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Advanced Photonic and Electronic Systems WILGA 2018

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***Abstract*—WILGA annual symposium on advanced photonic and electronic systems has been organized by young scientist for young scientists since two decades. It traditionally gathers around 400 young researchers and their tutors. Ph.D students and graduates present their recent achievements during well attended oral sessions. Wilga is a very good digest of Ph.D. works carried out at technical universities in electronics and photonics, as well as information sciences throughout Poland and some neighboring countries. Publishing patronage over Wilga keep Elektronika technical journal by SEP, IJET and Proceedings of SPIE. The latter world editorial series publishes annually more than 200 papers from Wilga. Wilga 2018 was the XLII edition of this meeting. The following topical tracks were distinguished: photonics, electronics, information technologies and system research. The article is a digest of some chosen works presented during Wilga 2018 symposium. WILGA 2017 works were published in Proc. SPIE vol.10445. WILGA 2018 works were published in Proc. SPIE vol.10808.**

***Keywords*—photonic systems, electron technology, material engineering, electronics, photonics, optoelectronics, lasers, telecommunications, informatics, electronic systems, large research experiments, young researchers meetings, WILGA Symposium, Wilga**

I. Introduction

THIS year, the Symposium of Young Scientists WILGA on Photonics Applications and Web Engineering marked the 42th edition and 21th anniversary of the summer meetings and its diligent service to the photonics and electronics research communities. The symposium gathered nearly 400 participants young scientists from all over the country and from abroad. There were presented over 350 research papers, out of which, after peer reviews, around 250 were published in Proc. SPIE. Wilga Symposium enjoys the patronage of Committee of Electronics and Telecommunications of the Polish Academy of Science [1], Polish Optoelectronics Committee of SEP, Photonics Society of Poland [http://pkopto.ise.pw.edu.pl/], SPIE – The International Society for Optics and Photonics [spie.org], IJET Journal [ijet.pl], Institute of Electronics Systems WUT [http://www.ise.pw.edu.pl/], and WEiTI WUT [http://www.elka.pw.edu.pl/]. Wilga Symposium [2-8] works are published in the Proceedings of SPIE, Photonics Letters of Poland [photonics.pl], International Journal of Electronics and Telecommunications, and Elektronika, konstrukcje, technologie, zastosowania [http://www.elektronika.orf.pl/]. Wilga Symposium [2-8] has always several sessions on photonics [9-16], astronomy and astroparticle physics [17], large research experiments including high energy particle physics, hot plasma fusion energy, free electron lasers and large accelerator infrastructures [18-26].

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II. Topical Sessions of XLII WILGA 2018

The following topical tracks were organized during WILGA 2018 symposium:

- Photonics: optical fibre communications, bio-photonics and opto-genetics, optical and optoelectronic sensors and photonic systems components, application of photonic equipment in research, astronomy, and industry;
- Electronics: functional systems development, applications in research and industry, functional IoT systems;
- Informatics: information technologies, software engineering, hardware-software co-design, artificial intelligence development for functional systems, bioinformatics;
- System research: theory, design, construction and implementation of large and very large functional systems;
- Applications of complex functional systems in the following sectors: safety and defence, airborne and space, large research experiments, large functional infrastructures, energy and large industrial utilities,

Following chapters contain short descriptions of chosen work presented during the major topical tracks of Wilga 2018 Symposium. Most of these presentations were published in Proc. SPIE vol. 10808 [spie.org] where they are available in extended form. There are presented abstracts from some of the most interesting contributions.

III. Photonics Applications

One of the main tasks of computer graphics is increasing the realism of synthesized images. A lighting model was implemented that takes into account the effects of scattering of light. 3D object visualization requires embedding into its natural environment. A model for fog rendering was added. An algorithm for lowering of computation costs was proposed. Real time GPU calculations were applied by introduction of relevant approximations in geometry and quality. The vertex shaders compute the light reaching the eye from a source or a reflective object and fog component. New practically applied technologies enable the use of a large number of digital effects in the visualization of three dimensional objects, which until now could not be used in real time on computers for the mass market.

