additional material property was defined. ***Normal grain*** - the ability to change the shape of the surface visually without changing the geometry.

Light objects also play an important role in displaying geometric objects. The light source is characterized by emitting light radiation. The basic properties of these objects are **shape**, **size**, **position**, **direction**, **intensity** and **colour**. Based on these characteristics, we described the most common light sources of computer graphics. For example if we determine the size of the light source close to zero, uniform strength in all directions and the yellow colour, we got the light similar to incandescent bulbs.

Sound objects are within the framework of sound. Their basic feature is to play or generate sound. However, those objects also have properties and other extensions in conjunction with the physical objects can create a powerful audio experience as surround sound, echo simulation, proximity and distance of the sound source.

Physical objects are within the kinematics framework and allow obtain the physical properties of real-world objects to virtual objects. In this case objects may be subjected to gravity, wind and rain but also get volume or mass on a basis which can then collide with other objects.

From an implementation point of view, the description of the individual objects, their properties and even the virtual world itself we need descriptive tools or languages. For example VRML, VRML97, SVR, Java 3D, Chrome, X3D. [9] All of these implementation languages are suitable but we decide to close explore only one of them.

We chose VRML because of its simplicity and enormous complexity. [6][7] Identification of WRL file browser is possible through his header. The header is carrier of the information that talks about character encoding (code table, we can also define a set of national alphabets simultaneously). Individual objects of the virtual world described by nodes (nodes) are defined by a certain set of parameters describing the particular properties. [8]

The individual parts of a file are not binding. In the general information we summarized information describing the overall performance of the virtual world (WorldInfo- information about files and author Viewpoint- list of interesting places in virtual world). In the section describing the individual elements and their properties (it's always the largest component of the group) has been collected information on individual objects of our virtual world. This section defines the shape, color and other properties. The last part of the definition of active connections with static elements defined in the virtual space.

III. Implementation

These and other findings summarized in a paper for dissertation examination resulted in the creation of 3D CAVE techcnology workplace for future science and research.[11] That consists of hardware and software implementation parts. Hardware part consists of 20 projection screens created from 3D monitors, including ceiling and floor, powerful computer cluster, optical position tracking and surround sound system. Software part is based on Super Engine modified version for virtual reality systems with support for Ruby script which brings possibilities of dynamic work with objects like making animations, resulting collision and implementation of motion tracking. Model created in 3D editor is converted with language VRML and subsequently optimized for OSG (Fig. 2). The software and hardware solutions imposes requirements described in this and previous paper [10][11][12].

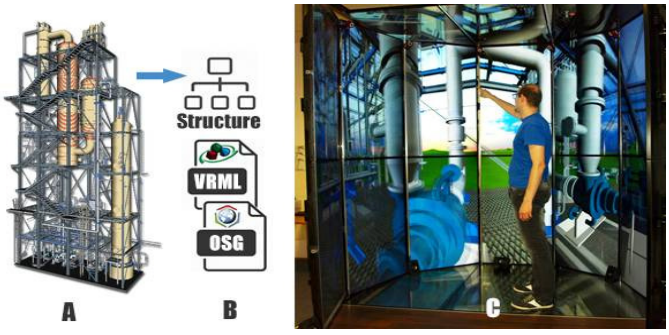

Fig. 2. A) 3d model B) structure conversion VRML / OSG C) implementation in CAVE

IV. Conclusion

This paper aims on structure and description of the scenes of virtual reality. We found that this term is tremendously complex matter. Implementation of objects and determine their properties as real as possible is the time-consuming process requiring a number of experimental testing but it has huge impact for realistic visualization of 3d content. In the very next phase of the study will be necessary to identify and define the parameter properties other possible objects of the virtual world, properly assess and describe the relationships between objects and their interaction as well as interaction with the user.

Acknowledgment

Technologies and practices mentioned in this article may be useful for the simplification of computer work for handicapped persons. This work has been supported by the KEGA grant no. 083TUKE-4/2015 „Virtual-reality technologies in the process of handicapped persons education“.

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The Internet of Things trends and issues – a survey

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***Abstract*—The Internet of Things is a vision based on interconnecting physical world with cyberspace, thus enabling applications benefit from the world's context information. By having billions of devices connected to the Internet, it is possible to acquire data from all kind of different situations and use them for better decision making. However, managing that amount of devices is not an easy task. Therefore, this paper provides a survey of trends and issues of the Internet of Things, as well as it describes how cloud computing can be helpful in the context of the IoT.**

***Keywords*—Bluemix, Cloud Computing, Internet of Things, Microsoft Azure.**

I. Introduction

Over the past 50 years, the Internet has exponentially grown and has successfully established as a part of people's everyday lives. More than 40% of the world population has an internet connection today and the trend is clear – everything has to be on the Internet.[1] However, it is not only about the people anymore. The continual miniaturization and cost reduction of electronic devices has broadened the Internet of People with a new dimension: The Internet of Things.

The Internet of Things is based on everyday physical things that are enhanced with local intelligence and connectivity to the Internet by having small computational components attached to them. These "smart objects" interconnects the physical world with the cyberspace and thus are also called cyber-physical systems.

However, it is important to mention that the idea behind the Internet of Things is not so new. The term Internet of Things was first coined by Kevin Ashton in 1999 in the context of supply chain management and even before there were already embedded systems connected to the Internet. [3]

The novelty is in the size. Sometimes between 2008 and 2009, the number of connected devices started to be higher than the number of whole world population and it is estimated that around 25 billion connected things will in use by the end of 2020.[3] The exponential growth of devices connected to the Internet is so significant it simply cannot be ignored.

This trend brings many exciting opportunities. By having so many devices generating so much data, it is possible to create solutions that were unimaginable 10 years ago. But it cannot be accomplished without overcoming several obstacles.

The aim of this paper is to provide a survey about the topic Internet of Things and to point out current challenges that have to be solved. Therefore, the remainder of the paper is organized as follows. The trends and issues of the Internet of Things are described in section II. Section III. is dedicated to cloud computing and its role in the IoT and the last section summarizes mentioned ideas.

II. The Internet of Things – Trends and Issues

The Internet of Things is a novel paradigm that bridge the gap between the physical world and its representation within the digital world. The idea is to integrate the state of the physical world into cyberspace thru smart objects, making applications benefits from the world's context information. The more applications understand the current situation, the more accordingly they can adapt to user's needs. Thus there is no doubt that the Internet of Things is truly popular.[4]

According to Gartner's IT Hype Cycle, which represents the emergence, adoption, maturity and impact on applications of specific technologies, the Internet of Things is on the peak of inflated expectations.[5]

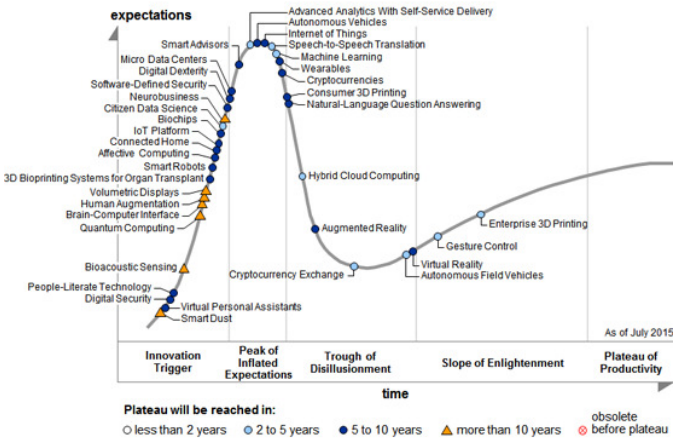

Fig. 1. The Gartner's IT Hype Cycle describing the emergence, adoption, maturity and impact on applications of specific technologies.[5]

In this phase, technologies reach the height of their publicity and a lot of companies enter the space. However, as Gartner depicted, the Internet of Things is still from five to ten years away from going mainstream. Before that, it has to go through the third stage, called trough of disillusionment, where things start becoming a little more realistic, and the fourth stage, called slope of enlightenment, where the real

use-cases of the technology become apparent and widely understood. The reason is that there are still many challenges requiring a large research effort. [6]

A. Technical Issues of the IoT

To have the Internet of Things widely used in mainstream, we have to solve several technical issues. Here is a general overview of some of them:[7]

1) Internet Integration

Depending on the computational capabilities and the available energy, cyber-physical systems can be connected to the Internet either directly or indirectly via a base station. The more powerful smart objects can have implemented a module for communication over the Internet, whereas power-constrained devices should rather communicate via a near gateway to spare some energy. For such environments, a number of major companies have formed an alliance called the Internet Engineering Task Force (IETF) with the aim to enable the direct integration of low-power cyber-physical systems into the Internet. IETF has initiated a working group 6LowPan on IPv6 over Low Power Wireless Area Networks to find an energy-efficient solution for integration of the IPv6 standard with the IEEE 802.15.4 wireless new field communication standard.[8]

2) Naming and Identification

To interconnect billions of things via the Internet and enable them mutual communication, it is necessary to have a well-though-out naming architecture for a proper identification. The Internet is using a hierarchical name structure, where every name is composed of a context where it can be resolved. Therefore, to have a universally interpretable name without reference to a specific naming context, we need a single context with a universally accepted name space. This is the approach taken by the RFID community, which intends to assign an Electronic Product Code (EPC) to every physical smart object. Anyway, it is still only a starting point and there is a need for more research on the proper design of name-space architectures in the Internet of Things.[9]

3) Energy-efficient communication

The Internet of Things is very demanding in the term of energy-efficient wireless communication. Besides the established WLANs (Wireless Local Area Networks), the cyber-physical systems often need to communicate over small distances, thus short-range energy-efficient WPANs (Wireless Personal Area Networks) are crucial for the proper progress of the IoT.[10] [10]

Among the most popular WPANs used in the Internet of Things are Bluetooth and ZigBee. Bluetooth is standardized in IEEE 802.15.1 and achieves a data rate of up to 3Mbit/s over a distance of 1 to 100m using the transmission technology of frequency hopping. ZigBee uses high-level communication protocols based on the IEEE 802.15.4 standard for low-power digital radios and is intended to be simpler, more energy efficient, and less expensive than Bluetooth. [10] [10]

Another very popular standard is the NFC (Near Field Communication), which is an extension of the ISO/IEC 14443 proximity-car standard. NFC enables the data exchange over a small distance (<20cm) due to a short-range high frequency wireless communication technology. [10] [10]

Improving energy-efficient communication networks, we can extend battery stamina on constrained smart objects and spare some valuable energy to make them run longer. [10] [10]

4) IoT Device Capabilities

Cyber-physical systems differ widely in power and energy capabilities. In general, we can say that the more constrained object it is, the more sensitive approach we have to take. Therefore, at some point it might be more appropriate to stop executing tasks locally at the object itself and rather send data to make calculations on some more powerful device. And here the cloud computing comes into play. Since cyber-physical systems have access to the Internet, they can take advantage of services offered by the cloud, thus saving their own resources. If the energy required to execute a task locally is larger than the energy required to send the task parameters to a server in the cloud, then the task is a perfect candidate for remote processing. Nevertheless, there are many important aspects as well, for instance autonomy of the cyber-physical systems, response time, reliability, and security. The question how to distribute work is not as easy as it might look like, but it is undoubtedly that the cloud plays an important role in the IoT.[7]

5) Autonomic management

In the world where billions of devices are executing tasks and making decisions, there must be some amount of autonomic system management without the need of frequent human interactions. This autonomic management must cover topics like network service discovery, system configuration and optimization, diagnosis of failures and recovery after failures, and system adaptation and evolution. Because of the overall complexity, there is a need for a multi-level autonomic management system that would be able to monitor, analyze, plan and execute (MAPE).[7]

As early as 2001 IBM defined eight key elements of autonomic systems. According to them, the autonomic computing system should possess the following eight key characteristics:[7]

1. to “know itself” – and comprise components that also possess a system identity,
2. must be able to configure and reconfigure itself under varying and unpredictable conditions,
3. never settles for the status quo – it always looks for ways to optimize its workings,
4. must perform something akin to healing – it must be able to recover from routine and extraordinary events that might cause some of its parts to malfunction,
5. must be an expert in self-protection, since a virtual world is no less dangerous than the physical one,
6. knows its environment and the context surrounding its activity, and acts accordingly,
7. cannot exist in a hermetic environment,
8. will anticipate the optimized resources needed while keeping its complexity hidden.

They didn’t even consider it for the Internet of Things at those times, but it nicely illustrates how the information technology emerges and these relatively old ideas are still valuable even in 2016. Actually, they realistically confessed it would be very difficult to build a system like that. But with

the arrival of the Internet of Things, the self-awareness of systems was never better.

III. CLOUD COMPUTING AND ITS ROLE IN THE INTERNET OF THINGS

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.[7]

Cloud computing is therefore a way how to share computing resources and provide them as a service, thus allowing users to take benefits from these technologies without the need of deep knowledge about them. Depending on the type of deployment model, we recognize four cloud infrastructures:[7] [7]

- private cloud used by a single organization,
- community cloud used by a specific community of users,
- public cloud used by the general public,
- hybrid cloud, which is a composition of two or more distinct cloud infrastructures.

When talking about services, we define three service models:[7] [7]

- Software as a Service (SaaS) – the capability provided to the consumer is to use the provider's applications running on a cloud infrastructure.
- Platform as a Service (PaaS) – the capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created applications.
- Infrastructure as a Service (IaaS) – the capability provided to the consumer is to provision fundamental computing resources for running software, which can include operating systems and applications.

As it was mentioned in the previous section, the cloud computing plays an important role in the Internet of Things. The growing amount of smart objects produce enormous collections of data that have to be processed somehow. The cloud can act as a great integration platform, where all smart objects send data for further processing. The cloud providers are aware of this advantage, and therefore, offer whole range of different services. To explain how the cloud can be helpful in the context of the IoT, two cloud platforms are described more in-depth – Microsoft Azure created by Microsoft and Bluemix created by IBM.

A. *IoT services in Microsoft Azure*

Microsoft offers a family of services for complete IoT solutions, from acquiring data up to analyzing and presenting them in a meaningful way. The ambition is to reduce the required effort to bare minimum, so people can focus on the added value instead of technological issues. Microsoft knows that the biggest advantage of the IoT is in its application part, so they created numerous services to make a building process easier.

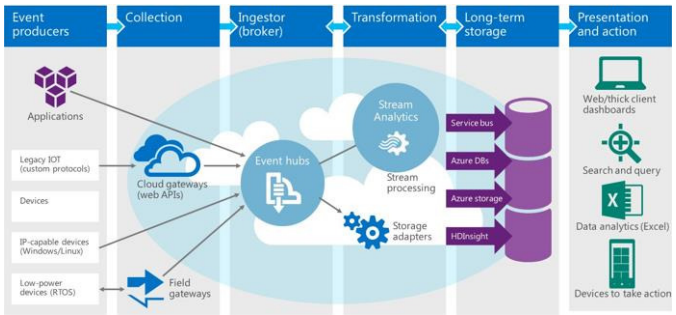

Fig. 2. Microsoft IoT services created for the IoT.[17]

IoT Hub is a service responsible for connecting things together as it enables bi-directional communication. Thanks to this service, it is possible to easily collect data and provide them for other services.[18]

Once the data are on the cloud, Stream Analytics acts as a transformation layer, which sends data to different outputs. The output can be a regular database, any kind of applications, or another service.[18]

HDInsight is one possible output for Stream Analytics. It is a cloud-based Big Data service used for data visualizations. For data analysis, a service called Machine Learning can be used.[18]

B. *IoT services in Bluemix*

Like Microsoft, IBM has created its own cloud called Bluemix. In many ways, it is a direct competition to Microsoft Azure, but Bluemix use different technologies to achieve similar results. In the term of the Internet of Things, Watson IoT Platform service is the main building block.

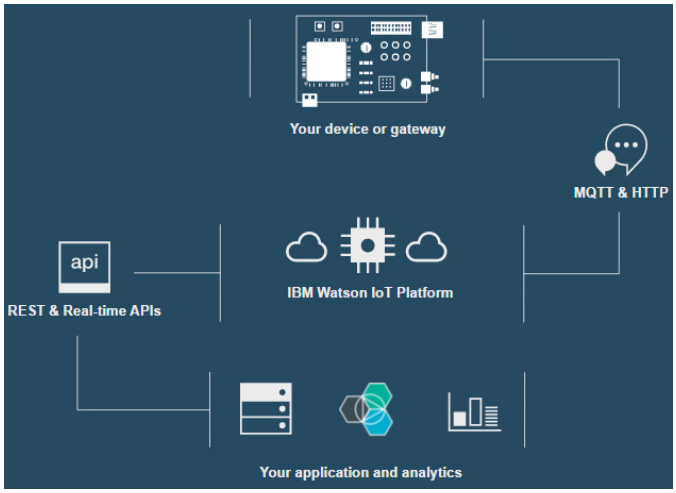

Fig. 3. IBM Watson IoT Platform service in the IoT architecture.[19]

IBM Watson IoT Platform service is the hub of all things IBM IoT. It allows users to set up and manage their connected devices so that the applications can access their live and historical data.[20]

As the figure depicts, a device is connected to the IBM Watson IoT Platform using a protocol like MQTT, HTTP or other. The service then provides RESTful API to have the acquired data accessible from user's applications. The concept is pretty straightforward and easy to use, so again, a developer can focus on activities that matter the most.[20]

IV. Summary

As we described in previous sections, bridging the Internet of Things with cloud computing can be very beneficial. The amount of connected cyber-physical systems together with their constrained resources make the cloud an ideal technology to accelerate the Internet of Things progress and spread it to the mainstream.

On the other hand, the cloud is not a solution for everything. One of the biggest disadvantages of the clouds, either Microsoft Azure or Bluemix, is price for using services. They are not cheap. However, this is rather a technological issue than scientific.

From the scientific perspective, there is a question how much we actually want to move from local systems to the cloud. Transferring data around to world when you only need communication on a local level might not be the best solution. Here is when fog computing, which is based on the logical distribution of processes between local systems and clouds, could be a good alternative. General services on the clouds can be very helpful, but one must still think of what is an actual goal. A one universal solution for all kind of situations in the IoT simply doesn't exist.

From our point of view, the most interesting part of the Internet of Things is autonomic management. Making systems context-aware of the environment, it is possible eliminate human intervention. Therefore, our research focus on environment automation, where a shared intelligence would be created to make autonomic decisions and actions. We would like to give cyber-physical systems enough smartness to be able to evaluate situation and decide whether or not send measured data and thus spare some energy. Furthermore, we would like to propose a solution how to make devices auto-configurable, so that other devices would recognize them. The reason is that even establishing communication is fairly easy within proprietary networks, the interoperability still remains a big challenge. And the last but not least, the acquired data should not only be used for better human understanding, but to make computers understand as well.

We believe the opportunities were never better and the Internet of Things, together with shared cloud computing, opens us a new era of possibilities.

Acknowledgment

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[20] IBM Bluemix Documentation https://console.ng.bluemix.net/docs/

The Obfuscation Efficiency Measuring Schemes

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***Abstract*—Obfuscation is primarily used as tool for protecting the written code against reverse engineering, but there also exist other schemas for the obfuscation process, which primarily focus on hiding the true purpose of the written code by transforming its blocks, which causes the inability of comparison the obfuscated code sequence to code stored in database by static or hybrid analysis. When trying to overcome this type of analysis weakness, man should be well educated in obfuscation schemas.**

***Keywords*—Code obfuscation, analysis, efficiency, measuring tools.**

I. Introduction

According to Collbergs work [1] as reference it is important to define a metric commonly
used to evaluate the efficiency of obfuscators. It can be defined as follows:

- ***The potential*** which serves to evaluate the understanding of the obfuscated code complexity during analysis run by human (human-driven analysis);
- ***The resilience*** which is meant as measure of the of the inverse operation (deobfuscation) complexity by using of the automatic tools;
- ***The cost***, which defines the price it needs to be paid in terms of computing time and memory space required for the analysis [2].

It is clearly visible that in terms of the malicious software, the main field of interest would be the resilience. In matter of fact, resilience can informally be addressed as the difficulty of detection the malicious software code sequence. The main approach study presents the using of the opaque predicates in terms of increasing the resilience of an obfuscated program. Predicate P can be considered as opaque if it has a property q known to the obfuscator algorithm, but which is hard for a deobfuscator to deduce and reproduce.

II. General Obfuscation Measurement

In [3] a simple definition of a general measure of an obfuscating transformation was given. It was defined as a combination of three basic measures: potency, resilience and cost. It is hard to entangle these measures in the way allowing to obtain single value, especially because indeed they are not orthogonal .According to general analysis, based only on definitions of these measures, following dependencies can be concluded, shown in Table 1. Growth of potency does not have to cause growth of resilience, because general complexity of program does not have to be connected with complexity of deobfuscation process. In opposite way, growth of resilience must cause growth of potency, because general complexity of a program grows always. Cost of a transformation grows more or less, when resilience and/or potency grows, but growth of cost does not have to cause the growth of neither potency nor resilience, because a complexity can remain the same.

Growth	**Potency**	**Resilience**	**Cost**
Potency		Variously	Grows
Resilience	Grows		Grows
Cost	Grows	Variously	

Table 1 Dependencies between measures of obfuscation transformation

In final decision, it has been decided to show results of quality measures of obfuscating transformations in the form of four objects: numerical value of an average potency of transformation, empirically determined cost and two descriptive measures: resilience and cost. From the presented material can be seen, that all analytical measures have rather relative meaning and should be used in the group of results obtained for different programs, to provide a broad view for comparison. Giving the analytical measures only for single program can provide false information sets. In practice the same program is measured before and after obfuscation, which gives quite good comparison.

III. Limits of The Obfuscation

It is a very well-known and can be proven that the bulletproof obfuscation is impossible to achieve. The semantics of the given code sequence cannot be perfectly hidden [4, 5]. In other words, however good obfuscation technique or combination of them, given code semantics can always be recovered, but the semantics extraction cannot be achieved by automated process (Rice theorem [6]). Because of that, some detection experimental approaches try to build a model of the created program by using code compiling optimizations [7]. This creation process is performed in two basic steps:

- Control flow graph of the examined sequence is built. This graph is a model of the possible program execution flows.

- Data flows are analyzed and simplified. In case of finding the more obstacles in the process, it is repeated simplify it.

Yet there is no easy answer to question: how to unobfuscate? It can be observed, that obfuscation is a contrary process to code optimization. Another area close to deobfuscation is decompilation of programs. Either optimization of compiled code [8] or decompilation of machine code to high-level languages representation ([9]), are covered very wide in scientific literature.

Sample classification of methods used in deobfuscation of code was presented in [10]. Using own experience and results of current state-of-the-art research authors selected following methods:

- identifying and evaluating opaque constructs —allows to detect and remove inserted opaque constructs [11],
- identification by pattern matching —comparison of fragments with database of patterns to detect inserted parts,
- identification by program slicing — is one of the classic methods of decompilation, can detect unimportant fragments of code ([12], [13]),
- statistical analysis —analysis of partial results in code extracted during program execution [14],
- evaluation by data flow analysis —classic method of optimization, allows to bind separated fragments of original program and remove inserted code ([15], [16], [17], [18]),
- evaluation by theorem proving —allows to obtain result of program without its execution, useful only for simple constructions [19].

It can be seen now, that there are lot of well described techniques, efficiently deobfuscating program code. The only problem which arises very often is very high computational complexity of the deobfuscating algorithms (with no chances for simplification). This weak spot is used during obfuscation and only using such property can guarantee an efficient protection against unauthorized analysis of obfuscated program code.

IV. Obfuscation Schemes Test Results Applied Against Antivirus Software

This simple test shows obfuscation schemes efficiency, when applied on well-known malware sample called Max++ or Zero Access.

Assumptions:

- Obfuscation of the part of the well-known malware code will increase the possibility of avoiding the detection by antivirus software.

As the well-known malware code, the Maxx++ header written in Assembly language is used:

```
00413BC8 MOV EDI,EDI
00413BCA PUSH EBP
00413BCB MOV EBP,ESP
00413BCD XOR ECX,ECX
00413BD0 MOV EDX,ECX
00413BD2 INC EDX
00413BD3 MOV EAX,EDX
00413BD5 LEAVE
00413BD6 INT 2D
00413BD9 RETN
```

It is obfuscated using the various data-flow and control-flow obfuscation schemes (NOP insertion, Instruction Substitution, Variable Substitution, Unconditional Jumps Insertion) and then tested against web service http://www.virustotal.com, which serves as online testing portal and stores 51 different antivirus software samples. Results are shown in Fig.1.

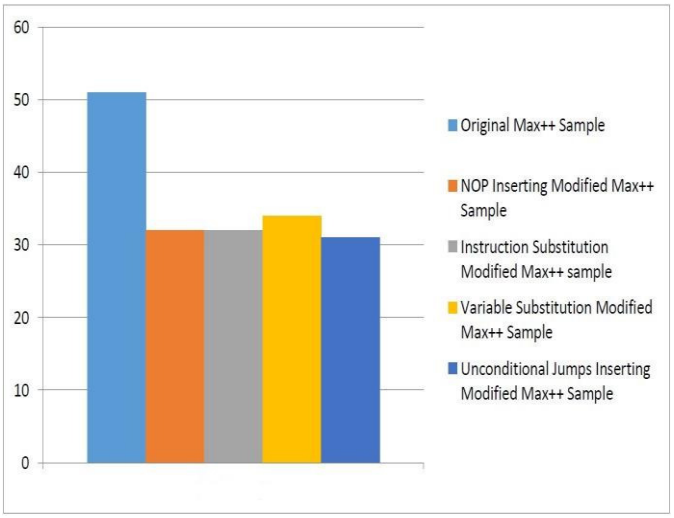

Fig. 1 Results of the detection test, unobfuscated vs. obfuscated well-known virus sample.

As can be seen from the test results, even sample obfuscation schemes can be proven as very efficient against modern malware detection techniques.

V. Conclusion

Based on previous presented knowledge the general assumptions have been made:

- Obfuscation of the machine code is less complex in comparison to high-level programming,
- Obfuscation of the machine code can be very effective in terms of hiding tool during code scanning by signature based algorithms.

Based on these assumptions, the future work is planned as follows:

1. Try to apply the obfuscation principles proven efficient on high programming type of language,
2. Measuring the complexity of the obfuscated code in high level language, its limitations and usefulness.

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The Principle and Design of an EDFA in the Software Package OptSim

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***Abstract*—The purpose of this article is design and description of EDFA (Erbium Doped Fiber Amplifier) in the software package OptSim. The topology of 10 Gbps line is designed for comparison of basic parameters of EDFA. Currently it is not possible to create a WDM (Wavelength Division Multiplexing) system without the use of software tools for simulation of the real system. The WDM systems use mostly optical amplifiers EDFA for its good features such as: low noise figure, temperature stability, reliability and sufficient profit.**

***Keywords*—DWDM, EDFA, OptSim**

I. Introduction

EDFA is currently the most used amplifier for WDM and is formed by doped Er^{3+} ions. The EDFA principle was discovered in 1960 and since then an intensive development to improve the technology has started. Completely new generation of optical systems has been developed with the invention of EDFA. The main advantage is the ability to amplify the optical signal at all wavelengths. This ability is a presumption for increasing the carrying capacity rather than increasing the bit rate. That means to increase the number of wavelengths by which the signal is transmitted with one optical fiber (WDM) [1], [2] and [3]. Using EDFA has brought a dramatic reduction in prices on long-haul routes and increased their capacity. Instead of one expensive opto-electrical repeater for one wavelength, it uses an optical amplifier for the entire range of wavelengths on a single fiber.

WDM systems with EDFA started in the mid-nineties increase the capacity of optical networks and today it is possible to achieve $Tbit.s^{-1}$ through a single fiber.

II. The EDFA Principle

Due to bound radiation from the pump laser (at wavelength of 980 nm or 1480 nm) into the special fiber with a length of several meters (about 10 meters), a carbon doped element excitation happens - in this case erbium ions Er^{3+}. The absorbed energy enables the transition to a higher energy level E3. In this so-called metastable state the ions remain for a very short time (several milliseconds) [4], [5]. This is followed by non-radioactive transition to the E2 levels in the conduction band. After reaching population inversion state, when the majority of erbium ions are in an excited state, due to the presence of the transmitted signal the energy is released. Following the return of the excited ions to the basic energy level E1 in the valence band accompanied by stimulated emission of radiation of the same wavelength and phase of the transmitted signal [6], [7]. This temporarily stores the energy obtained from the pump laser radiation. It amplifies transmitted optical signal at a wavelength of 1550 nm [8]. During amplification the noise is amplified in the amplified band and spontaneous emission processes intensify (the natural transition of an electron to a lower level). The amplification transmits optical signal at a wavelength of 1550 nm.

The Fig.1 illustrates the excitation of atoms due to erbium pumping radiation emission.

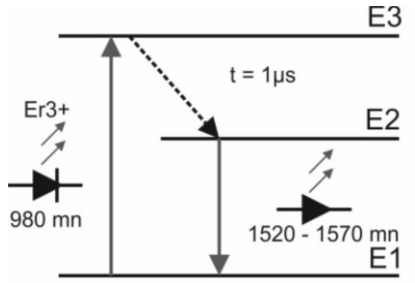

Fig. 1 The erbium excitation as a result of pumping radiation emission.

III. Proposal of EDFA in Software Package OptSim

EDFA simulation has been performed in the programming environment OptSim, where the topology was created with changing of level of EDFA input signal (-40 dBm, -20 dBm and 0 dBm) for comparing the basic parameters of the amplifier.

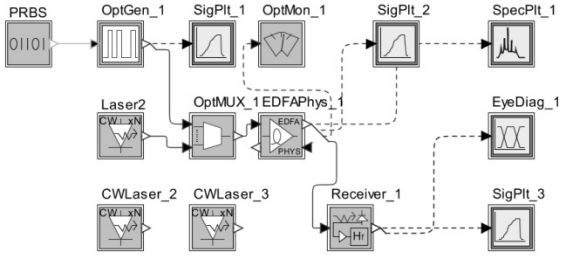

Fig. 2. EDFA Topology in programme package OptSim.

The topology in Fig.2 includes a transmitter, EDFA and receiver. The line bit rate is 10 Gbps and for ease of simulation the chosen type of encoding NRZ (Non Return to Zero).Noise figure was set up on 4 dB. In Fig.3 an increase in the input signal is shown and we can see that with increasing levels of the input power at the laser pump and constant wavelength, the overall erbium inversion is reducing. In Fig.4 ASE (Amplified Spontaneous Emission) decreases nearly in proportion with the increase of the input power: a signal with higher performance use more energized erbium to gain amplification, while less energized erbium is used to amplify the spontaneous emission. The EDFA pump was set at a wavelength of 980 nm. The wavelength was set to 1535 nm, which corresponds to the C-band and optical fiber length 14 m was constant during the simulation.

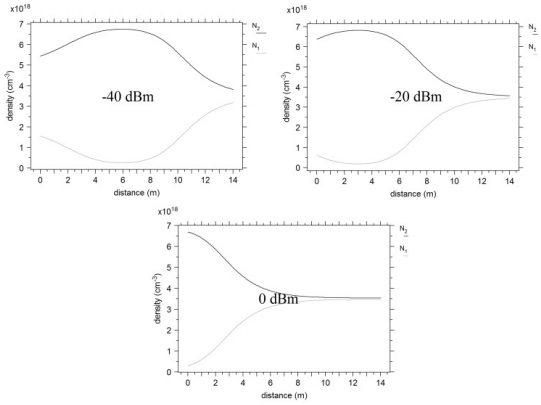

Fig. 3. Excited erbium state densities at different input signal levels: -40 dBm, -20 dBm, 0 dBm (N2 – excited state, N1 – ground state).

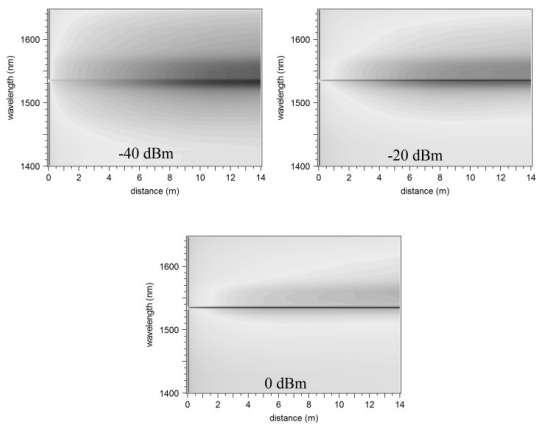

Fig. 4. ASE generation at different input signal levels: -40 dBm, -20 dBm, 0 dBm.

IV. Future Work

The following year will be devoted to design of DWDM (Dense Wavelength Division Multiplexing) system in accordance with ITU-T G.694.1. This system will include EDFA, while in the topology it will be used as a booster, in-line or as a preamplifier. The input power, the spacing between channels, wavelength and bit rate of the system could be changed, while the line quality will be assessed based on the BER (Bit Error Rate). The output of this system is the elimination of non-linear phenomena in the flow and the SPM (Self Phase Modulation), FWM (Four Wave Mixing) and CPM (Cross Phase Modulation) that occur in DWDM system. Each of these phenomena can be influenced by input power, spacing between channels in a very dense WDM or transmission speed. DWDM output will result in the elimination or minimization of these phenomena. Block coding and modulation unit will be created in MATLAB programming environment and other components in OptSim. In Fig.5 one channel DWDM, is shown which will be implemented by Laboratory of Optoelectronics Systems (LOS) at TUKE.

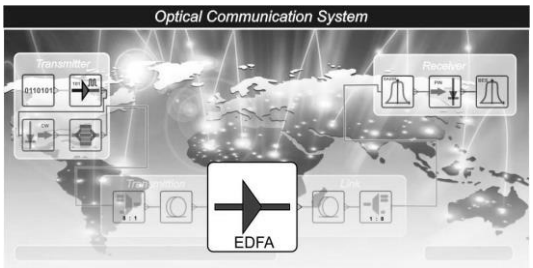

Fig. 5. The DWDM channel.

V. Conclusion

This article contains basic information about EDFA and its principles. The simulation pointed out that the higher valued signal activates (excites) more erbium thereby provides higher gain. In real terms it is used 10 to 15 meters long erbium doped fiber with typical input signal of -30 dBm to -10 dBm while making profits from 30 to 50 dB.

ACKNOWLEDGMENT

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The overview of four years personal and scientific development

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***Abstract*—For years in a mans live is like a trip on a roller-coaster. One starts fast, goes fast up on a peak but there is also even a faster falling, but still you are going forward. The same is true for the live of a young scientist. At the begging, a young man has his visions plans and enthusiasm to transform his dream to come true. Naturally, during the journey, he has to challenge many troubles a disappointments, but on the end of the day it is important to face them. This short article summarizes the four year work done during the four years period of the Ph.D. study at the Technical university in Košice.**

***Keywords*—education, generalized frequency division multiplexing, wireless communication.**

INTRODUCTION

A Ph.D. study requires to cope with many challenges, but on the other hand there are many opportunities which can be offered just by the academic environment. It is the possibility to study and develop the latest technologies, teach young and talented people, contribute to several research projects or even go abroad and study and take part on a research stage on the best universities in the world. The chance to go study in foreign countries was one of the main motivating factors what I had in my mind when I decided to continues my study after achieving my masters degree.

Thanks to prof. Dušan Kocur (Technical university in Košice) and Dr. Emil Matuš (Technical university Dresden) and the German Academic Exchange Service (also known as DAAD - Deutcher Akademischer Austauschdients) I had the opportunity to take part on a research stay in Germany on the Vodafone Chair Mobile Communications Systems, TU Dresden. It was an exciting stay and it helped me a lot to improve my scientific career as well as to gain valuable personal experiences. The second stay on foreign university was the one in Bulgaria at the Technical University Sofia, Sofia, during the program Intercultural Knowledge Transfer In Engineering for a Sustainable Global ICT Community: SUSCOMTEC 2014. This one was targeted to the area of Information and Communication Technologies specialized on the evolution and sustainability in the following years. Lastly, a stage in the United States of America was the top event during which I had the opportunity to work with DirecTV, now part of AT&T, in Los Angeles California.

This contribution will be organized as follows. The main research results and the enumeration of the papers written and publisher can be found in the following section. Next, the short description of the research projects I take part during the last years. The teaching aspects of the study will be presented in the last section.