Time series were analysed reflecting changes in time of selected flame geometric parameters, in the co-firing of pulverized coal and biomass. These parameters were: contour length, area size, X and Y coordinates of the geometric centre of gravity. Fractal dimensions were estimated. Several variants of co-firing fuel proportions were applied, involving various heat power settings, and air flow rate. Applied fractal dimensions parameters can be a feature that allows to recognize

particular variants of the combustion process. Furthermore, the fractal dimension evaluated by the image-gram method of estimation gives good results for most variants providing good separability of the observations. The obtained results confirm the possibilities of using fractal analysis in flame studies in the co-firing of pulverized coal and biomass.

Diagnosis of the combustion process in industrial conditions was implemented. Efficiency and quality of the combustion depends on process parameters in the boilers of various design. The role of the diagnostics is to impose optimal solution to reduce the amount of pollutants emitted to the atmosphere. The monitoring systems, based on optical sensors, is directly connected to each burner in the combustion chamber of a boiler. Such application of sensors aims at obtaining the best diagnostic parameters. In the case of the low emission combustion technologies, the presence of free hydrocarbon radicals – which are always found in the flames produced from fossil fuels – has a great significance for the efficiency of NOx reduction. The larger the flame, the higher concentration of hydrocarbon radicals and better reduction properties of the flame.

3D images generated by TOF method are used for automatic detection and location of images in the machine workspace and on the production lines. Robotic station with TOF sensor, gathering spatial data, was implemented in a testing model. Fast data pre-processing is applied for image filtering, features extraction and enhancing characteristic properties. The images are contextualized for the production line conditions. Possible disruptions, always present with some probability in industrial conditions, are estimated. Work of the system in presence of distortions and disturbances is evaluated.

Processing of digital images of objects which surfaces are inaccessible poses an additional technical challenge. Analytical method of image data estimation is developed for finding abnormal areas. The applied algorithm analyses matrices of brightness fluctuation, differences variations and correlations, coordinates, sizes and shapes. The change in these regularities on various parts of the surface contain information on the state of the object. The aim is to develop non-destructive measuring methods of objects which surface is hidden from direct visual inspection.

An intelligent system of neural networking recognition of multicolour spot images of laser beam profile is under development. The method concerns adaptive processing and compression of colour spot images of laser beams. The multicolour spotted images are pre-processed and compressed in the NN system. This enables the recognition process of spotted laser images to be performed faster and with greater accuracy. The aim is to do better laser beam profiling. The system was applied for data recognition in photo-thermographic maps of geographical areas.

IV. Computational Intelligence

IoT architectures are penetrating various areas of services including trade, shopping, health, tourist industry, etc. Modular solutions for leisure industry use increasingly frequently all the convenient features offered by the full IoT including real time interactions, big data, fog, cloud and the fast edge. Distributed sensing network and fast data analytics enable such dynamic, useful and user friendly features like service personalization, user and operator feedback, fast and optimized reaction to the requests, predicting the requests, providing anonymity at relevant level, etc. The system incorporates mobility by coupling wireless access to the edge and enabling there fast computations and transmission. System development embraces adding more features and computational intelligence including wireless tracking, self-optimization of modular architecture, embedded behavioural features, social engineering approach, active discriminative and predictive algorithms, etc.

FPGA circuits enable fast and flexible system prototyping using relatively advanced and user friendly, i.e. fast to be mastered, graphical programming environments. A digital control system is used for laboratory prototyping of pulsed nuclear quadruple resonance NQR Fourier radio spectrometer. FPGA prototyping enables software – hardware co-design approach. The NQR is modelled by functional blocks to which relevant software is optimally fit. Such approach lowers costs, required human effort, energy demands, and simplifies the system structure.