I. PUBLICATIONS

The following section will shortly describe some chosen publication which create the main portion of the published papers. A list of all published parers will be presented as well. The main goal of [1] is to propose an iterative receiver structure for deliberately clipped GFDM signals. The simulations show that the bit error rate performance of the Generalized Frequency Division Multiplexing (GFDM) system, undergoing clipping as peak-to-average ratio reduction technique, can be significantly improved using the proposed iterative receiver. Investigation of the effects of nonlinearities in GFDM and introduction of an iterative receiver scheme to reduce the error probability of GFDM signals undergoing nonlinear amplification is published in [2]. The proposed technique is based on successive estimation and cancellation of the in-band distortion introduced by the nonlinear nature of the high power amplifier characteristics. The performance improvement of the iterative receiver structure is expressed by the bit error performance and error vector magnitude. The aim of [3] is to evaluate the performance of Generalized frequency division multiplexing systems undergoing nonlinear amplification. The results showed that the fault rate is apparently affected according to the particular high power amplifier model and its transmission parameters.

The list of published papers is following:

- ***Jurnal papers:*** [3], [4], [5] and [6]
- ***Conference papers:*** [7], [2], [8], [9], [1], [10], [11], [12] and [13]
- ***In proceedings:*** [14], [15], [16], [17] and [18]
- ***Other:*** [19]

II. PROJECTS

A. The research of coexistence between broadband LTE networks and digital terrestrial TV broadcasting DVB-T/DVB-T2

The project deals with the research of coexistence between broadband LTE800 and digital DVB-T/-T2 terrestrial TV broadcasting in the Slovak Republic. Part of the project will be focused on research of mutual influence of radio communications systems that were invented only a few years ago and even some of their new additions are currently under development. The project was successfully ended and besides other valuable deliverables and practical output the results of the project were published in [5], [17], [19] and [13].

B. Interactive Multiview Video Streaming for Supporting Education

The project is oriented to development and application of accessible software and hardware for interactive streaming of multimedia content, without necessity to save it in local data store. The aim of project is to elaborate and realize methods of access to various formats of multimedia content, such as video, sound record, and access to web cameras array with multiple visual angles (multi-view video streaming), as well. It is planned to design multimedia educational content for exploitation of such access. A multi-view e-learning system for supporting remote education, as an output of this project, is published in [11].

C. Agent based modeling of the spectrum distribution in cognitive radio networks

The goal of the project is the design of the novel and efficient models of the spectrum sharing and trading mechanisms in the cognitive radio networks. In the paper [7], we propose an agent-based model for spectrum trading in the shared use model of dynamic spectrum access. The results demonstrate that in risky environment, total revenue and total payoff of the auctioneer and bidder respectively is higher, than in the case of system with lower level of risk. On the other hand, normalized revenue and payoff per a single auction round is higher in the case with lower level of risk. In the paper [8], we tackled the spectrum allocation problem in cognitive radio networks with the combined solution using the cooperative spectrum sensing a and adaptive spectrum auction process.

III. Teaching

An inherent part of the doctoral studies is teaching. During my time at the faculty I was responsible for teaching the following courses:

- Introduction to programming and networking
- Programming in C
- Switching theory

An other aspect of the teaching responsibilities is the consultant role to support the student by the creation of their bachelor and master thesis. I was responsible to consult 4 bachelor and 7 master student which successfully ended they thesis and acquired they aimed academic degree. Teaching was an challenging task but also brought a lot of experience and will always remember to those beautiful days.

Conclusion

Four years might be long time is a humans live, but when one has a lot of work to do it just a moment. At the beginning of my doctoral studies I was excited to be part of the great scientific family but on the other hand, to be honest a had a big respect and was a bit afraid of the challenge and responsibility what stayed in front of me. However, know I can declare, that I tackled the challenge I did my best. Of course, when looking back, one can always do more or better, but just then if a man has the necessary knowledge and experience. I can surrey reveal that I archived them and that the doctoral study has made me an experienced, hard working, well educated and a confident man. What left to say is, that I hope, I will be able to complete my journey and defend my doctoral thesis so in the end a will be able to say *I did it*.

Acknowledgment

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A big thank needs to be said to my wife Katka and my parents and brother. They have always stand behind me when I needed them. And last but least I would like to thank my supervisor, tutor and I might say friend prof. Stanislav Marchevský.

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The use of dictionary approach for opinion classification

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***Abstract*—More and more people use internet every day. They produce extreme volume of textual data. It is very difficult to analyze their polarity manually. The best way how to analyze them is to use automatic methods to opinion analysis. It is very complicated task which consist from lot of small problems. This work is about the tasks which have already been solved. We describe the work, that has been done. In the last part, we write about the unsolved problems and future work in my research.**

***Keywords*—dictionary approach, opinion analysis, topic modeling**

I. Introduction

Nowadays, a lot of people use web for communication with each others. They express their opinions and emotions in different ways. This information influences the others who use the Internet. This people produce more and more contributions every day. It is often difficult to read all of these texts and analyze them. An automatic opinion classification can be used for analysis of this data. The opinion classification allows the users to analyze big volumes of textual information and make faster decisions.

The opinion classification is a process, in which the user's opinions are analyzed. These opinions can be expressed on different topics. The evaluation factor determines the opinion. The evaluation factor can be positive, neutral or negative. We can also use the strength of the evaluation factor for better determination of the opinion. The evaluation factor and strength are based on polarities of words in the contribution and their quantity. The topic means for example some persons, books, products or objects. The person who has specific opinion about the topic is called author or opinion holder.

The opinion analysis in not simple process. We use different types of methods to solve this problem. These methods can be divided into two main groups. The first group of methods are approaches using lexicons. The methods in the second group use methods base on machine learning. The machine learning methods can be also divided on supervised and unsupervised methods. The lexicon based approaches use words and phrases that are stored in dictionaries. The opinion lexicon is called a dictionary. Words in dictionaries have also assigned polarities and strengths of polarity. These approaches calculate semantic orientation of contribution by counting of polarities of each word. Lexicons for these methods can be created in different ways:

- manually - translating from other language or searching subjective words in text.
- semi-automatically - deriving from existing dictionaries (WordNet or SentiWordNet)
- automatically - using association

The machine learning approaches use for classification classifiers such as Naive Bayes classifier (NBc), Support Vector Machines (SVM), k-Nearest Neighbors (k-NN). The classifiers work in two steps. They are trained on a particular dataset using different types of features in the first step. It can be used unigrams or bigrams with or without Part-Of-Speech (POS) tagging. The most successful features are unigrams [1]. The classifier classify the unlabeled contributions in the second step. The machine learning methods achieve good results in the domain that they are trained, their performance drops down when they are used in the another domain.

In this work we decided to work with dictionary approach in Slovak language. We created lexicon with subjective words in Slovak and tested different language rules to gaining the best results.

II. Related work

Dictionary approach was used in many works. The best type of words which can be used for analysis in lexicon approach is adjectives. Benamara et al. [2] used three scoring methods (variable scoring, adjective priority scoring and adverb first scoring). The best results achieved adjective priority scoring. Taboada el al. [3] created manually generated dictionaries for opinion classification of contributions. Their approach also used different methods of text processing such as intensification or negation. Created dictionaries contain intensifiers (words, that change strength of polarity) and negation (words, that reverse the polarity). The authors added some adverbs, nouns and verbs into the dictionaries. They compared their approach with the others on the sample from work Pang and Lee [4]. Taboada et al. achieved the best results in comparison the other works.

Pang and Lee [4] compared three methods of machine learning (NBc, SVM and Maximum entropy). The classifiers analyzed comments from web page IMDB.com. The best results achieved SVM classifier with unigrams. SVM was also used in work Abbasi et al. [5]. They tested classifier on three samples. The first dataset contained ratings of digital cameras from Epinion.com. The second contained ratings of cars and the third samples was from work Pang and Lee [4]. The classifier achieved accuracy 89.65%.

The work [6], Li and Wu combined dictionary approach and machine learning methods. They analyzed sentiment on

on-line forums for detection and prediction disturbed locations. It was created an algorithm which analyzed emotion polarity for each part of text, in the first step. After that they used combination of K-means clustering and SVM classifier for creation of unsupervised method to analyzing sentiment. The centers of clusters represented searched areas. The dataset contained more than 220 thousand contributions. The results demonstrated that SVM achieved quite consistent results with K-means. The top 10 hot areas returned by SVM were in 80% similar with K-means.

III. Dictionary approach improvements

In our research, we worked with dictionary approach mainly. We studied different possibilities how to improve precision and recall by using different types of text processing. In our work [7] we studied the impact of negation on language processing in Slovak language. They were compared two basic types of negation:

- switch negation - the value of the word changes into a word with equal strength but of opposite polarity
- shift negation - the value of the word is determined by the shift towards the opposite polarity by an exact value (e.g. 4)

The results showed in table I, that usage of switch negation achieved worse results than the method without negation. The reason of this result can be that switch negation is very inaccurate approach to negation. The shift negation achieved comparable results to method without negation. We decided to try new approach to negation. It combined both types of negation. The switch negation was used for negation words with values +/-1 and +/-2. Otherwise the shift negation was used for words with values +/-3. This combined approach achieved the best results and outperform method which without negation. Disadvantages of these methods were, that the negation influenced only words which were after negation and we did not limit the distance of influence of negation. We tested this approach on dataset which contained 5242 contribution. From these contributions, 2572 were positive and 2668 were negative.

TABLE I
The results of comparison of different types o negation

Measure	Precision(%)		Recall(%)	
Approach	Pos.	Neg.	Pos.	Neg.
without negation	56.9	82.1	**70**	40.2
switch negation	57	81.2	69.3	**41**
shift negation	56.9	82	69.7	40.1
combined negation	**58.6**	**84.7**	**70**	**41**

In next work [8], we improved dictionary approach by using topic modeling method. In our previous research, we identified specific human behavior, that people describe aspects of some object more than whole object. We decided to implement topic modeling for identification the topics about which people speak. The algorithm tries to identify topics in the first part. It was used Latent Dirichlet Allocation algorithm for obtaining topics. It generated list of 50 words which represented the topics. The topics words were filtered and the subjective words (words, that were in dictionary) were removed. The final list of topics contained 15 words, that identified the topics. In the second part, the topic words were used for giving weights to sentences which contained topic words. Each sentence was analyzed by dictionary approach described in work Mikula and Machová [9]. The used weight was 2 which means double polarity value of sentence containing topic word. This approach was tested on dataset containing 1287 contribution about films. We tested two versions of algorithm (with and without topic identification). The presented results showed, that can be useful for sentiment analysis. In spite of the topic modeling achieved only small improvement the results indicated, that topic modeling can have positive impact for sentiment analysis.

We continued in studying the topic modeling in sentiment analysis also in our next work [10]. It was used more simple method of topic identification. We created topic list by using term frequency in this work. We implemented stop words filtering because these words usually have the biggest term frequency. Created list of topic words were filtered and subjective words were removed. When the topic list was created we used its for sentiment analysis. In case, that the analyzed sentence contained topic word, polarity value was changed by weight. We tested different weights in this work. The best results achieved weight 1.5. This weight was used in next experiments. We used same dictionary approach for sentiment analysis as in the previous work. The experiments were done on same dataset as in our first work ([7]). The achieved results indicated, that topic identification improved results (in table II).

TABLE II
Evaluation of the precision and recall for our approach with and without topic identification (TI)

Measure	Precision(%)		Recall(%)	
Approach	Pos.	Neg.	Pos.	Neg.
without TI	60	78	87	44.2
with TI	**60.5**	**79.2**	**87.8**	**44.8**

IV. Future work

In our future work we want to aim to three topics. The first is influence of spam contributions. Spam has negative meaning based mainly on negative meaning from e-mail communication. But it can have positive impact in some cases. Positive influence can be connected with awareness of product. This is the reason why we want to analyze impact of spam for opinion analysis in Slovak language. The second theme is connected with topic identification. In our works, we identified the behavior pattern, when the people described parts of product more than whole product. Then the rating of these parts was stronger than whole product. From this reason we want to implement topic identification to increase rating of whole product. We want to study more deeply some approaches for topic modeling and implement them to our method of opinion analysis. This combination should improved the results of precision and recall. The last topic is about combining dictionary approach with machine learning methods. There are words, that are domain dependent. These words are positive in one domain and negative in other domain. This is the reason, why is difficult to create dictionaries, that can be used on different domains. If we have the word in dictionary which is marked as positive and this word is used in text in negative meaning, it has negative effect on

evaluation of contribution. We want to combine dictionary approach which create training set from unlabeled dataset and machine learning approach which will be trained on this set. The machine learning approach will be then used to classification of the other documents. This method can help to analyze contributions, that are domain dependent.

V. Conclusion

This article is dedicated to opinion analysis. In the first part we introduced what opinion analysis is. We described the research tasks which were already solved. In the next part, we summarized tasks which were solved and described obtained results. The last part is dedicated to future tasks, that we would like to solved in next years.

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Towards Cloud-based Affective Loop for Human-Machine Interaction

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***Abstract* — This paper offers a brief overview of the most recent methods in the field of human-machine interaction with the emphasis on the multi-modal emotion recognition. The presented solutions depict the importance of emotions in a feedback driven communication where the transferred information is enriched by the information about the emotional state of the human. Furthermore, this paper proposes a cloud-based solution for an affective loop which implements the human-center approach of human-machine interaction.**

***Keywords* — human-machine interaction, emotion recognition, affective loop, cloud, computer vision**

I. Introduction

Emotions in inter-human communication are being proven every day to be one of the main drivers of the communication topic change, response formulation and decision making. Usually, we are not focusing actively on the emotion of the person we are communicating with but we are perceiving them subconsciously. This subconscious perception can be considered as feeding received emotional data to our inner emotional model for an intuitive emotional atmosphere evaluation. This way we are able to evaluate for example tension in the communication if the other side is angry or nervous.

In the field of human-robot interaction (HRI) one of the most crucial parts is the communication between the robot and the human. In general, in human-to-human interaction we can recognize multiple channels of communication, which provide exact information transfer between these two subjects. However, in HRI the number of communication channels, which can be measured is significantly lower, because of the high complexity of human's output channels. This complexity differs from human to human and also from the information being transferred, while a single written word can be relatively easy to be read by a computer, recognizing the precise emotional state/mood of the human is sometimes a very hard task for an another human, not mentioning the computer. On the other hand, such information about the emotional state/mood can lead to communication quality enhancement by modifying the communication atmosphere using musical stimuli, gestures or mimic, or by changing the topic of the interaction.

Solution of the problem of the emotional channels recognition can lead to various scenarios where robots can participate in the human's everyday life which would eventually lead to creation of companion and social robots. The main issue that has to be addressed in these fields is how to make these "social" robots behave adequately regarding the incoming information. The linking parts which would partially address the problem could be the Cloud and creation of an affective loop.

II. Analysis of Human-Machine Interaction

As Darwin stated in [1], emotions play an essential role in biological processes which affect the anatomical and psychological adaptations of the subjects i.e. human or animal. These adaptations can vary from slight change in the behavior of the subject to an extreme situation where the subject can behave in an uncontrollable way. The multi-modality of emotions is represented by various modes of communication according to human's senses (sight, touch, hearing, smell, taste), where not all modes are necessarily present in the communication.

The field which studies processing of information exchange during the interaction between humans and machines and tries to simulate the natural perception of interaction for the machine is known as human-machine interaction (HMI). With the machine side of interaction is dealing the field of affective computing.

In [2] Rosalind Picard states the goals of affective computing. She also explains the importance of embedding emotion recognition systems into machines, presents possible analyzes drawn upon data from wide spectrum of disciplines, from neurobiology to folk psychology. Picard emphasizes the design and construction of computers which should have human-like capabilities of observation, interpretation and generation of affect features.

Creation of such systems is not an easy task, but by defining the term of multimodal HMI system as a system that responds to inputs in more than modality or communication channel [3] we can identify two main roles in this system: the addresser and the responder. These two roles appear in both approaches possible in HMI i.e. human-centered and machine-centered. For social robotics the most used approach is the human-

centered approach where the addresser is the human and the responder is the machine.

In the context of HMI, the human-centered approach requires an interface for the communication with the machine. However, the multi-modal nature of emotions during communication hardly allows the use of a single interface, therefore we can usually recognize three types of interfaces in HMI: perceptual, attentive and enactive interfaces.

III. Computer vision in human-machine interaction

Computer vision plays a very important role in two types of human-machine interfaces namely in the perceptual and attentive interface. In perceptual interfaces [4] which are defined in [5] as highly interactive, multimodal interfaces that enable rich, natural, and efficient interaction with computers. This type of interface greatly benefits from computer vision while it offers interaction interfaces for interactions not feasible with standard interfaces and common I/O devices. The attentive interfaces [6] are context-aware interfaces that rely on an addresser's attention as the primary input. This indicates that the desired interface has to be able to process the human's reactions to a given output from the machine or to use this gathered information to estimate the best time and approach for communicating with the user.

We can classify vision techniques for multimodal human-machine interaction using a human-centered approach by dividing them according to human body parts: whole-body movements, hand gestures, gaze and facial information recognition.

Whole-body movements

Tracking of whole-body movements is necessary in case of pose and motion interpretation which have broad application potential in the field of multimodal human-machine interaction. The human pose interpretation is already known from the Microsoft Kinect sensors [7] which offer usability in large variety of pose estimation applications where a computer with the specific Kinect software development kit (SDK) is present and the sensor is connected to it.

However, the sensor is not a necessity for extraction of poses in form of whole body skeletons, an example is the approach explained in [8] where the authors used a deep neural network to determine the human's pose or an approach using hybrid architectures with deep Convolutional Network and a Markov Random field presented in [9]. For the motion interpretations most used solutions are usually the same as in pose estimation, but with a modification which allows continuous pose measurement in a specific time window.

Hand gestures

There are two main hand gesture types which are possible to recognize from the available range of gestures in a multimodal human-machine interaction: symbolic and non-symbolic gestures.

Under symbolic gestures we understand various gestures referring to for example sign language, simulation of actions or objects (motion and distance indication, geometric or specific subject representation). On the other hand, non-symbolic gestures usually refer to gestures the addresser expresses subconsciously whether he wants to support his explanation or speech, or to express gesture based emotions.

Also in this field it is common to use the Microsoft Kinect sensor, which natively offers in it's SDK a tool to recognize and track human gestures. However, it is possible to enhance the effectiveness even further for example by using a dedicated calibration techniques as in [10] where the authors used a gesture description language semantic classifier to eliminate segmentation and tracking errors during recognition. However, same as for whole-body movements it is possible to omit the Kinect sensor and use a simple camera to recognize gestures. For example in [11] the authors were using a wavelet network classifier based on fast wavelet transform in order to convert hand shapes or trajectories recognized by classic segmentation methods commonly used in computer vision to computer orders which enables the computer to process the gestures easier.