Artificial intelligence tools like expert systems based on fuzzy logic are used to support stock market decisions. Full, classical technical analysis is augmented by fuzzy logic procedures. Fuzzy logic expert system is expected to support the accuracy estimation of future trends. Values of technical analysis indicators are calculated basing on historical data. A multilevel decision generation process is launched using the first level results and making various simulations and inter-comparisons on possible future data fluctuations. Artificial neural networks enhance the system ability to analyse trends with derivatives of both signs.

Increasingly more complex full logics systems are implemented digitally. The most popular classical logic images the reality not very accurately because it bases on two logical values - truth and false. Three valued logic of strong belief is one of the researched and practically applied extensions. L3 logic is used to describe the beliefs of a cognitive subject. The logic defines the way in which the agent determines the logical values – truth or falseness – of complex sentences. A division to external and internal logic is introduced. Logics verifies whether the studied sentence is valid and satisfies the rules or is a tautology. Extended logic may use also Internet or proprietary databases for checking the status of defined expressions.

Labour costs are optimized by relevant introduction of ICT in enterprises and businesses. Characteristics and local features of existing criteria and methods for evaluating the effectiveness of IT implementation are investigated for East European business conditions. The aim function is developing effective strategy for particular enterprise under analysis via reducing the complexity of all relevant and involved processes. The enterprise is treated theoretically and modelled as a complex dynamic system of multicellular and multilayer structure. It realizes various production, management, marketing and general business tasks tight together on a common, yet hybrid, platform. It is assumed that the company under analysis relies on big data. Distributed data processing required introduction of an entity called automatic workplace. Indicators are introduced to measure effectiveness of company networking like ratios between automated workplaces to the number of employees and the number of networked workplaces. These measures were used to build a model of the company and its permeation degree by the ICT. The data resources in concern embraced material, energy, human, information, costs and time.

Extensive data mining computations require applications of various relevant parallel clustering technologies and effective data storage. Clustering involves scalable and distributed architectures of computations and work with heterogeneous hardware and software platforms including CPU, GPU, GPUPU, FPGA, ASICS, DSP units as hardware and MapReduce, CUDA/OpenCL, OpenMP, MPI as programming models/environments. Comparison between these methods of parallel processing of immense data sets, including their positive and negative sides, reveal some indications for further technical developments in this area. One of the fundamental issues of task parallelization is identification of nondependent operations. Usually, however, in large data sets to be processed there are a lot of complex interdependencies. Large computation costs of clustering algorithms are associated with not defined a priori number of required iterations and validation steps. Parallel and distributed clustering uses either memory based or disc based i.e. Hadoop technologies, which are further divided to classes of different properties: partitioning, hierarchical, density-based, model-based, graph based and grid-based. Better scalability and performance is expected in parallel clustering than with the usage of sequential data processing methods. Significant improvement is obtained only if clustering algorithms can be easily paralleled. Hadoop implementing MapReduce processing model based on reconfigurable FPGA platform has been recently proven as one of the optimal choices.

Various classes of software metrics can be used for evaluation of such parameters, features and figures of merit as: compactness, ruggedness, labour costs, complexity, relevance, flexibility, scalability, susceptibility to errors, and defects. Correlation of some software process metrics with defects are observed. Evaluation of such dependencies enables identification of processes and characteristics responsible for these issues and estimation of problems in software modules under development. Mining old and well checked data allows for creation of predictive models. These models used for new software modules generate defect susceptibility indicators. Software reliability growth models and other predicting schemes, which estimate the reliability or predict the number of remaining bugs basing on strictly defined development and testing processes have been recently subject to industrial standardization. Various software metrics have essential impact on defect probability. There were compared fine and coarse grained investigations, with the fine relevant to modules and coarse to the whole multi-modular system under research. Coarse grained analysis has proven to be more effective in estimations of the system reliability.

Scrum model and agile software development and management, using Jira and Git, is subject to applications and research. They differ essentially from standard development methods divided usually to long lasting project stages associated with a collection of requirements, design, implementation, verification and maintenance. Projects i.e. information systems were developed using Scrum decomposition to well specified modules – and assigned as sprints. Then the project progress and effectiveness are evaluated by studying defined standardized repositories of software done both ways. A specific commercial complex project, realized by distributed teams, was analysed which requires constant upgrades and extensions. Such conditions of project realization hamper overall management. Scrum procedures require dynamic and adaptive kind of team work with continuous consultations and frequent meetings. Research on Scrum efficacy is aimed at correlating various software metrics with the development processes.