Gaze detection

In computer vision gaze is defined as the direction to which the eyes are pointing in space, is a strong indicator of attention, and it has been studied extensively since as early as 1879 in psychology, and more recently in neuroscience and in computing applications [12].

Researches in the past few years in the field of gaze detections were accelerated after the announcement of release of a virtual reality headset the Oculus Rift [13] which promoted the gaze detection problem to more important position in the human-machine interaction. As one of many the authors in [14] developed a method using eye and pupil detection with adaptive boosting algorithm (Adaboost) and continuously adaptive mean shift (CAMshift) algorithms for gaze detection.

Facial expression recognition

The facial expression recognition (FER) is one of the most important part of multimodal non-verbal emotion recognition while the human face and especially mimics are most suitable for depiction of emotions. For the FER research the most common emotional model which was inspired by the work of Ekman [15]. The Ekman's model of emotions works with Facial Action Coding System (FACS) where the basic elements are the Action Units (AU). However, there are many representations of AUs, but the most commonly used is in the original form where the AUs code emotions based on the face's features and their state relative to the whole face and other facial features.

There are two main approaches for FER namely feature-based and region-based approach. The feature-based FER can be further divided to classic feature-based techniques [16] where the emphasis is on the geometric distribution of facial features and model based techniques [16] where usually a statistical model is created from a large variety of human faces. In the region-based approach the face is processed as a whole and the proposed methods for FER are using various area, appearance and texture based techniques to extract the AUs. The most recent studies are utilizating Hidden Markov Models and Optical flow for such extraction for example in [17, 18].

IV. Summary of solved and unsolved problems

The interaction between humans can be simply described as a feedback loop where each side has own system in the loop which should be synchronized according to the topic of the interaction. In the simplest way, the systems in this loop is represented by an inner model of the human which processes the input information and generates a response which enters a controller that represents the cognitive and perceptive processes of the human and modifies the original response according to the addressers reaction (see Fig. 1).

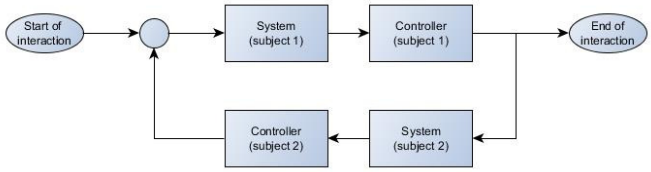

Fig. 1. Affective loop during interaction of two humans in form of feedback loop. The subject 1 and subject 2 are the participants of the interaction.

In the HMI the principle is similar, however the things get complicated when we want to create the machine part of the affective loop while the computational resources needed for real-time multimodal communication are often not available on a single machine and it is highly unpractical to equip each machine with suitable hardware. Therefore, some sort of computational load distribution is needed where the cloud can be the solution. We propose to use Microsoft Azure Cloud [19].

The reasons behind why to choose cloud-based solution over a server-based for computational load distribution are several. The first of all is the ease of application deployment where the deployment to the Microsoft Azure Cloud is straightforward and much faster than the deployment a server. The second one is the use of dedicated virtual machines for computational applications, which offer adapted operating systems where the software resources installed are only necessary bundles needed for the exact application whereas to create a similar virtual machine on the server it would take several configuration modifications or preparations of such lightweight operating systems. The third and probably the main reason why to choose cloud over servers is the resource scaling capability on the Microsoft Azure. To explain the scalability of services on the cloud we can consider a scenario in social robotics where the robot is interacting with the human. The robot in this scenario serves not only as a communication interface but also as a data gathering device. In general it is not difficult to feed the data gathered during interaction to the cloud/server environment, process them, and afterwards return the desired interaction feedback action to the robot. The problem occurs, when there are more robots connecting to a processing service on the cloud/server hence the computation resources required to process the data raises exponentially. On the Microsoft Azure Cloud there are easy-to-use load distribution mechanisms which offer automatic unlimited scale-outs of the given service or virtual machine in the means of creation of multiple instances where the load distribution mechanisms are able to effectively distribute load evenly to each instance. In the server environment it is very hard to implement such mechanisms, while the resources are often limited and the available bandwidth is fixed.

The affective loop structure for a cloud solution (see Fig.2) can be divided into four main parts: interaction client, communication processing module, cognition module, and the knowledge base. As this is a multiplatform solution for multimodal HMI the machine communicating with the human can be any suitable device allowing transferring multimodal information. Of course, the robot or the machine has to have a stable internet connection with sufficient bandwidth available to be able to connect to the cloud services.

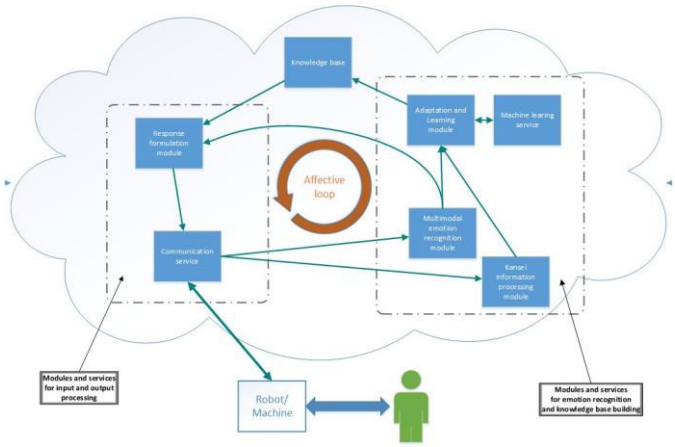

Fig. 2 The cloud-based affective loop solution architecture.

Interaction client

As we propose a multiplatform solution the client machine for HMI the client application hosted either on a specific robot platform or computer has to be also multiplatform, and being able to gather data and communicate with the user in at least one interaction modality. This can be achieved by creation of a thin client which is available to install on any operating system with no additional libraries included which could cause several problems during installation or running the application. The idea is to leave the main functionalities in the cloud storage where they are easily accessible and downloadable on demand, and where they can be easily managed by the means of patching. These functionalities we can call as controllers for various peripherals where each controller is able to work independently from other controllers, and is also able to connect the cloud communication module.

Communication processing module

The service communication processing module is a fully cloud-hosted application which ensures duplex communication for client applications and formulation module for creating an appropriate response based on the previous input from the addresser. This module is the starting and also the ending point of the cloud-based affective loop. The communication method is dependent from the type of the data transferred from the client application and therefore it would be hard to use only one transfer technology. Mostly every communication which doesn't require sending large amounts of data and are in an appropriate form (basic data types of programming languages) can be carried out by Websocket technologies [20] embedded in the SignalR technology [21].

Cognition module

In our solution the most computationally demanding part is the cognitive part where the main recognition and processing takes part. Same as the communication processing module this module is also fully cloud-hosted application. Under the

cognition module we recognize four submodules: multimodal emotion recognition module, kansei information processing module, adaptation and learning module, and machine learning module. The possible methods of the multimodal emotion recognition described in the previous sections of the module would be implemented in the form of stand-alone applications with a suitable inter-module communication solution. The kansei information processing module draws from the research of Hirota et al. [22], which defines a very similar way of implementing emotion recognition for social robotics through human's implicit emotional impression like the affective loop. The reason why this module was included is to detect possible differences in emotion recognition which could lead to creation of more precise and relevant knowledge base. The adaptation and learning module handles the creation and management of the knowledge base using various methods of artificial intelligence. This module also works together with the machine learning module which in fact a stand-alone service offered by Microsoft Azure, where mainly the data analysis will take place.

V. Conclusion

In this paper we define the recent approaches in the human-computer interaction with emphasis on emotion recognition methods in various modes of interaction with the emphasis on the computer vison which offers the greatest space for improvement of existing methods and development. Furthermore, in this paper we propose a centralized cloud-based implementation of an affective loop solution for multi-modal emotion recognition, which would lead to a sophisticated solution for human-robot interaction social robotics where the robots/machines are able of collaborative learning and information sharing.

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Towards Formalization of Component-Based Systems Behavior

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***Abstract*—In this contribution we briefly present basic notions from component-based systems, category theory and our modal linear logic. We understand a component-based system as new approach to software engineering, which based on the definition, has to be exactly formally specified.**

***Keywords*—Category theory, coalgebras, component-based systems, linear logic, modal logic.**

I. Introduction

Today's society is legitimately called an information society. With that comes requirement to develop large program systems. One possibility to do so, is to develop them using component-based systems. Each component can be developed by different parties, programming languages or paradigms. To such a program system to be functonal, component-based systems have to be exactly documented and specified [1]. Currently, there are many formal methods in use, based on mathematics, algebras, logical systems etc., [2], [3]. In this paper, we present our recent work, suggestions and ideas how to formally specify and model component-based systems behavior using mentioned formal methods.

Firstly, we briefly introduce what component-based systems are, then we present basic notions of the most common used formal methods by us, namely: category theory, coalgebras for an appropriate polynomial endofunctor and we bring definition of our modal linear logic. At the end, we present our recent work in the field formalization of program systems and we bring our ideas in formalization of component-based systems behavior.

II. Component-based systems

Development of component-based systems is relatively new approach of software engineering [4]. It is based on programming a program system from already existing components through their composition [5]. Individual components can work in quite different program systems. In the other words, it is a software development concept, based on a reuse of already existing software rather than developing a whole program system.

A. Software components

At the beginning, it is important to define what software components are. There are several definitions [6], [7], [8], but we present the two most common ones, in both of them we enhance the most important key words and then we explain their meaning in detail:

- *Councill and Heinmann:* A software component is a software element that *conforms to a component model* and can be *independently deployed* and composed without modification according to a *composition standard*.
- *Szyperski and Pfister:* A software component is a unit of *composition* with contractually *specified interfaces* and *explicit context dependencies*. A software component can be *deployed independently* and is subject to *composition* by third-parties.

Szyperski in his work [8] characterize basic notions of a software component based on the definitions above as follows:

- *Standardisation:* A software component must fulfill a standard component model which define interfaces, documentation, composition and deployment.
- *Independence:* A software component is independently deployable entity, meaning that it is possible to deploy a component without requirement to have any other components. If a component requires externally provided data, it has to be explicitly documented in interface specification.
- *Composition:* To be a software component composable, all external interactions must be exactly and publicly defined in interfaces by which are individual components composed.
- *Documentation:* Every software component must be fully documented and a syntax and a semantics of interfaces must be exactly specificated.

According to [9], other significant properties of a software component are:

- it has hidden implementation (based on that, it is sometimes compared to black box);
- it is independent at using programming language and programming paradigms;
- it has no externally observable state;
- it is a unit of independent deployment. It means that a software component cannot be deployed partially;
- it is a unit of composition by third party. In this context a third party is consider to be one that cannot be expected to have access to the component inside.

B. Component models

According to [10], a component model is definition of standards and conventions for implementation, specifica-

tion/documentation, that are necessary to allow the component composition of independently developed components.

Every component model consists of:

- component frameworks that specify interfaces and typed ports,
- rules for cooperation between frameworks, that provides conditions for cooperation of components by defining their relationships (interactions).

C. Basic notions in component-based systems

In this subsection, we describe the most common notions in component-based systems namely: component interfaces and typed data ports, classifications of interactions, contracts and context dependencies. Based on that one can specify component model.

1) Interfaces and typed data ports: An interface of a software component is according to [11], [12], its only visible part and it defines a component's entry point. Usually a component has more interfaces, every interface provides different service. Content of interface indicates how a given component can be used after component deployment.

An interface consists of:

- typed data structures;
- operations over typed data structures and
- typed ports.

Typed ports are entry points for transfer of data. Every port is input or output for receiving or sending data to other component(s).

2) Classification of interactions: Basic definition of interactions is presented in the subsection (II-B) [8]. There are many definitions of classifications in different literature. The most common one is classification of interactions based on three basis:

- interactions based on Horae's pre- and post- conditions;
- interactions that are dealing with concurrency and internal/external non-determinism;
- interactions based on choice and its causality.

3) Contracts: Contracts specify correlation between data constructing component's typed ports and data extracting component's typed ports and set requirements at interfaces of other components which must be fulfilled for component to be able to work [8]. Contracts also ensure that components can be deployed independently.

According to [7] a contract is an ordered pair:

$$(A, G)$$

where

- A is a specification of assumptions that contains requirements on an environment of a component;
- G is a specification of guaranties that formulate what components provide if assumptions are satisfied.

Component-based system consisting from n components where $n \in \mathbb{N}$, will be working only if all assumptions and quarantines of n components are satisfied.

4) Context dependencies: Contracts are not enough for successful work of a component-based system [13], [14]. The last thing that is needed are context dependencies. Dependencies describe relations between components. For example lets consider two components C_1 and C_2. If a component C_1 uses a component C_2, then component C_1 depends on a component C_2.

Context dependencies consist from composition and deployment dependencies [8].

- Composition context dependencies specify requirements on composition for successful composition.
- Deployment context dependencies specify possible platforms i.e. hardware and software where component is able to work.

III. Category theory

Category theory is relatively young branch of mathematics. It was founded in 1945 as part Eilenberg's and MacLane's work as part of their research in the field of algebraic topology [15], where they formulated a notion of categories, functors and natural transformations of functors as a formalism for describing mathematical structures. Nowadays [16], category theory is a universal abstract frame used for description of various structures as mathematical, algebraic or abstract data structures used in computer science.

We introduce in this section basic definitions about categories, functors and coalgebras and their necessary properties and we define basic notions of coalgebras for an appropriate endofunctor.

According to [17], [18], a category $\mathbf{C}$ consists from:

- a class of objects $C_o \in \mathbf{C}$, where $C_o = \{X, Y, Z...\}$ and
- a class of morphisms between objects $C_m \in \mathbf{C}$, where $C_m = \{f, g, h...\}$.

Every category possesses following well defined properties:

- If there is a morphism $f \in C_m$ between two objects $X, Y \in C_o$, it is denoted as $f : X \to Y$.
- A morphism $f \in C_m$ has domain and codomain.
- Lets have a morphism $f \in C_m$ defined as $f : X \to Y$. Then object $X \in C_o$ is domain of a morphism and object $Y \in C_o$ is its codomain.
- For every object $X \in C_o$ there is an identity morphism $id_X \in C_m$ defined as: $id_X : X \to X$, where domain and codomain of such a morphism is X.
- The most important property of category $\mathbf{C}$ is that for that morphisms are composable i.e. lets have $X, Y, Z \in C_o$ and two morphisms $f, g \in C_m$ define as follows: $f : X \to Y$ and $g : Y \to Z$, then there is a morphism $g \circ f : X \to Z$.

A. Functors

As we wrote above, many mathematical structures can be formulated as categories. Since categories are also mathematical structures [19], [20], [21], one should consider a category of categories, where objects are categories and morphisms of such a category are structure preserving maps between categories called functors.

Let $\mathbf{C}$ and $\mathbf{D}$ be categories and a functor $F : \mathbf{C} \to \mathbf{D}$ which is a morphism from the source category $\mathbf{C}$ to the destination category $\mathbf{D}$ [22]. A functor F assigns to every object $X \in \mathbf{C}$ an object $F(X) \in \mathbf{D}$ and to every morphism $F(f) : F(X) \to F(Y)$ satisfying following conditions:

- for every object $X \in \mathbf{C}$ and its identity object morphism $id_X : X \to X$ there is;

$$F(id_X) = id_{F(X)};$$

- for every two morphisms $f, g \in \mathbf{C}$ a functor F preserves composition properties $(g \circ f)$ such as:

$$F(g \circ f) = F(g) \circ F(f).$$

This kind of functors are called simple. Another example of simple functors are for example:

- identity functor $ID_{\mathbf{C}} : \mathbf{C} \to \mathbf{C}$;
- endofunctor $E : \mathbf{C} \to \mathbf{C}$, where source and destination category are the same.

In our approach, we use special kind of endofunctor called polynomial endofunctor [23], [24], [25]. A polynomial endofunctor over category $\mathbf{C}$ is an endofunctor formed by polynomial operations shown in BNF's production rule as follows:

$$T(X) ::= X|X \times Y|X + Y|X^Y. \tag{1}$$

B. Coalgebra for an appropriate endofunctor

Coalgebras are useful categorical structures in computer science [26], [27]. In our approach we use them for modeling state oriented behavior of program systems.

Lets have category $\mathbf{C}$ and polynomial endofunctor T [28], [29], [30], then a coalgebra for an appropriate endofunctor T (sometimes also called T-coalgebra) is formally an ordered pair:

$$(X, \zeta), \tag{2}$$

where

- X is a object of category $\mathbf{C}$ and
- ζ is a morphism of category $\mathbf{C}$ such as $\zeta : X \to TX$.

Object $X \in \mathbf{C}$ is coalgebra's state space and morphism ζ is structural function of coalgebra.

IV. Modal Linear logic

In our recent work in the field of formal description of program systems behavior through logical systems [31], [32], [33], [34], we have decided to create our own logical system. It is based on multiplicative fragment of Girard's resource oriented linear logic [35], [36] and modal operators (modalities) of Aristotle's modal logic. In [37], we have named it the Modal Linear Logic (MLL).

Generally, every logical system consists from three fundamental pillars, namely: syntax, semantics and proof system respectively. In this contribution we present whole definition of MLL syntax and semantics. Then we present brief introduction to methods which we have used in our publication for definition of proof system.