Anomaly detection, or identifying abnormal instances of data, can be seen as an unsupervised learning task in which a predictive model created on historical data is used to detect outlying instances in new data. The process can be considered generally as a variation of binary data classification. The subject of research is text data in which certain key word are searched. For example in forum posts there are filtered off some key words related to crime. Forum posts are challenging source of data for text mining because of its professional discussion character. However, the data available there are full of imperfections inherent to open discussion. Global Vector GloVe is used for text representation and word embedding. These methods are combined with SVM classifications. Anomaly detection in GloVe represented text data originating in forums is based on cluster dissimilarity approach which outperforms one-class SVM. Assumed anomaly score list determines essentially the performance of cluster dissimilarity method in reference to searched feature detection.

Numerable evolutionary optimization tasks involving computational intelligence are using R language algorithms. Various R implementations of optimization techniques are compared showing different results. This indicates that the selection of particular implementation for specific experiment has a key role. There are researched families of evolutionary algorithms widely implemented including CMA-ES and DE. The first one solves non-linear non-convex optimization tasks in continuous domains and multi-dimensional space. The latter is a simple and effective global optimization method. Algorithms effectiveness is evaluated by benchmarks like global OptTests, CEC2017, CMA-ES and its R implementations were evaluated as one of the most effective stochastic optimization tools. Using different implementations one obtains, however, varied results.

Supercapacitors are described by fractional order derivatives. They have different current – voltage dynamics as classical capacitors, which stems from their technology requiring extremely large plate areas and small separation between the plates, also large value of permittivity. There were used two different definitions of fractional derivative Caputo and CFD to describe the signal from the supercapacitor placed in a circuit with voltage source, loaded and next discharged through external resistor. It was shown that Caputo definition is better than CFD to describe the real behaviour of the supercapacitor. It is assumed that the supercapacitor charging depends on its history of previous charging and discharges.

Networked power industry is subject to multi-domain statistical investigations for costs, energy usage optimizations, and introduction of computational intelligence based management. A number of power network parameters are subject to random changes in time which have to be described by probabilistic models. Some of these values have been measured for long time which enables introduction of advanced estimation and predictive technologies, including complex multilevel couplings between various values. A relevant set of quantities may include even several tens of variable functions like weather conditions, electrical values, loads, related community conditions, etc. Statistical analysis of these values and finding complex direct and indirect relations between them

allows to build more advanced and precise models of energy usage by the community, to balance demand and supply in a more skilful way.

Implementation of symmetric AES encryption standard requires combined software/hardware solution. Reversible circuits are used to build symmetric block encoders using scalable VHDL and FPGA solutions. Depending on the state of the encryption key, a cascade of reconfigurable reversible gates is changing their types. Longer bit keys, providing more safety, require more and wider gate cascades, what is provided by the scalability of FPGA solution. The input data is processed in several stages/rounds with changing status of the encryption key. The Feistel algorithm, was used. The encoder may contain m cascades of n gates and implement R encryption rounds. The listed parameters may be changed fitting to the system requirements like signal processing rate, system size and security level. The encoder offers 16! solutions of 4 variable functions.

New symmetric encryption and decryption algorithms for block ciphers are under constant development. The basis development space is to obtain the largest possible size of the key and the highest processing speed. The algorithms are physically implemented using complex, long reversible logic/circuits cascades and VHDL/FPGA platform. Reversibility is understood in the following way: the set of n balanced Boolean functions of n variables is called reversible if each input vector is mapping into a unique output vector. The Boolean function is called balanced if the number of 0's minterms is equal to the number of 1's minterms. From this definition originates the main feature of reversible circuits. It is possible to determine the input vector if the output vector is known. Such circuits fulfil Landauer principle and there is no loss of information. Several scalable algorithms were proposed and tested for key and data modifications.