A. Syntax of MLL

We use production rule in backus-naur form as notion technique for description of syntax of MLL as follows

$$\begin{aligned}\varphi ::= a_n \mid \mathbf{1} \mid \bot \mid \varphi \otimes \psi \mid \varphi \parr \psi \mid \varphi \multimap \psi \\ \mid \varphi^{\bot} \mid \Box\varphi \mid \Diamond\varphi.\end{aligned} \tag{3}$$

All formulæ *(actions)* of MLL can be constructed by this rule. The set of all MLL formulæ can be denoted as $MLLForm$ [31] (in the original paper it is denoted as $CMLLForm$). Where elements of the production rule above mean following:

- a_n means elementary formulæ, where $n \in \mathbb{N}$,
- $\varphi^{\bot}$ is a linear negation, which expresses duality between action (φ) and reaction ($\varphi^{\bot}$), in the other words: available and consumed resource,
- $\varphi \multimap \psi$ is linear implication, which expresses fact that a (re)action ψ is a causal consequence of action φ and after performing such a implication, the resource φ became consumed ($\varphi^{\bot}$),
- $\varphi \otimes \psi$ has neutral element $\mathbf{1}$ and is multiplicative conjunction, which expresses the performing of both actions simultaneously,
- $\varphi \parr \psi$ has neutral element $\bot$ is multiplicative disjunction, which expresses commutativity of duality between available and consumed resources by performing either action φ or action ψ,
- $\Diamond\varphi$ is modal operator expressing possibility of the action,
- $\Box\varphi$ is modal operator expressing necessity of the action,

In proposed logical system, we formulate the following De Morgan's laws:

$$\begin{aligned}
\mathbf{1}^{\bot} &\equiv \bot \\
\bot^{\bot} &\equiv \mathbf{1} \\
(\varphi^{\bot})^{\bot} &\equiv \varphi \\
(\varphi \otimes \psi)^{\bot} &\equiv \varphi^{\bot} \parr \psi^{\bot} \\
(\varphi \parr \psi)^{\bot} &\equiv \varphi^{\bot} \otimes \psi^{\bot} \\
\varphi \multimap \psi &\equiv \varphi^{\bot} \parr \psi \\
\Diamond\varphi &\equiv \Box\varphi^{\bot} \\
\Box\varphi &\equiv \Diamond\varphi^{\bot}
\end{aligned}$$

B. Semantics of MLL

In [37], we have defined semantics for our logical system in form of Kripke's possible worlds semantical method by constructing its model.

Kripke's model $\mathbf{M}$ is ordered quadruple $\mathbf{M} = (W, \leq, \models, x)$, where:

- W is non-empty set of possible worlds: $W = \{x_1, x_2, \ldots, x_n \mid n \in \mathbb{N}\}$,
- $\leq$ is a binary accessibility relation between worlds: $\leq \subseteq W \times W$,
- $\models$ is intensional relation: $\models : W \times MLLForm \to \{\mathbf{1}, \bot\}$, where $\models (x_1, a)$ assigns to the elementary formula a in world x, value from set: $\{\mathbf{1}, \bot\}$,
- x is designated world $x \in W$.

Based on definition above we construct Kripke's model of modal linear logic as follows:

$$\begin{array}{lll}
\mathbf{M}, x \models a & \textbf{iff} & \models (x, a) = \mathbf{1} \\
\mathbf{M}, x \models \mathbf{1} & \textbf{iff} & \models (x, \mathbf{1}) = \mathbf{1} \\
\mathbf{M}, x \models \bot & \textbf{iff} & \models (x, \bot) = \bot \\
\mathbf{M}, x \models \varphi^{\bot} & \textbf{iff} & \mathbf{M}, x \not\models \varphi \\
\mathbf{M}, x \models \varphi \otimes \psi & \textbf{iff} & \mathbf{M}, x \models \varphi \quad \textit{and at the same time} \\
 & & \mathbf{M}, x \models \psi \\
\mathbf{M}, x \models \varphi \parr \psi & \textbf{iff} & \mathbf{M}, x \models \varphi \quad \textit{xor} \quad \mathbf{M}, x \models \psi \\
\mathbf{M}, x \models \varphi \multimap \psi & \textbf{iff} & (\forall x_n) x \leq x_n \quad \textit{if} \quad \mathbf{M}, x_n \models \varphi \\
 & & \textit{then} \quad \mathbf{M}, x_n \models \psi \\
\mathbf{M}, x \models \Box\varphi & \textbf{iff} & (\forall x_n) x \leq x_n : \mathbf{M}, x_n \models \varphi \\
\mathbf{M}, x \models \Diamond\varphi & \textbf{iff} & (\exists x_n) x \leq x_n : \mathbf{M}, x_n \models \varphi
\end{array}$$

Notation $\mathbf{M}, x \models \varphi$ can be read as "modal linear formula φ has sense in world x, in model $\mathbf{M} = (W, \leq, \models, x)$".

C. Proof system of MLL

For definition of a proof system for our logical system, we have used the Gentzen's Double Sided Calculus (GDSC) style [31]. Compared to other proof system styles, its most important advantage is that the creation of the proof is fundamentally

simpler and, more important, the proofs in GDSC show real process which is described by formulæ. The inference rules for double side GDSC have following form:

$$\underbrace{\Gamma}_{\varphi_1,\ldots,\varphi_n} \vdash \underbrace{\Delta}_{\psi_1,\ldots,\psi_m} \tag{4}$$

where Γ, Δ are finite sets of formulæ. Notation $\Gamma \vdash \Delta$ means

$$\varphi_1 \otimes \cdots \otimes \varphi_n \vdash \psi_1 \parr \ldots \parr \psi_m \tag{5}$$

and it could be read as "the multiplicative disjunction of formulæ on the right side is provable from the multiplicative conjunction of formulæ on the left side of the sequent".

Whole definition of GDSC and deduction rules for MLL are published in [31], where we have formally described behavior of the intrusion detection system as modal linear logic formula. In [37], we have extended our approach applying time-spatial calculus from Girard's Ludics theory.

V. Conclusion and Future Work

In this paper we have introduced and analyzed basic notions of component-based systems, then we have presented brief introduction to formal methods which are the most common used by us. In the future, we would like use them to formally describe behavior of component-based systems.

Main goal of our research is construction of verifiable model of component-based systems behavior. Using modal linear logic, we would like to specify behavior of component based systems as modal linear logic formulæ and to describe interactions and dependencies using Girard's time-spatial calculus called Ludics.

In terms of category theory, we can model interfaces as objects and interactions as morphisms. Then we would like to construct a coalgebra for an appropriate polynomial endofunctor over state-space category as a model allowing observation of component-based systems behavior.

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Usage of requirements in self-*systems

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***Abstract* — There is much more emphasis on architecture than on knowledge representation in self-* system development. We think that there should be more attention given to knowledge selection and representation, because self-adaption or self-healing cannot be implemented without knowledge about the requirements and architecture of the system. We focus this paper on requirement knowledge representation and usage in self-* systems. Our goal is to present an approach, which takes different software development methods into consideration. Using them, we find the proper form of requirement representation. We also show related methods of knowledge extraction from the selected requirement representation - which are user stories. Finally, for the presented representation, we outline our usage model prototype, which is also used to show further research and development directions.**

***Keywords*— self-*system, requirement, knowledge**

I. Introduction

Software industry aims to produce software systems, which are domainspecic to full user requirements and which are fault-tolerant to reduce explicit maintenance costs. These properties also imply a level of adaptiveness, which is usually achieved by software system configuration at install-time.

As there are different types of failures coming from inside the software and from outside attacks, the property of being fault-tolerant is in many cases not enough. This problem is addressed by self-*systems [1] - software systems implementing several self-*properties described with the definition of autonomous computing.

We focus our paper on usage and representation of system knowledge hidden or public in the requirements [2]. This orientation requires a more detailed architecture, method and data description before presenting our core idea of using requirements knowledge in selected processes within an autonomous self-* system[9].

High costs of modifications, corrections, changes and extensions are often rooted in the need to realize new analyses and reengineering of the actual system, and searching for coherence between this code and the new requirements. But it often happens that these new requirements are only extensions or modifications of the old ones. Therefore, the coherence between the old code and the new requirements might also be an extension or modification of the old relations, which ones were earlier recognized during system development. Integration of knowledge about the relations between the requirements and the code into the actual version of the system could improve the process of searching for the „what“ and „how“ when it comes to the need for fast and successful creation of a new version of the system. Especially, when it comes to self-modifications. In this case, requirements are the most important factor to be taken into consideration as we also state in [3].

II. The core idea

As presented above, the main problem to store knowledge into the knowledge base of an autonomic manager is what knowledge to use and how. Considering the variety of self-* systems architectures, the problem is not trivial. One needs to define adaptation policies mainly based on symptoms recognized in system behavior. All these policies should know about the system architecture, i.e. topology. We are extending this list by requirements. Requirements, because we think that without the knowledge about the aim of the system any automated computing is useless and, in the worst scenario, it could turn from a self-healing system into a self-willing one.

The second part of the approach focuses on the easy adoption of the process into different software development methods. The ideal case would be to identify existing development steps and assign knowledge acquisition procedures to them, which would mean that adoption is equal to using one more plugin in the preferred software engineering tool.

A. How to get knowledge from user stories into the knowledge base?

Knowledge stored in user stories is distributed between the story card and acceptance criteria. More precisely, we have very clearly located sources of data, which have to be transformed into knowledge. According to the knowledge pyramid [4, 5], to achieve the level ´knowledge´ through `information' we could process these data manually or in an automated way as we present in Fig. 1. Automated processing could create policy rules from acceptance criteria, because there are specific values that could be processed by an algorithm. One needs to de ne a structure for them - data transformation with xed ruleset. The remaining knowledge needs manual supervision resp. definition. During development, developers create different models including ones for requirement expression. These models could be directly included as knowledge. Data in requirements tracking tools are also relevant knowledge, which are created semi-manually. The mentioned data with a little extension that expresses relations between manually and automatically extracted knowledge represent requirement knowledge.

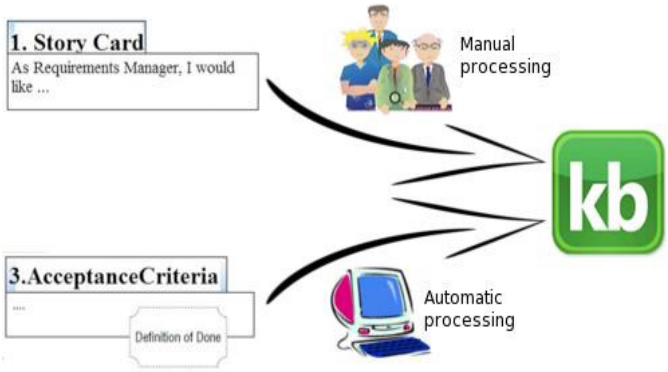

Figure 1 Knowledge extraction from user stories.

B. How to use it?

In the MAPE (monitor, analyze, plan, execute) architecture of the autonomic manager [6], we assign the most important role to requirements knowledge in the monitor and execute phases.

Monitor is checking the system behavior against acceptance criteria. Requirements also determine level of acceptance, therefore these knowledge are required for a good performance and quality service of the monitor. It is still recommended to deduce other symptoms and sub-symptoms for the monitor, but the majority of the symptoms is located inside the user stories.

In the analyzer, rule inference is emphasized. This part of the autonomic manager does not differentiate between kinds of knowledge. Analysis of relevant symptoms is more or less a filter, which is aimed to identify required actions.

During planning, these actions are evaluated against acceptance criteria as well to achieve a better system, which is aimed to be `closer' to these criteria. Again, it is easier to use the criteria included with the user stories as well as the story card and the scenarios to guard the system before behavioral failures[8].

Execution is the phase of MAPE, where changes are provided (or no action, if the plan is empty for some reasons) into the system. Here, an evaluation part is also needed if it comes to automatic change in the architecture or code/implementation of the system. I.e. the new `self-healed' system could be deployed only after a self-testing activity. Model-based testing (MBT), which is used in self-testing to make available the above mentioned changes, relies on a well-formed requirements representation - user stories provide almost all information needed to build the required knowledge for MBT.

To conclude, building the knowledge base of the autonomic managers should be based on requirements representation, more precisely on user stories, because these are short and simple. The previously mentioned properties are significant in current requirement elicitation techniques of modern software development methods.

III. Conclusion and Future Work

To conclude our results, we defined in this paper one new term: requirement knowledge.

Requirement knowledge: is knowledge located in user stories. It is distributed between its visible parts: story card and acceptance criteria. By their nature, acceptance criteria could be processed automatically, while story cards (scenarios etc.) need further refinement until implementation. The refinement process produces the remaining part of knowledge. Automatic or semi-automatic collection of these knowledge could be implemented using requirements tracking tools.

One could say that requirement knowledge is the same as project knowledge [7], but obviously there is a difference: project knowledge does not include user stories; and requirement knowledge does not consider methodology-related information.

Requirement knowledge could be used within the knowledge base of autonomic managers of self-* systems. We also presented our vision of this usage. Implementation prototype should be the next. For different systems, such as the classical DVD store and an information system supporting university teachers in education.

Possible significant problems could occur with the adoption of internal representation to the existing architectures of self-* systems. But only to those, which use their internal formats; XML-based representation represents a technical problem of a second transformation only.

Our future work will focus on self-* system prototyping with a tracking of user story data to recover knowledge originated in these user stories and used in different phases of development. Acquisition of related architectural knowledge will be also important. Finally, a user story tracking system will be designed to generate XML data representing requirements knowledge - directly includable into autonomic managers.

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Use and Characteristics of Medical Data Mining Methods

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***Abstract*— Hidden information and knowledge which are not obvious at the first glance might be discovered from the data saved in the databases using the data mining methods. This knowledge is highly significant and important in the medical field, as it may assist in doctors 'decision making during the critical situations. This article provides state of the art analysis of the medical data mining. The main part of the article is focused on the overview of the techniques and methods of the medical data mining. The methods described were categorized into the following basic groups: Classification, Regression, Clustering, Association Rules and Optimal Cut-off Values. The most often used algorithms were selected for the methods above and their practical research use was referred to.**

***Keywords*—medical data mining, characteristics of medical data, methods of data mining**

I. Introduction

Data mining is one of the most substantial and highly motivated scientific fields in terms of identifying and discovering new and unrecognized knowledge based on the available data of different kinds and extent. Nowadays there are several different methods and techniques in place to assist in discovery of hidden knowledge in various application fields, such as telecommunication, banking and capital markets, finance or medicine [1]. Due to complexity and sophistication within the medical field, it is often necessary to consult and cooperate with the domain expert (the doctor). It is also essential to keep concentrated on a single disease rather than analyzing several disease types at the same time. The traditional medical disease diagnostics process is repeatedly very difficult and time consuming. Foremost, the doctor needs to gather required information and the patients 'examination results and based on these to stipulate the decision in relation to the diagnosis and further appropriate medical procedures [2]. Eventually, the amount of the data increases and this is where the data mining methods can be used to accelerate the process and also assist doctors in decision making during the critical situations.

The second chapter of the article is devoted to the basic medical data description and characteristics. In addition, the typical issues in medical data processing as well as their distinction from other fields' data are covered here.

The basic methods and techniques of the data mining adjusted for the needs of the medical data field are the core topic of the third chapter.

II. Medical Data

The usefulness of the knowledge discovered from the databases using the data mining methods is dictated not only by the data quality, but also by many other factors. If irrelevant, excessive or redundant data are available, obtaining useful knowledge is much more complicated and sometimes impossible [3] [4]. The next part is focused on the typical medical data characteristics.

A. Redundancy

Medical records of individual patients are multiplying daily, therefore entries might repeat themselves or even contradict over time. The typical model are the databases using single table which includes the attributes about the disease type, examination results, patients' symptoms or medical procedures undertaken.

B. Complexity

Complexity is the typical characteristic of the medical data, given these can be recorded in various forms. The most convenient form for applying the data mining methods are the pure structured data (tests results, parameter values). However, other forms used are pictures (SPECT), signals (ECG) or plain text (written patient's record, diagnosis detection represented by plain text, symptoms description).

C. Privacy

Medical data contain significant amount of sensitive information regarding the individuals, who do not necessarily agree to disclose these to public. Researchers hence need to conduct the medical data mining in a way to ensure the patients' anonymity and privacy. In recent years, breaches of safety and privacy were detected in some hospitals and local surgeries. The stolen data can be used in some cases to pay invoices for the medical treatment on behalf of other person. Also present is a dispute of individuals and organizations over the information technologies used in health care, as these may constitute the opportunity for undesirable disclosure of patients' health.

D. Missing Values

The main function of the data mining is identifying appropriate and regular patterns for individual diseases. The main objective of the medical staff is to gather as much relevant information as possible in relation to the patients 'health to be able to diagnose the disease and provide for the accurate treatment. Therefore medical staff do not primarily focus on

processing and recording the information in a fashion it could further be analyzed. This is the reason why the collected data are often incomplete. The human factor might as well cause the errors and the deficiencies in the patients' records. Also some expressions and abbreviations used by the medical staff could be assessed as unclear. Eventually, it is important to note, individual patient's records cannot contain the information for all the types of diseases.

III. Medical Data Mining

Data mining methods [5] occur in various medical domains and are mainly used to support the medical staff decision making. The next part describes the most substantial methods of medical data analysis, such as clustering, classification, association rules and some others. These are currently used across diverse health care organizations in order to optimize the health care provided.

A. Classification

Particular attribute is generally identified in the patients' database, which is monitored due to its significance and it is desired to predict this attribute in newly collected data. The value of the attribute is used as the resulting target class. The attribute can be expressed as a nominal value (high, medium, low) or a binary value (yes, no). In order to assess the precision of the classification, the data need to be subdivided into the training and testing sets, alternatively the validation set may be required for the algorithm's parameters optimization. The training set is used to learn the model to classify the target class of the data available. The testing set serves to compare the known results and the variables obtained using the learned model in order to objectively evaluate the precision of the learned model. Classification, as one of the data mining methods, was used in many researches conducted. One of these is the skin disease diagnostics using basic and weighted kNN classifier [6]. Several different classification algorithms are used in the medical field, such as: Decision Trees, K-Nearest Neighbours, Naive Bayes Classifier and many others.

1) Decision Tree

Decision tree modeling is generally very popular data mining method within the medical field, but also across other areas. The method is characterized predominantly by the uncomplicated output (decision tree), which is simple to understand. The user, who is making the decision is not required to have informatics expertise. The decision tree usually has graphical form, consisting of intermediate nodes (attribute test), branches (intermediate nodes outcome) and leaf nodes (target class) [7]. The typical decision tree [8] implementation is the patients' classification based on the severity and the disease stage, e.g. breast cancer.

2) K-Nearest Neighbours

The basic principle of the method stands in the fact that records within the training set have *n* attributes and each record is then represented as a point in the *n*-dimensional space. When target attribute is to be identified in the new record, the most similar samples are looked up by classifier within the training set space. The similarity of two records is calculated based on their distance within the *n*-dimensional space. Ultimately, the target attribute value is assigned to the new record, based on the prevalent occurrence of the class value among k-nearest neighbours. This data mining method was used in the research, whereby authors were looking to classify chronic diseases in order to create the early warning system and avoid potential complications [9]. The correlation between high blood pressure, cardiovascular diseases and their risk factors were analyzed in the referenced paper.

3) Naive Bayes Classifier

The classifier contains the word naive 'in the name due to the fact that it assumes mutual independence between the attributes. This constitutes the situation, where the effect of each attribute towards the target class is not impacted by any other data attributes. The derived probabilities of a new record placement into particular target classes are considered as the result. The medical field however suggests mutual attributes interdependence – for instance, patients' symptoms correlate with their overall health condition. Therefore Naive Bayes Classifier might be considered less practical in medical data mining. There are several instances though, where independent data are available, or the data mutual correlation is very low. In these cases excellent results were obtained using this classification method. Naive Bayes Classifier was used in the research [10] to classify the swine flu patients into one of the groups based on probability (remote, possible, probable). 110 disease symptoms (attributes) were available altogether, out of which 17 attributes were selected as most relevant with the rate of classifier success of 63.33%.

B. Regression

Regression method [5] employs the training set in order to create the mathematical model, which is expressed by function (generally, linear function) to describe the relation between given variables. Regression output function contains dependent variable (can be just one) and independent variable (can be one or more). This function can be used to predict the values of dependent variable based on the known inputs of the independent variable or variables. There are more types of regression widely used, refer below for the descriptions of the types most frequently applied.

Linear function finding the approximation line in a way to minimize the error between the line and the actual data is used to build the **linear regression** model. Individual function coefficients are calculated by the least squares method. In case of employing several independent variables in order to predict the dependent variable, **multiple regression** model is used.

Logistic regression is a regression model where the dependent variable is categorical. The variables must thus be translated into numerical values. The typical instance is where categorical variable of yes/no classes is translated into the values of 1/0. The outcome of this method is the probability prediction of the record within the target class. There is further subdivision of logistic regression:

- *Binary regression* – target attribute only contains two potential classes, for instance alive/dead, or yes/no.
- *Multinomial regression* – model used to predict probabilities of different possible outcomes of a categorically distributed dependent variable, for instance low/medium/high risk.

The paper [11] applied binary regression model in order to identify the probability of heart disease occurrence. The outcomes of binary regression model were set side by side with the outcomes of the decision tree method and the neural network method.

Conventional linear and logistic regression models might seem inadequate in the medical field, given the target class levels need to be clearly identified (low/medium/high risk). These values however are not unambiguously defined and thus discrepancies might be encountered in respect of different health care providers' outcome attributes. Therefore survival

models / proportional hazards models were introduced to increase the data mining efficiency in the medical field. These are used for probability prediction in relation to the event occurrence for each patient. Predictions obtained using survival models provide for better comprehension of given situation, given they account for expected probability. In return, specific and targeted treatment is provided to patients.

The most commonly used regression type among survival models is **Cox Regression** [12]. Using Cox Regression can create the model representing comprehensive information regarding the relation between the risk function and the predictors used. The main function of the model is to recognize the effects of several variables on patients' survival. Due to its relative simplicity and significant popularity among the users, Cox Regression was implemented in various statistical software (such as SAS, SPSS or STATA). Implementing this specific regression type in the medical field can assist in isolating patients' treatment responses from other variables responses.

Cox Regression model was used in the research [13], where different reactions of people working in hot and damp environment were monitored. These conditions were assumed to be harmful for the employees causing their productivity to decline. Physiological parameters such as the internal temperature, the blood pressure and the heart frequency were monitored in the sample. The parameters' limits for the above indicators needed to be defined in order to ensure the workers' safety. The research outcome stipulated the general survival and risk functions curves, which determined the safe working times in the hot and damp environment.

C. Clustering

Unlike the classification, clustering [14] is the method of the uncontrolled learning, because the target attribute classes are not predefined. Individual data points available are clustered into the clusters based on the degree of similarity among the points. Objects assigned into one individual cluster are more similar compared to the objects derived from two different clusters. Also, it is anticipated for the objects derived from various clusters to be as distinct as possible.

Since the target attribute is not defined within this method, users can elect finite number of clusters. The next section deals with the clustering algorithms most frequently used in the medical field.

1) Partitioned Clustering

When using partitioned clustering method [5], the data comprising the objects are distributed over K-classes or groups called clusters. There is a presumption, that each object can only be included into one cluster. The quantity of the clusters needs to be defined before the actual data distribution. There are two versions which both attempt to minimize the distance between points labeled to be in a cluster and a point designated as the center of that cluster: K-means and K-medoids.

K-means clustering aims to partition *n* objects into *k* clusters in which each object belongs to the cluster with the nearest mean, serving as a prototype of the cluster. The procedure follows a simple way to classify a given data set through a certain number of clusters fixed a priori. The main concept is to define *k* centroids, one for each cluster. These should be placed in a suitable way, since different location causes different result. The next step is to take each object belonging to the data set and associate it to the nearest centroid.

Another variation of this method is K-medoids, where medoid is the object centrally placed in the data, which least differs from all other objects. Every cluster is assigned its medoid first, with the most similar objects being assigned subsequently.

In the paper [15], clustering as the data mining method was implemented on data about people, whose health is affected by drinking water containing high volume of fluoride. Various risk factors were to be identified and, using clustering method, hidden patterns were to be determined in order to assist in the decision making process.

2) Hierarchical Clustering

The most remarkable advantage of hierarchical clustering is the fact that it is not necessary to define the number of clusters in advance. Individual objects are assigned into clusters using two alternative approaches: agglomerative and divisive methods [16]. The agglomerative method builds the hierarchy from the individual elements by progressively merging clusters. It is defined as ‚bottom up' approach, where each object starts in its own cluster, and pairs of clusters are merged as one moves up the hierarchy. The divisive variant of hierarchical clustering is also called ‚top down' approach, where all objects start in one cluster. This cluster is split using a flat clustering algorithm and the procedure is applied recursively until each object is in its own singleton cluster.

The research [17] applied hierarchical clustering in order to classify the patients into clusters based on the amount of days spent in the hospital. Having this piece of information, the health care providers are in a better position to make decisions in relation to the resources' utilization.

3) Density Based Clustering

The main distinguishing feature of density based clustering is its ability to partition the objects into clusters of different shapes, whereas the methods described earlier can only be used to partition the objects into circle-shaped clusters. Generally, if a particular object is situated in a sparsely populated data points region, it is deemed noise, error or marginal point. The most frequently used algorithm of the method concerned is DBSCAN, which groups together points that are closely packed together, marking as outliers points that lie alone in low-density regions. From this point of view, clustering is completed, once no more objects can be assigned into particular cluster [18]. Practically, the above method can be implemented for identifying different colors in graphic data. Using analytical skills, healthy and unhealthy regions can be graphically identified (for instance, skin coloration).

D. Association Rules

Critical relationships and patterns in the extensive amount of data can be determined using association rules. The indicators, which measure quality and interestingness of discovered association rules are support, reliability and Lift. Typical application of this method is the market basket analysis in the following fashion: If the customer purchases product 1, the probability of purchasing product 2 is high. There is an extremely wide use of association rules in the medical field too, whereby different relations between the diseases and the drugs' use can be determined. APRIORI algorithm [5] is employed in the method searching the association rules satisfying the minimum support and reliability condition. The research [19] conducted the heart disease prediction using APRIORI algorithm with the redundant rules being subsequently eliminated. Moreover, irrelevant association rules were detected, which aids to only retain the rules with the high degree of certainty.

E. Optimal Cut-off Values

This method is used in medical field very often. It is focused on the target attribute description in a way to be most efficiently used in prediction. The method outcome is specific numerical value or interval identifying high degree of risk for a patient. The publication [20] emphasizes the unhealthy lifestyle among children population. Limits for individual attributes were to be determined in order to identify the obesity risk. The example outcome of the method is cut-off value of two fast-food meals per week per child. The cut-off value interprets that two and more fast-food meals per week per child lead to a high obesity risk.

IV. Future Work

As previously discussed, obtaining the data from medical field might seem rather demanding because of the data being sensitive and protected. Thus cooperation with medical staff is frequently required, whereby the data regarding private patients' information is removed. In addition, the doctors may assist in better understanding of the medical data, because background knowledge in this field is also necessary.

It is our objective for the foreseeable future research to propose a methodology for selection of suitable data mining methods for a medical subdomain and verify it on given data sets. Our methodology will select the most suitable methods for the medical data analysis based on their type and characteristics, in order to arrive at influential conclusions. The models and the knowledge obtained should aid the doctors in their decision making process and provide for better health care. The data analysis is to be conducted using the R programming language, combining the features of IBM SPSS Statistics software. The obtained models, rules and conclusions will also be published in form of RShiny web application providing an interactive user interface. Using this application may assist the medical staff in easier comprehension and real life application of potential outcomes. The following research will be focused on the analysis of Parkinson´s disease, according to the recorded speech signal.

V. Conclusion

The amount of data available to obtain useful knowledge from it, by employing appropriate data mining methods is increasing on a daily basis. The most significant issue within the medical data field is to gather suitable data for further analysis. In order to ensure higher efficiency and gathering larger amount of data, it is necessary to improve the data sharing among the analysts. There are many restrictions and limitations among the researchers and the health care organizations that ought to be overcome. With the increased use of the Internet, the data became readily available to some extent (either text or spreadsheet format). Notwithstanding the fact that there are numerous data mining methods and techniques available to be implemented for the medical data, there is undoubtedly notable space for their improvement in order to obtain more efficient and useful solutions.

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Virtual reality technologies as a tool for people with special needs

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***Abstract*—In recent years, a virtual reality comes with more use in the world. It appears newer, cheaper and more effective solution that is open to new possibilities. A virtual reality has thus become not only a source of entertainment but also a helping tool in a variety of diseases, phobias, training or for people with special needs.**

***Keywords*—handicapped people, motor skills, physical education, training, virtual reality**

I. Introduction

As technology constantly advance in progress for various areas of life, people have begun to examine their current and future potential as well it creates impact on society. Many inventions help people to be better connected with the world, help at work or becomes part of everyday life. One of such a technology is the virtual reality (VR). The gradual development of this technology, more and more evidence of man immersed in a virtual world. It is opening up further possibilities for use, whether for economic or ergonomic of view [1]. It can be seen for example for helping disabled people, people with different types of phobia or different training system based on close motor skill. Recent technology also opens up another dimension to education and understanding things which normally can not be seen (such as gravity, convection and wind direction). Each VR system endeavors to focus on engaging the senses as much as possible and therefore is mostly made up of several components. Sometimes, it is not a cheap solution (eg. Cave Automatic Virtual Environment - CAVE) but sometimes it is (Oculus Rift, KPI-CGRS). Therefore, always take into account the type of use and for whom the VR system is intended (for example, disabled who do not have sufficient funds).

The purpose of this article is to examine the issue of virtual reality and identify opportunities for its use. The article is divided into four parts. The first part is focused on the current state of VR technology and available solutions. The second part describes possible uses and benefits of using VR technology. The third part discuss the motivation for the use on VR. The last part describes the possible future directions and use of virtual reality.

II. Current state of virtual reality

Field of virtual reality (VR) and computer graphics are a very current research topic. That is especially true for the field of Human Computer Interaction (HCI) [1], where they represent a significant step forward in the development of natural user interfaces.

The main goal of VR systems is fully immersed user into the virtual environment. Immersion is not only one important factor. To achieve the best VR system is needed to also follow the other principles such as interaction and presence [1], which allows involvement of other senses. According to Zeltzer [2], interaction is "the degree to which virtual environment parameters can be modified at runtime" (p. 128).

Jennett et al. [3] well defined concept of immersion by playing games where the player himself losing track of time, as well as the real world thus having the feeling of "being" in the task environment. In other words it is a perception of being physically present in non-physical world.

Currently, there are many tools supporting immersive VR approach and one example is the Cave Automatic Virtual Environment (CAVE). It is a room where all walls, as well as the floor and ceiling are projection screens or flat displays. With the 3D projection and 3D glasses user feels floating in the projected world where he can move around freely. Human motion capture is possible with the camera (e.g. OptiTrack). Mark (1 a)) may be affixed to the 3D glasses which can display the scene in the correct viewing angle for an observer. This enables e.g. down movement really look under the table.

Partial use of this technology can be seen in Cultural Heritage education [4]. Kenyon presents a new high resolution CAVE [5] while Leigh et al. describe a cylinder based CAVE [6].

Nan et al. study an alternative interface based on hand movement to be used in a CAVE system for design [7]. Hand interactions are triggered based on the real-time positions of the markers worn on the hands of the user (1).

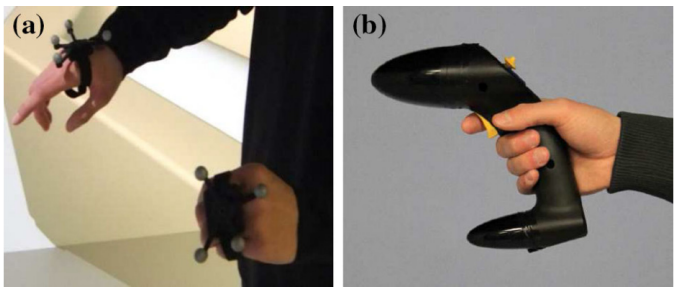

Fig. 1. Two interaction techniques: a) hand interactions via markers, and b) wand interactions [7]

The hand interactions in vDesign are classified into menu

navigation and object manipulations.

Thus, the system shows a new type of user interface. For menu navigation, we define two interactions:

- activating the main menu and
- selecting a menu item.

For object manipulations, we define three interactions:

- moving object;
- rotating object and
- scaling object.

With the hand interactions authors develop image segmentation and image composition functions in vDesign. In the image segmentation, the user can use the right hand to select the interested object and the left hand to select the unrelated background. Based on the user's selection, a graph-cut based image segmentation is performed to extract the interested objects from images. In the image composition, the user can manipulate the segmented objects with hands and then combine them together into a final image. The experimental results shows that the proposed hand interactions can provide faster and more accurate interactions compared to the traditional wand interactions Actually, in our LIRKIS laboratory we have also created such cylinder based CAVE [1] consist of 3D LCD panels distributed along the sides as well as the top and bottom sides as on the (2).

Fig. 2. Virtual cave prototype for LIRKIS laboratory

Next example of this VR system, shows in (3), is Head Mounted Display (HMD). This technological device is not widely spread, because of its price and often cause inconsistency between movements of the head and corresponding scene. Now, the commercial product Oculus Rift offers a good virtual simulation with an accessible price while other affordable products are developed [8], making the use of such systems more feasible also in the fields of education and training.

III. POSSIBLE USAGE OF VIRTUAL REALITY

Big interested about VR and creation of different concepts and products opens up opportunities for special applications whether in health care, movement training, simulations, presentations, etc.

In United States of America, the annual prevalence of people with anxiety disorders approximately 18% [10].

Fig. 3. Head Mounted Display (HMD)[9]

Anxiety disorders include separation anxiety disorder, specific phobias, social anxiety disorder, panic disorder, agoraphobia, generalized anxiety disorder, obsessive compulsive disorder (OCD), posttraumatic stress disorder (PTSD), substance/medication induced anxiety disorder, anxiety disorder due to another medical condition and other specified anxiety disorders. A Common treatment for anxiety disorders is cognitive behavioral therapy, in which patients are exposed to anxiety-provoking situations, generally in real life or through imaginal exposure where patients are asked to imagine a situation they are afraid of. In the last two decades, exposure treatment has also been offered through virtual reality, referred to as Virtual Reality Exposure Therapy (VRET) [11].

Therefore in [12] is focused on meta - analysis exploring the relation between self-reported presence and anxiety during virtual reality exposure therapy for anxiety disorders. The results shows that self-reported presence and anxiety are associated with each other during VRET. Nevertheless, the exception has occurred in social phobia, where no correlation was found. Due to confirm VRET effects on anxiety, one could assess the current demonstration of presence do not capture the essential sense of presence that is responsible for activating fear related to social anxiety in individuals.

Slater in his publication [13] also argued that presence at least has two independent components that contribute to realistic responses in VR:

- *place illusion* - feeling of being in the virtual environment and
- *plausibility* - illusion that what is happening in the virtual world is really happening in spite of the knowledge that it is mediated technology.

In 2009 Fink Foot and Waren [14] conducted a study to open motor skill using VR technology to baseball outfielders who sholud decide where to run between defenders to catch a flying ball. VR environment was projected for 16 different samples. The results shows 50% success rate in chatching the ball. In 2010 [15], a similar study was carried out for baseball outfielders, but using CAVE VR system. Percentage increased to 80%. However, these results did not demonstrate reality of the player's skill. Therefore, futher study [16] of pay was concluded:

"An experiment in which participants run to catch real balls, in a real environment, which has real variability in conditions (think of effects of wind, lighting, more complex feedback), obviously has more ecological validity than an experiment in

even the most advanced VR setup."

Based on this findings a study was conducted focused not only on motor skills, but also the educational impact VR technologies. Under certain conditions with the special students, VR may be used as tool for learning physical activity. This study also reports that students can be highly effective in providing information, which normally can not see (e.g. gravity, flow and wind direction, etc.).

VR systems also has it uses in training system which is shown in the research [17], aimed to training ballet dance through VR based on MS Kinect and visualization in CAVE. This was not however the focus on classical ballet dance, which is based on distinct aesthetic ideals, but ballet dance where there is required technically precise movements and dance creations (e.g. six basic positions). The purposed system consist of 4 components (Kinect motion capture, CAVE, gesture recognition, and gesture database) enables the student to determine its skills and weaknesses and evaluate them directly in a virtual environment. These results allow students to adapt and improve dance moves during an training session (4).

Fig. 4. Illustration of the fifth ballet position with overlay feedback [17]

Another effective way of using VR technologies is captured in article [18], targeted primarily at people with multiple handicaps, in particular at deaf-mute persons. The authors try to use the cheapest solution relative to economic situation of people with disabilities, specially on sign language. They use MS Kinekt sensor [19] and desktop application KPI-CGRS (5) as gesture recogition software. It is based on the Skeletal tracking [20], which is feature of the MS Kinect sensor. This process has one significant disadvantage that it can recognize only movements of arms, but not fingers. This could be eliminated by supplemented of further sensor. Authors also had intended to use the data glove, but it proved to be too uncomfortable for people with multiple handicaps.

A good overview and use of VR is written in [21]. There are also highlights usability of VR systems and benefits of HMDs for students, where increase attention through virtual image class.

Currently, in the market there is chepaer and more praktical product of HMD known as the Oculus Rift. There was conducted a study [22] that looked at the potential of this device in reducing pain in burn people. Their results showing reductions in pain intensity and pain unpleasantness, during the

Fig. 5. Contactless gesture recognition tool in recognition mode (screenshot) [18]

20 minutes of occupational therapy skin stretching exercises using a pair of VR goggles (6). Patients have reported even more fun during physical therapy with the use of goggles than without it. According to the mentioned authors above, the Oculus Rift VR goggles deserve more attention than the potential treatment for acute procedural pain of burn patients.