Embedded system ES development requires extensive debugging of software defining the basic and complex hardware functionalities. ES run pre-emptive RTOS of high performance including data processing rates and reliability. System complexity requires application of multiple MCU architectures. To take control of the complexity the diagnostics is inbuilt, in software and hardware alike, for anomaly detection. Diagnostics generates instructions trace and makes it available as physical interface readouts for further processing and control data acquisition. This enables recreation of the software context of executed instructions with their metadata including: source address, time, path, type, arguments, location, target address, etc. The aim is to control and diagnose program flow, RTOS activities verification, introducing and executing reliability, availability and other performance metrics.

Processing of digital data in networks with high level of noise is a challenging technical task. The opposing requirements are efficiency and reliability of data transmission vs data rate and computational intelligence resources needed to do the task. Gibbs effect in signal processing was eliminated by application of a method of determining the decomposition coefficients, which uses the replacement of the biorthogonal coefficients of the wavelet decomposition with the approximation sum using a series of quasi-random delta sequences. Spectrum of the signal is evaluated to enable adaptive threshold method. Multi-window average estimation of the logarithmic spectrum of the signal is used. The original data vector is split into blocks with remembered partition data, and median filtration processes the split parts in shorter time. Thus, the method of parallel fast wavelet transform is vastly improved.

Fuzzy controllers are used in telecommunications networks to improve the traffic scheduling processes. The algorithm tries to optimally manage the order in which data arrive at the node from different sources. System performance depends on the scheduling algorithms. Optimal routes are chosen to change the scheduling, which is supported by computational intelligence based on soft computing like NN, genetic algorithms and fuzzy logic FL. The final aim is to improve the QoS factor of the network. An adaptive neuro fuzzy inference system was applied basing on Tagaki – Sugeno inference system. It combines NN with FL. The controller enables selection of the most reliable nodes for building a stable path in the network.

V. Biomedical Applications

Wireless optogenetic implants devices were designed and constructed. They are used in freely moving mice kept in intelli-cages. The device stimulates specific regions of mice brain using light. The communication bases on NFC like technology using resonant LC circuits and relevant components with 470 nm LED. Targeted neurons are stimulated optogenetically with intensities up to 40mW/mm^2 using a standard cannula with sapphire needle. The RF device works in the frequency region 15-30Mhz. It was shown that the near field power supply system for optogenetic implant works efficiently.

Bioactive glass fibers were manufactured by modified rod-in-tube method from the bone reconstructive 45S5, S53P4 and 13-93 glasses. Bioactive fibers are considered for medical applications in nanocomposite biomaterials. Bioactive glasses are drawn to fibers to reinforce biomedical composite structures, biosensing systems and other biomedical components. Listed bioglass series exhibit very good biocompatibility with bone and tissue. Mechanical properties of biocompatible glass fibers are essential for reinforcement of polymer composites. Thermal and mechanical parameters of biocompatible glasses, fibers and components were measured.

Flexible humidity sensors for biomedical applications are manufactured with the aid of drop casting and ink jet printing technologies. The sensors are several comb shaped gold electrodes on a relevant thin foil. The foil is resistant to thermal and chemical interactions. The conducting components are printed on the foil and the sensing layer is Nafion. Sensor impedances were measured as function of the humidity to show their work characteristics. The sensor was modelled by resistors and constant phase components.

Unmanned aerial vehicles are used for environment monitoring, including detection of biological agents, air pollution, generation of NO_x agents around high voltage power transmission lines, etc. Air parameters acquisition module are measuring CO_2, water vapour or humidity, temperature, solid state particles with diameter histograms, wind speed and direction, wind gusts structures, etc. A UAV measurement system has been tested using ground control station UAV-GCS standard and MAVlink protocol.