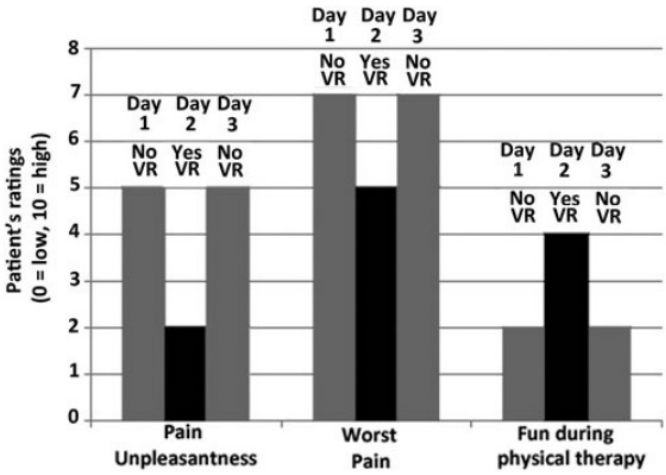

Fig. 6. Pain during passive range of motion exercises during no VR, (gray bars) vs. pain during the same exercises while in VR (black bar) [22]

IV. Motivations for the use of VR

From the reading of the papers, as we have seen, we argue that the main motivation for VR use is that it gives the opportunity to live and experiment those situations that "cannot be accessed physically". According to [23] this limit may be due to different kinds of reasons:

- *time problems* - travelling in time allows students to experiment different historical periods [24];
- *physical inaccessibility* - e.g. exploring the solar system by freely moving around planets [25];
- *limits due to a dangerous situation* - for example training fire fighters on the decision making process in a situation in which the physical and psychological stresses are analogous to live firefighting situations [26] and
- *ethic problems* - for example, performing a serious surgery by non-experts as is the case with neurosurgery [27].

V. Conclusion

Utilization of VR technologies is still very popular research topic. It is shown by the continuous development of new technologies and possibilities. VR technology has been applied in various areas of life (education, training systems, rehabilitation, therapy, etc.). Research shows that the using VR goggles were able to help patients with burns and use them alleviate pain during therapy.

Therefore it proves that it makes sense to study this theme. It covers a broad spectrum of application which should be be narrowed down and just to focus at a certain part. Based on the research one can say that in the case of training needs to make sense to address that topic. It is for a close motor skill only, because they are skills that are not influenced by external environment and other factors. VR can thus e.g. learn dance technique that requires good posture. Techniques you learned can be applied to real life with no problem. Within therapies and various phobias by VR applications systems might help early discover originator of fear, eventually get rid of some fear (e.g. fear of heights). Studies have also shown that the fear of public speaking while using VR has no effect because that requires phobia plausibility. The patient would have to believe that what is happening in the environment is really happening.

The decisive factor is the price of Velcro technology. It is evident from the Cave Automatic Virtual Environment (CAVE) systems and similar matters are better dealt for organizations than for individuals. This is not something that always cheap technology can not help. An example is a solution for deaf mutes, where using MS Kinect and software KPI-CGRS, which enables to capture hand gestures. In case of further enlargement of the technology could detect the fingers and thereby distinguish sign language.

The University of Prešov (Slovakia) has a Department of Special Education dealing with pedagogy for people with disabilities. Therefore we could apply and create a VR technology directly for them. Relative to organisation greatness would not have a problem with affordability. A CAVE system which we have in our laboratory could be therefore applicable. Disadvantage is that the children with different types of disability have different special educational methods. Therefore, in this case it would be needed to cooperate directly with them, consult different ideas and based on that we would be able find the most effective solutions.

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Visual and Non-visual Means in the Extraction of Anthropometric Parameters

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***Abstract*—In this paper the extraction of anthropometric parameters is presented. Such extraction is focused on two main areas – visual and non-visual. The first presumes the utilization of image processing algorithms and is working primary with the single image, both calibrated and uncalibrated image is considered. The latter presumes the design and deployment of a hardware prototype for the measurement of anthropometric parameters. The greatest advantage being the accuracy of extracted parameters that may be further used for comparison with the visual approach. The partial results of the researches are presented and future goals are following the outputs of the prior works creating the overall framework for the extraction of these parameters having as a main goal the smallest error in the measurement process.**

***Keywords*—anthropometry, dimensions, image processing, hardware meter, size estimation.**

I. Introduction

Conventional measurement is easy concept to handle. Various types of tools may be utilized in the measurement process. However once we presume the more complex conditions of measurement, such as measuring the circumference or distances between two independent nodes the whole idea becomes more difficult. There are many approaches and ways of measuring, however what we focus on in our research is the measurement of a human body. The field that is directly involved in such measurement is referred to as anthropometry. Static anthropometrical measurements are to be considered. Specifically we focus on the design and deployment of information tools in the extraction of the lengths of human body parts. Two principal approaches are being taken into the consideration - the visual and non-visual.

Visual approach is presuming the utilization of image processing algorithms. The complex framework for measurement is to be created and tested following the proposed methodology, i.e. combination of existing algorithms and development of new. Only the static image is considered, both calibrated and uncalibrated image. Visual approach also includes the utilization of depth camera.

Non-visual approach includes creation of hardware device for direct, contact measurement. The goal is to extract exact dimensions for the later comparison with the extracted visual data. Another subsequent goal is the development of skeletal human body model with precise dimensions.

II. Initial Status of Research Task

Research in the area of extraction of visual anthropometric parameters from uncalibrated image included in prior researches only the height estimation [1]. We focus on the extraction of multiple anthropometric parameters via creation of skeletal human body model mapped to the image. Several other approaches are being considered as well, such as ratios of known objects [2] or selective input from the real scene. Another approach is implementation of known dimensions of known objects in the image [3].

Research also focuses on the deployment of prior non-technical approaches [4] that were considered as relevant due extensive mathematic background. This includes the estimation of vanishing point and vanishing lines. Further, known anthropometric relations, such as the presence of the PI in the human body is utilized as an aid in the estimation process.

No other researches that focus on the extraction of anthropometric parameters by developed electronic hardware device were found. Hence the prototype hardware is to be developed using own unique and innovative approach. Goal of such prototype is the creation of skeletal human body model.

III. Partial Results

In the following section are presented the partial results of the research regarding both, visual and non-visual approach. Further published and submitted researches related to the topic are presented.

A. *Visual-based approach*

Extraction of information from uncalibrated single image is a complex task. We proposed estimation of dimensional parameters, e.g. of human person, providing we have sufficient information on the conditions in the process of the image shooting. This kind of information is in our case the height from which was the image shot. Following the proposed equations based on basic trigonometry rules we achieved the extraction of real dimensions. See the IEEE publication [5] by the author for further details on the topic. Note that research is still in the process, application enabling the automatic estimation of height via smartphone device is to be deployed in the months to come.

Another visual approach, yet to be published, is working with the ratios and known lengths. In this case we presumed

the uncalibrated image of a person in one plane, perspective distortion between camera and person is presumed to be the smallest or not present. The height of person and selected lengths or human body model are extracted from the image by the semiautomatic selection of head edges and known distance between the eyes. Subsequently the skeletal model is mapped to human body.

Analogous approach, having as a reference value the length of human eye is being tested on single uncalibrated image, in this case only the height is the object of the interested. Further the approach is to be extended by the combination of several reference values, e.g. also distance between the eyes. Also several selected anthropometric parameters will be considered. Results seem promising, with the error in height of 1 to 3 centimeters.

Extraction of lengths in the calibrated image was also considered and shows the extracted values to be of high accuracy, providing the distance of the pattern in one plane is kept. Scene is calibrated with predefined calibration pattern. Approach has not yet been tested on the estimation of anthropometric parameters.

The previously mentioned non-technical approach to extraction of lengths from the uncalibrated image with one known length in the picture is being deployed and tested. This includes the correction of perspective distortion and estimation of both, vanishing point and vanishing line. Results of this approach are yet to be published.

Depth camera has been also utilized as tool for the lengths extraction. Kinect 360 and Kinect for Xbox One was tested and proved successful in the mapping of skeletal model with subsequent extraction of selected lengths, so far height and limbs lengths were extracted. The overall comparison to other approaches is yet to be done. Another comparison of both Kinect devices is to be carried out.

B. Anthropometer

Principal idea of anthropometer is the proposal of a device for the measurement of a human body part by direct contact. This presumes the utilization of the tape meter. The circumference of articulations (or nodes) are to be estimated except for the distances be between the articulations e.g. from knee to ankle. Measurement is to follow conventional anthropometric measurements in order to achieve high accuracy. Hardware prototype device was created and tested on sample of twenty persons with very promising results. Hardware for the development include optical sensor, traditionally used in the pointing devices, this sensor was adjusted and utilized along with conventional tape meter to allow measurement of the circumference and lengths as well. The outputs of this research are yet to be published.

Related to visual and non-visual means, the interface for collecting of anthropometric data was created and implemented, having as a goal the comparison of such data with subsequent correlation analysis. Data may be input also by the external user.

C. Other Areas of Research

Part of the research not directly related to the above stated was focused on tracking of the hand by created hardware device that enables the reading of surface electromyography signal. Signal is not only processed but also recognized by the Support Vector Machine. The outputs of this research are to be published in the upcoming months.

Another focus of the research is the enhancement of the educational process related to the computer network courses. Few publications by the author were presented, primarily regarding the enhancement in these courses. Specific methodology to enhance the educational process was published in [6].

IV. Future Research

The overall idea of research is the extraction of lengths related to the human body, i.e. field of the anthropometry. The extracted data and proposed approaches may be used in several areas – security, demographic statistics, 3D modeling. Information of the height and length of selected parameters may be useful in the identification of person and may be used as an aid in the whole identification process. Combination of above described approaches is to be yet the goal of future research. Other goals are the following:

- Extend the functionality of prototype hardware device.
- Propose approach that is to enable the creation of a skeletal human body model with precise dimensions using the smartphone device.
- Propose descriptive language for human body parameters and implement is as a part of the prototype hardware device.
- Test, describe and evaluate selected approaches on the larger group of samples.
- Propose a framework for the visual extraction of anthropometric parameters from the uncalibrated image.

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Visual similarities in workflow correctness check

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***Abstract*— The main aim of this paper is to summarize the last year of experiments in the area of optical similarity. The main aim was placed on workflow correctness analysis and camera pose estimation. We are using only visually captured data from video camera. The main focal point was placed on comparison of the image histograms (Bhattacharyya coefficient). All used cameras were mounted on users head's. Our test consists of three videos. The first video is capturing the correct workflow. The second video is capturing the correct workflow from different field of view. Finally the third video is capturing the incorrect workflow. Our evaluations says, that the correctness check using only histograms comparison is usable only in varied scenes. Environments with not enough color and gradient diversity reports unsatisfying results.**

***Keywords*— histograms, image similarities, workflow correctness check, model design, Bhattacharyya coefficient.**

I. Introduction

The correctness of workflow (working process) is in many sides of life the main objective to finalize the entire working processes correctly. The key role plays the used resources and total expenses. Therefore the real-time process check plays the main key role. This can be done with manual corrections and observations. Another way is to use an automatized system. Many automatic systems are based on step by step confirmations. They are using electronic user guides or identifications [2] in the workflow area / on the working parts. Our idea is to fully automate this system. This will be done by promoting it to the role of automatic director of the workflow. Whole system will be based on three main parts: camera captured video from user field of view, space determination markers in workspace and the evaluation unit. The last part can directly control the working tools (back propagation). The captured video is filtered to environmental noise and displays only the area markers and working tools. We were inspired by human orientation principle. It is used to determine the position in space. Based on this we designed the first experimental model for the camera pose estimation (or directly workflow correctness check). It is based on comparison of the histograms of image.

A. Discovered Principles for Optical Orientation

Our previous research depicted in [1] shows following facts. All results based on human orientation experiment made on 10 people. The two main and one hybrid optical in-space orientation principles has been discovered: Absolute orientation principle (based on surface patterns and space maps), Relative orientation principle (based on relative optical flow and history of movements) and finally the Hybrid orientation principle (based on mix of both previous).

II. Histograms as Correctness Evaluation Principle

Our approach for workflow process analysis is based on whole image content (as one entity). The main idea is to expressly achieve the camera position and the workflow correctness on one time. This will be done by building a system based on absolute orientation principle.

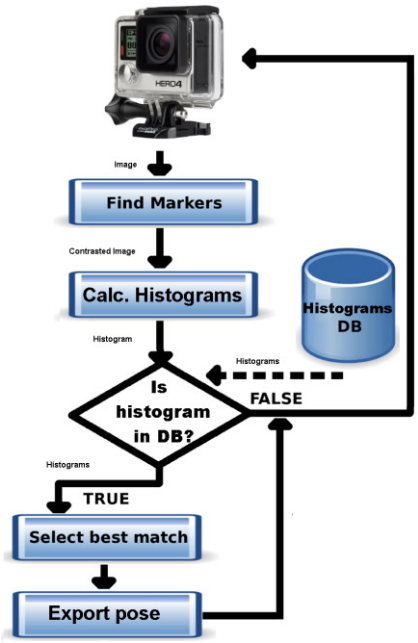

Fig. 1. The histogram based camera pose estimation model concept with database of histograms set. The evaluated pose is passed into the workflow evaluation algorithm.

Using image histograms we try to describe the actual camera view similarity with pre-trained view. Training data contains the known camera pose too.

A. Histogram pose estimation model explanation

We depicted our approach of pose estimation model based on absolute orientation principle in Fig.1. The image captured by the camera is moved into the filtration procedure. All environmental noises can be separated from area markers here. The filtered and contrasted image is send into the core process of histogram calculation. The Dataflow then contains only histogram results. The image data will be not father propagated. Our model using for workflow correctness check (camera pose estimation) the pre-trained histogram database.

Each good position in workflow is stored in DB with its unique ID and its histogram (captured from the camera view in correct time). The model core compares histograms from DB with histogram from *calc. histogram* process. The comparison is based on the Bhattacharyya distance metric (*d(H1,H2)*). This distance is defined by equation (1), where *H1* and *H2* are the histograms and *N* is the number of histogram bins.

$$d(H_1, H_2) = \sqrt{1 - \frac{1}{\sqrt{\bar{H}_1 \bar{H}_2 N^2}} \sum_I \sqrt{H_1(I) \cdot H_2(I)}} \quad (1)$$

If satisfactory set of histogram candidates is found, then the best match is selected. This candidate is used for calculation of the camera pose. It can be used to check the workflow correctness too. The correct histogram ID in the correct time is considered as the enough condition to determine the workflow correctness. In the case of camera pose estimation, the minimum of 4 workspace markers must be found in camera view. They are used to find the perspective transformation matrix from camera view to real world space.

B. *Evaluation of histogram-based model*

We tested the similarity difference (result "0" equals perfect similarity, result "1" absolute non-similarity) in two ways. The first way was to compare the five images similarity difference each other. User looks on to the same marker five times. Each time from the different field of view. The difference between the users views reach in some cases the value 0.4 (Fig. 2.). This represents the 40% of difference. Places with similarity difference 0 in Fig. 2. equals comparison of the image with itself.

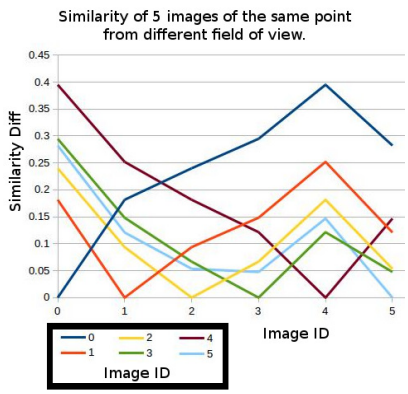

Fig. 2. The histogram similarity comparison (based on Bhattacharyya distance metric) of 5 different field of view images of the same point each other. Zero similarity diff equals comparison of the image with itself.

The second way is illustrated in Fig. 3. (The results of similarity difference). We made the tests on two videos. Video *V1* (reference video) capturing the correct workflow. Video *V2* (correct workflow video) capturing the correct workflow from different field of view. We selected the frame *731* (considered as view on correct state of workflow) from *V1* and compared it with V1 and V2.

The similarity differences of the frame *731 V1* with all frames from *V2 are depicted on* the Fig.3. The principal equivalent of *731 V1* is 962 *V2* (highlighted in red circle). The red circle highlights the frame, where is the camera view aimed at the same object (in the ideal case similarity must = 0). Discovered similarity of a few other frames in *V2* is in some cases better. This implicates the final conclusion - Our method is not completely deterministic in order to solve the correctness of workflow process.

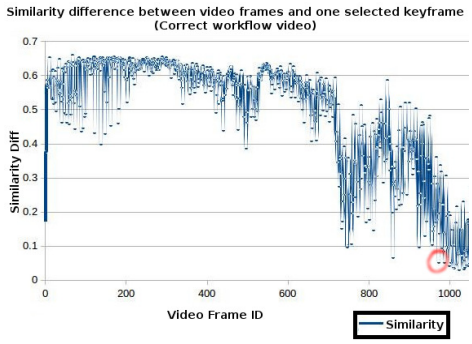

Fig. 3. Similarity difference of one frame from reference video comparing all frames from different video with correct workflow order. Similarity difference level zero equals the perfect 100% result of comparison (the images are equal). The results are based on Bhattacharyya distance metric.

Conclusion

The histogram based methods of image analysis are used in several image searching services too. This was the main idea for our model approach. These use-cases produce satisfactory results due to big image texture diversity [3]. Rather they produce poor similarity results in all our tests. The similarity between images is observable, however not exactly usable. Frames from the correct workflow video reached very similar results comparing incorrect work-flow frames. In the terms of similarity, significant difference was observed in several frames from video with correct work-flow (compared to the frames from correct work-flow captured from different angle). Based on the obtained results can be said, that this principle is not applicable to determine workflow correctness in exactly way. The method is suitable just in cases, when image similarity approximation is needed (for example the system presented in [4]). Based on all evaluated disadvantages and problems, the complex model for position and workflow analysis must be designed in future.