Wearable, energy efficient devices, systems and networks are used to help elderly people to increase the quality of their life. Uninterrupted measurements of key life parameters enables detection of specific diseases in their early stages. Among such

devices are wrist wearable monitors for increasing number of physiological signals like blood pressure, temperature, blood oxygenation, heart rate, physical effort, etc. Several new solutions for a wide family of wrist wearable devices were proposed and tested. The devices were coupled to the IoT environments via the edge and to the cloud.

Currently applied automatic speech recognition ASR systems have today quite high efficiency, but it is not enough for future purposes. Research is conducted on the increase of their performance. The efficiency of ASR depends on learning. It may decrease when used with non-native speakers with differently distorted pronunciation features, depending on the person. Quality and efficiency of learning depends on the availability of samples of labelled, standardized data sets of non-native speech. ASR targeting for non-native speakers is under research for different languages. A style transfer methodology STM, usually exercised in graphical domain, was applied to solve the issue. STM was shown to be compatible with already existing ASR methods. Thus, it is not necessary to train extensively the new researched systems.

Changes in genomic sequence might influence the gene expression, protein function and, what is related to phenotype of the organism. The Next Generation Sequencing provides a big amount of data that could be used in predicting the single nucleotide variants between analysed and reference genome. NGS is aiming at fast and efficient analysing of big data sets. Some of the serious human genetic disorders are caused by variants resulted in nonfunctional proteins. Variants are non-genetic harmful and biologically useless regions. NGS is used to identify useful and nonuseful regions. Bioinformatic tools are used for screening polymorphisms over genomic sequence. Bioinformastics software for analysis of single nucleotide variants were overviewed.

Current genomics uses libraries built in bacterial artificial chromosome BAC vectors. BAC is used for other living organisms. BAC cloning and HQ genomic libraries are tools for genetic research like physical mapping, cytogenetic investigations, but primarily identification and isolation of genes, sequencing and genomic assembly. Genomic libraries of long inserts are also tools for characterization of entire regions of a genome. BAC clones are used in construction and integration of chromosomal maps. The basic features of BAC libraries are: easy arraying and pooling techniques for screening, and manipulation of clones using classical molecular techniques. Developing sequencing technologies and bioinformatics tools give wider possibility for better usage and draw information from such resources.

Bioinformatics tools are used for research on protein interaction. Protein annotation is used at two distinct levels, structural and functional. Proteins are analysed for characteristic features of domains, families, and functionalities of molecular networks. The aim is to determine the role of protein in the molecular network. Large sets of proteomic data involve usage of increasingly complex analytic tools. Big data concern domains, protein families, molecular functions and interactions. Analysing tools on the development are thoroughly reviewed.

The research on scaffolding goes into low cost sequencing and generation of longer contigs. The second generation sequencing methods produce high-quality short reads, which are assembled into contigs by DNA assemblers. Single read is limited to 500bp. Thus, it is difficult to assembly genomes of full chromosomes. Generation of 20kbp reads is enabled by link contigs creation from second generation reads using reads from third generation sequencers. This approach is time and memory consuming for larger genomes. Optimal filter and usage of memory efficient associative array speeds considerably the algorithm.

VI. Astronomy, Plasma, High Energy Physics Experiments

WEST thermal fusion reactor is an experimental place for technologies to be applied in ITER. Plasma impurities diagnostics is necessary equipment in fusion reactors to sustain the high temperature process. The impurities from the reactor chamber walls subtract the energy from the H-D chain. Real-time high-throughput diagnostic system was tested to do a sort of radiation tomography of the plasma chain in the range of soft X-rays. Applied multichannel detectors base on GEMs. GEM detectors are resistant to high levels of ionizing radiation. The diagnostics is used to prevent the plasma disruptions and to increase the energy efficiency of the fusion processes.

A model of sequencer algorithm in MatLab was implemented to be used in the second generation of GEM detector. The sequencer can collect data from numerable sources and distribute them in a strict and unambiguous order. It can adjust its parameters to the specific data processing task. The requirements for the measurement system of the second generation are very restrictive including online mode available for spectral analysis and histogramming in less than one millisecond. Data are collected with increased frequency and processed faster. The sequencer architecture belongs to the system firmware. The algorithm is efficient, fast, low latency and allows GEM detector switching to the online mode.

Data distribution and dispatching software is under development for processing of measurement data acquired from SXR GEM based detectors. The algorithms include data acquisition handling from multiple FPGA chips, execution of numerical calculations along multiple threads, data post calculation, storage and transfer. Data is transferred to the CPU using DMA via PCIe interface. The presented concept is prepared for tests with hardware, which is able to handle up to 128 channels within 1D GEM detector. The solution uses double buffering which can be changed to more optimal data invalidation subsystem, which should notify the computational part that the processed data was overwritten.

Advanced, real-time data quality monitoring model for tokamak plasma diagnostics is under research and implementation. Modular measurement systems for data processing and acquisition are the best solutions for large experiments. They are connected to feedback loop to execute the real-time experiment control. The hardware platform consists of analog and digital data path, with data pre-processing in FPGAs and real-time output products computation in embedded PC. The measurement system output should be data of high quality, obtained via data evaluation, and real-time quality monitoring. The model is based on iterative signal classification unit working in real-time. Additional sub-diagnostics allows recording and analysis of the events in terms of raw data and statistical information.

The fixed target Compressed Baryonic Matter CBM experiment serves for discovery of the properties of gluon quark

plasma GQP, which is a part of the QCD phase diagram in the region of high baryon densities. The experiment is under development at FAIR. Complex control, measurement, data acquisition and diagnostics system is under development for the CBM. The distributed CBM readout chain consists of front end boards FEB and data acquisition system DAQ. The system is optimized for costs and the number of used expensive FPGA chips of large computation resources. Optimization embraces also optical fiber links connecting the FEBs and the DAQ. All system is placed inside the MTCA crates. The system is standardised by usage of common readout interface CRI boards. Prototypes of CRI boards are under development. Firmware development and testing is underway. Key parameters include reference clock recovery and distribution.

VHDL based parameterized clock manager simulator for FPGA is under development. FPGA chips contain a considerable number of clock signal management modules. Optimal clocking is required for internal memory devices, I/O ports, fast LVDS serial interfaces, DDR memory, etc. Measures are undertaken to improve the quality of the delivered clock signal including reduction of jitter and improvement of clock duty factor. Different clock domains are defined in a single FPGA chip with various clock frequency and phase. It is not uncommon to use a single functional block with multiple clock signals. A simple parameterized simulation module for clock signal management can gather all of the mentioned functionalities.

The Compact Linear Collider (CLIC) is a concept for a next-generation machine at CERN, colliding electrons and positrons at energies up to several TeV. Higgs boson studies, top-quark physics and searches for Beyond the Standard Model (BSM) phenomena are the three pillars of the CLIC research programme. One of the main goals at the initial CLIC running stage is the measurement of the top-quark mass and width in a scan of the beam energy through the pair production threshold.

Testing is an embedded feature in the MicroTCA architecture used popularly in the research laboratories. JTAG Switch Modules (JSM) that are available on the market offer limited capability. Hardware JTAG debugger module with Ethernet interface was implemented for MicroTCA architecture. This module allows user to remotely program and debug AMC modules, which are connected to the MicroTCA shelf. All JTAG signals in MicroTCA crate are routed to this module via backplane and this single module allows testing and debugging of all modules plugged into the MicroTCA crate. Remote usage of JTAG may be needed, when there are many MicroTCA crates in use or when the system is installed in hazardous environment, like high energy particles accelerators.

The community researching quantum computers have developed their own hardware and software standards optimized for their purposes. These local standards are based on MicroTCA. Sinara is an open-source hardware ecosystem designed for use in quantum physics experiments. It aims to ease quantum calculations control by providing well-tested, reliable and useful hardware for research. Sinara is designed to be used with Artiq, a framework which provides high-level language for describing complex experiments, further simplifying complexity of real-time control systems. Sinara uses MicroTCA and EEM. A driver module Kasli for quantum computer experiments was designed, implemented and tested. Kasli is a module to control up to 12 EEMs. It is a simpler version of a MicroTCA controller. Kasli modules can be daisy-chained to manage more extensions. Kasli communicates with a master controller or directly with a PC.