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Wideband Antennas for UWB Radar Systems and their Measurements

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***Abstract*—The article describes the tasks and obtained results solved in previous year of PhD. study. Solved research tasks and published articles are presented here. The paper deals with theoretical background of ultra-wideband (UWB) radars and antennas for UWB radars. The paper also describes designing of antennas suitable for UWB radars, non-standards antenna measuring methods and some experimental results from measurements.**

***Keywords*— Impulse response, UWB radar, Vivaldi antenna.**

I. Introduction

Nowadays, ultra-wideband radars hold great promise for a variety of applications. Motion sensing and imaging ultra-wideband radar systems have strong potential for use in medicine [1], ground penetrating radar (GPR) systems [3], impedance spectroscopy [2], through-wall measurements for emergency services [4], as well as in UWB sensor networks and other usable applications. A key element in named or any UWB radar systems is one or more antennas, depending on the application [5].

The antenna represents a very important role in modern Ultra-Wide Band (UWB) systems and UWB sensor networks. The minimum ringing is one of the main requirements for the UWB antenna used by radar systems. Another requirement is to cover the largest frequency bandwidth possible which it operates in. UWB device is defined as any device operating in absolute bandwidth greater than 500 MHz or fractional bandwidth greater than 0.2 of central frequency [6]. Other required properties of the antenna for UWB radars include directivity, linear polarization, width of main lobe at least 90°, low-profile, simple manufacturing and small dimensions while maintaining f_{min} = 1 GHz. The above mentioned properties of the antenna are normally measured with the vector network analyzer (VNA) in an anechoic chamber, but this is a very expensive solution. Alternative manner to measure all named electric properties is use of the UWB impulse radar. It is much cheaper device than measurement in anechoic chamber and provides a more compact option for verification of some important parameters of the antenna. This article presents design of the antenna suitable for UWB radars, alternative or non-standard methods of the antenna measuring, some experimental results of measurements and future work which is planned to do.

II. What Was Done

A. Design of the suitable antenna for UWB Sensor networks

Last year I participated on Short Term Scientific Missions (STSM) for the COST Action IC1301 entitled „Wireless Power Transmission for Sustainable Electronics (WiPE)“ at Brno University of Technology during May and June 2015. I was integrated in team of prof. Zbynek Raida. The main objective of the STSM was focused on the design of an Ultra-Wide Band (UWB) antenna for energy harvesting applications and for UWB radar/sensor networks. Based on the cooperation with prof. Raida a planar antipodal Vivaldi antenna for UWB radars was designed. The antenna is depicted in Fig. 1 and it was designed with use of analytical curves. More information about antenna design is published in the following publications [7, 8]. The main advantage of proposed Vivaldi antenna is that wide frequency bandwidth starts from 0.81 GHz to more than 10 GHz with few small acceptable variations at the beginning to satisfy the requirements of the UWB technology. Next advantages are: stable radiation pattern, low ringing, low cost and small dimensions.

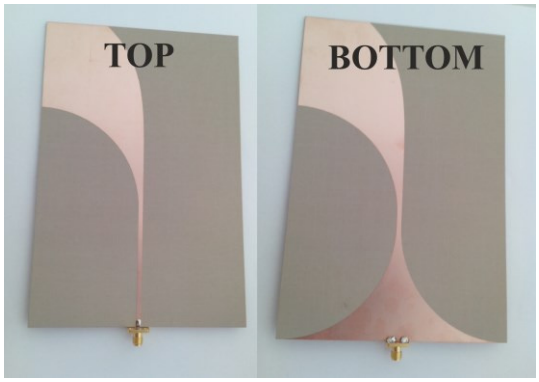

Fig. 1 Top and bottom side of the manufactured Vivaldi antenna

B. Measuring of the proposed antenna with non-standard methods

The antennas can be measured by an UWB impulse radar using two different methods. The first method uses reflected impulse response (with this method, an impulse response (ringing) and s_{11} parameter of the antenna are obtained) and second one uses transition impulse response (with this method, radiation pattern of the antenna is obtained).

The system of first measurement method (Fig. 2a) consists of *pulse generator*, *scope*, *measured antenna*, *microwave coupling elements* and *cables*.

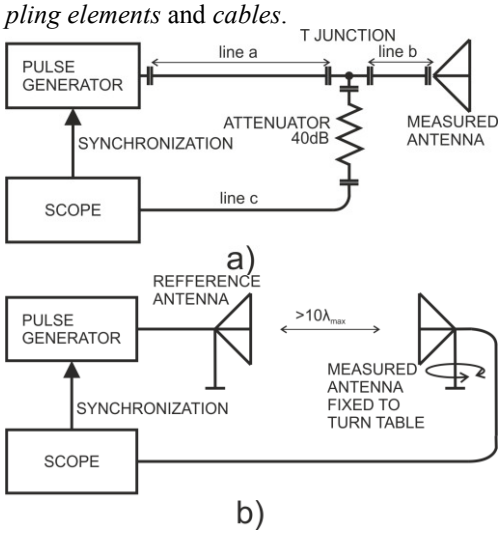

Fig. 2 Block diagrams of antenna measurement: a) reflection impulse response, b) transition impulse response.

Position of the scope time window is selected according to the cable length (line a, line b, line c) to avoid any reflections from space inhomogeneities and from the measurement fixtures in the observed time interval. The time which electromagnetic wave needs to overcome distance between antenna and walls (floors etc.) and back to antenna is longer than the end of scope observation window. The pulse generator transmits a narrow pulse (in our case *lambda* shape). The reflected signal is received from the antenna after adjusting the observation window of the scope according to the lengths of *lines a, b* and *c*. The whole principle of measuring using impulse UWB radar is shown in Fig. 2a.

The second method uses same measurement equipment but connected in a different configuration (Fig. 2b).

The pulse from a generator is radiated by the reference antenna. The measured antenna is fixed to the turn table and receives radiated pulse at different angles. The received signal is sampled, recorded and displayed in the scope window and mathematically processed. The distance between the antennas must be greater than $10\lambda_{max}$ to guarantee far field and plane wave conditions.

C. Experimental results

The self-made Vivaldi antenna for experimental measurements was used. Next figure (Fig. 3) shows s_{11} parameter of Vivaldi antenna. The figure shows results obtained from simulations and from measurements with VNA in anechoic chamber and with use of UWB impulse radar.

More results of the antenna measurements are published in [9]. In the mentioned publication are impulse response (ringing) of the Vivaldi antenna compared with other commercial wideband antennas and radiation pattern measured by UWB pulse radar.

III. Future work

In the future we would like to improve methods of the antenna measurement with UWB pulse radar and increase the measurement accuracy by mentioned UWB radar.

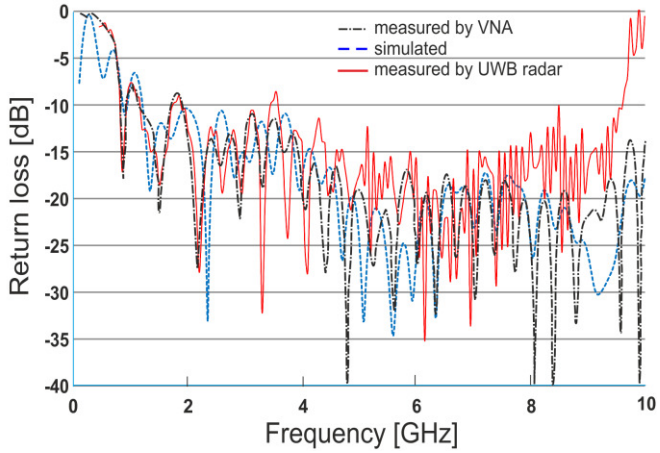

Fig. 3 S_{11} parameter of the Vivaldi antenna.

Also, we would like to continue in design of the wideband antennas where *Wide slot Ultra-wideband* antenna is in the process of optimizing the final dimensions and Spiral antenna is in the design process with using parametric curves. Another goal is to achieve more types of own manufactured antennas suitable for through-wall measurements with UWB radar and compare them with commercial antennas. At the end, the own manufactured Vivaldi antenna was used in the detection and obtaining a frequency respiration with UWB radar. The results of named measurement will be published in the next works.

Acknowledgment

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Wireless Optical Communication Links – Free Space Optics – Advantages and Challenges

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***Abstract*—This paper deals with advanced wireless optical communication systems. Optical wireless communication, commonly known as Free Space Optics (FSO), satisfies most of the current communication's requirements. Eventually, FSO refers point-to-point communication gaining advantages such as high speed, low cost and free license communication alternative and complementary informational channel. Similarly to RF (Radio Frequency) links, FSO also suffers from weather behavior (atmospheric conditions). Considering FSO wavelengths, it's important to compensate the channel attenuation caused when fog occurs. Heavy channel attenuation events usually result in a total link fade. That's why the FSO has to be duplicated with some other link (RF for example). This paper will propose some methods to determine when bad atmospheric behavior approaches. These are based on gathering of some useful information characterizing current atmospheric state. In particular, the evaluation of gathered data results in a decision wheatear to use the duplicate link or not.**

***Keywords*— availability, FSO, fog, received optical power**

I. Introduction

The main FSO requirement is a direct visibility between two transceivers. Rain, heavy snowing, fog, dust, random flying objects, birds, trees leaves and many others factors more or less influence FSO operability [1-2]. When heavy fog occurs the attenuation of link reaches critical values and usually causes a total link fade. On the other hand, long time fades are rather rare in comparison to short fade events (few seconds). It turns out that the link availability and reliability are important parameters characterizing particular link from the quality point of view. The link availability is easily calculated as the ratio between fade link time T_f and the total time when link was up T_u (this parameter is normally calculated from yearly records). Considering the fact that, it's not possible to prevent randomly occurring signal fades, it's important to determine when such an event most likely is going to take place [3-5]. This paper will propose a few approaches to find out the reliable solution in this matter. In particular, there are two parameters which are going to be briefly discussed in this paper. The first one is so called particle density concentration – *pdc* [mg/m^3] – measured by optical sensor. The received optical power measured in [dBm] is the second parameter [5].

II. 850 Nm FSO Link At TUKE

The FSO link currently operating within the TUKE campus is constructed for 850 nm wavelength. Despite the fact that this link does not represent the FSO state of art, there is no doubt of using of this link as a demonstration able one when dealing with negative atmospheric condition. The effect of fog phenomena has exactly the same impact on every FSO link mainly depending on an operational wavelength. It's important to empathize that the distance between TUKE FSO transceivers is almost 300 meters.

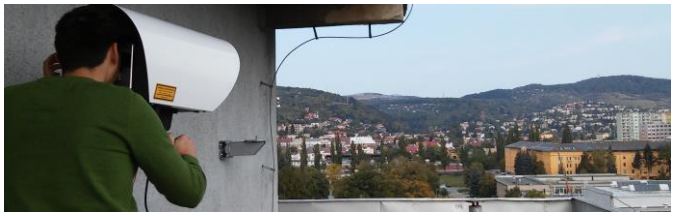

Fig. 1. FlightStrata 155E – LightPoint. The particular FSO transceiver operates at 850 nm wavelength. It's located at Letná 9 Technical University of Košice roof. The maximum data rate is 155Mbps with receiving sensitivity -45dBm. The maximum output power is 24 mW. The actual data bit rate is strongly dependent on the atmospheric conditions. When the imaginary transmission path gets filled with obstacles in form of fog (fog particles which size is comparable with 850 nm – it's important to realize that fog particles are distributed in a certain range) the FSO link signal happens to be heavily attenuated.

III. Strategic Parameters Measurment

Particle density concentration – *pdc* – parameter is measured in [mg/m^3] refers to the certain amount of fog particles present in a cubic meter. The received optical power – *rop* – is measured by the FSO transceiver itself in [dBm].

A. Particle Density Concentration

This indicator is measured by optical sensor based on light scattering. Implicitly, this parameter can be approximated to liquid water content *LWC* and further recalculated to the actual *Visibility* in meters. It's obvious that a direct visibility is a necessary condition. Optical sensor used for measuring of this parameter is controlled by a computer. This sensor with the computer and several other sensors (temperature, humidity, and pressure) are encapsulated in the outside unit mounted about 30 cm far from FSO transceiver. All mentioned data is periodically collected and stored in a database. Even more, the entire process is controlled by scripts. These send data to

Nagios open source monitoring software (this software has to be customized for a certain usage – FSO use in this matter). Data can be displayed in detain in form of scalable charts. The following Fig. 2 represents the lifecycle of *pdc* data collection. This figure refers to initial setting needed to lunch the initial processes.

```
[root@monitoring sensor]# crontab -l
# /bin/bash ./fillupRS232.sh  # ==> has to be lunched!
# collects data from /opt/sensor/rs232.txt file like
# evert 15 seconds; postprocesses them and filling up
# MySQL database on this 000.000.00.00 machine port 33
* * * * * sleep 00; /bin/bash /opt/sensor/collect.sh
* * * * * sleep 15; /bin/bash /opt/sensor/collect.sh
* * * * * sleep 30; /bin/bash /opt/sensor/collect.sh
* * * * * sleep 45; /bin/bash /opt/sensor/collect.sh
```

Fig. 2. The overall "lifecycle" process for *pdc* collection.

The actual data are accessible through the simple web as show in Fig. 3.

fiber.web.tuke.sk/mon/index.php

Database on monitoring station .30!

#lwc	temp	temp [C]	humi	humi[%]	timestamp	lwc_p	lwc_web
112	4564	5.640	1844	58.111	2016-03-14 23:08:17	-0.064053	14.1508
115	4564	5.640	1840	57.997	2016-03-14 23:08:03	-0.062188	14.5318
114	4566	5.660	1838	57.943	2016-03-14 23:07:47	-0.062810	14.4048
113	4567	5.670	1837	57.916	2016-03-14 23:07:32	-0.063431	14.2778
113	4567	5.670	1837	57.916	2016-03-14 23:07:17	-0.063431	14.2778
112	4567	5.670	1838	57.944	2016-03-14 23:07:03	-0.064053	14.1508
113	4564	5.640	1839	57.968	2016-03-14 23:06:47	-0.063431	14.2778
114	4564	5.640	1838	57.940	2016-03-14 23:06:32	-0.062810	14.4048
112	4562	5.620	1837	57.908	2016-03-14 23:06:17	-0.064053	14.1508
114	4562	5.620	1834	57.822	2016-03-14 23:06:02	-0.062810	14.4048

.pi .141

mount -o bind /opt/GP2Y1010AU0F/ /opt/chroot/master_mysql/var/www/html/mon/_mount/

2016-03-14-23:09:00;	0
2016-03-14-23:09:01;	0
2016-03-14-23:09:02;	0
2016-03-14-23:09:03;	0
2016-03-14-23:09:04;	2
2016-03-14-23:09:05;	0
2016-03-14-23:09:06;	0
2016-03-14-23:09:07;	0
2016-03-14-23:09:08;	0
2016-03-14-23:09:09;	0
2016-03-14-23:09:10;	0
2016-03-14-23:09:12;	0
2016-03-14-23:09:13;	0
2016-03-14-23:09:14;	0
2016-03-14-23:09:15;	0
2016-03-14-23:09:16;	0
2016-03-14-23:09:17;	0
2016-03-14-23:09:18;	0
2016-03-14-23:09:19;	0
2016-03-14-23:09:20;	8

picking up Received Optical Power [dBm] from .30

id_rop	_____SampleTaken	[rop dBm]
100053	2016-03-14 23:07:11.163000	-24
100052	2016-03-14 23:06:11.337000	-24
100051	2016-03-14 23:05:11.511000	-24
100050	2016-03-14 23:04:11.701000	-24
100049	2016-03-14 23:03:11.656000	-24
100048	2016-03-14 23:02:11.034000	-24
100047	2016-03-14 23:01:11.193000	-24
100046	2016-03-14 23:00:11.366000	-24
100045	2016-03-14 22:59:11.509000	-24
100044	2016-03-14 22:58:11.589000	-24
100043	2016-03-14 22:57:10.859000	-24
100042	2016-03-14 22:56:11.032000	-24
100041	2016-03-14 22:55:11.222000	-23
100040	2016-03-14 22:54:11.380000	-24
100039	2016-03-14 22:53:11.445000	-24

Fig. 3. Particle density concentration – *pdc* – parameter is marked in a green frame. The value of this parameter varies from 0 (clean atmosphere) to 752 (heavy fog). Received optical power – *rop* – marked within red region is measured by the FSO heads themselves.

B. Received Optical Power

Received optical power [dBm] measured directly by both of FSO transceivers is the second important parameter in context of FSO communication. Essentially, the process of extracting the actual *rop* is rather complicated, especially for the FSO link which is used at TUKE. Obviously, the most important process is the preprocessing of collected data. The result of this assumption should be algorithm which will be able to surly decide that incoming optical signal on both FSO ends is converging to critical values indicating the FSO link outage. Eventually, the system should switch FSO link to duplicate source (e.g. RF) in advance. As soon as both indicators *rop* and *pdc* report "positive" numerical values, the system has to be flexible enough to roll back the entire communication via FSO link. In order to achieve so, some statistical calculations have been done within a range of specific time interval as can be seen in Fig. 4. The *rop* parameter gains fairly similar values most of the time.

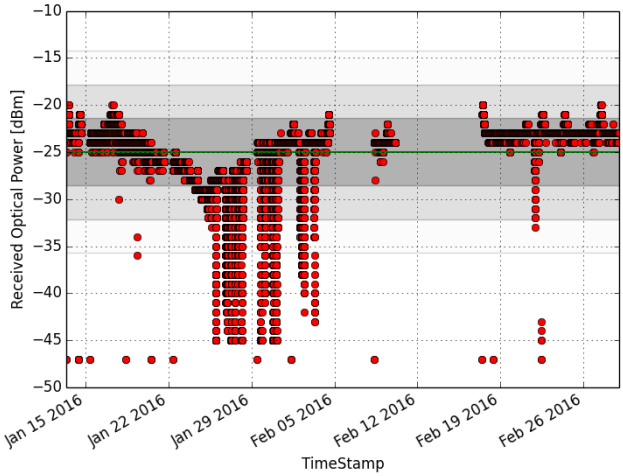

Fig. 4. Received optical power (January 1st – February 29th).

Three horizontal regions represented by shades of gray explicitly refer to 3σ – levels of standard deviation around a mean value (μ: -24.9785971057 and σ: 3.57081850448). Eventually, statistical parameters (μ,σ) are strongly depend on the length of a selected time interval.

IV. Future Work

This further research will be paying attention to the detailed analyze in order to determine sharp received optical power changes. Received optical power as the key parameter should have been precisely combined with other measured parameters such as *pdc*, temperature, humidity etc. These will be used with advantage in a reliable FSO/duplicate link switching process.

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