The Rotating Drum Spectrometer (RDS) experiment is planned to be placed onboard Ruscosmos Multipurpose Laboratory Module ”NAUKA” on the International Space Station (ISS) in 2019. The experiment is designed to measure X-ray spectra of Solar flares using Bragg reflection from flat crystals. Additionally to the reflection of Xray photons crystals produce luminescent light. In order to separate those physical effects during real experiment data analysis, computer simulations are necessary. The results shows that the luminescent background is significantly lower for four of the used crystals than the observed solar continuum emission and is comparable with it for the rest of crystals.

The Spectrometer/Telescope for Imaging X-rays (STIX) is one of the Solar Orbiter instruments and will operate on heliocentric orbit with a perihelion distance of 0.3 a.u. Such close approach to the Sun is connected with severe influence of Solar Energetic Particle (SEP) event. Monte Carlo simulations of expected X-ray background from SEP and cosmic X-rays (CXB) for Caliste-SO detectors, which are used in STIX are underway. Simulations are implemented in Geant4 toolkit. Detector effects are considered, which affect measured energy like hole tailing, Fano and electronic noise. The largest background is caused by SEPs electrons, while background from protons is negligibly low. The expected CXB caused background is low and can be detected only during periods of low solar activity

Multi-Purpose Detector (MPD) is a part of Nuclotron-based Ion Collider fAcility (NICA) located in Dubna. For full functionality, the MPD needs an additional trigger system for off-beam calibration of MPD subdetectors and for rejection of cosmic ray particles, which are mainly muons. The system could also be useful for astrophysics observations of cosmic showers initiated by high energy primary particles. The consortium NICA-PL comprised of several scientific institutions has been formed to define goals and basic assumptions for MPD Cosmic Ray Detector (MCORD). The system is at the early stage design of the MCORD detector based on plastic scintillators with silicon photomultiplier photodetectors for scintillation readout and electronic system based on MicroTCA crate. Simulations of MCORD detector performance are underway.

VII. Material Engineering

Nanocomposite optical glasses and fibers give a novel way to manage luminescent properties of RE ions, mainly due to their unique properties, obtained as a result of the interaction of nanoparticles with photons. Effects of alkali content on spectroscopic, mechanical and thermal properties of Er/Ag(Au) co-doped, low phonon energy and wide transparency antimony-germanate glasses are researched. The glasses with different Na and K ions were co-doped with noble metals and rare Earths to induce and modify luminescence in the IR region. Luminescence signal is enhanced in the VIS region by energy transfer between the dopants. Present surface plasmon resonance results in increase of the electric field within the RE nano-domains. The developed antimony-germanate glasses co-doped with erbium and silver ions are a promising material for waveguide structures operating in the near-infrared region.

Sol-gel method was combined with laser processing to obtain in three stages high quality titanium oxide coatings. Laser application is a substitute for the traditional calcination. Anatase-rutile coatings are obtained. Wide gap semiconductor titanium layers of multiple polymorphous forms are used for their photo catalytic properties. Rutile is the most stable form of titanium dioxide, while anatase is a metastable form, created in lower temperatures than rutile. Anatase has higher specific surface area, porosity and a higher number of surface hydroxyl groups as compared to rutile. Anatase transforms into rutile in higher temperature. Building of titanium oxide coating results from the thermolytic transition by laser radiation from the amorphous initial phase which is liquid crystal to the crystalline one. Low temperature deposition of titanium dioxide layers is suitable for polymers, plastics and complex shape surfaces.

TiO2 thin films were deposited on glass substrates at room temperature by means of high target utilization sputtering (HiTUS). Structural investigation of TiO2 thin films of different thickness was performed by X-ray diffraction. Refractive index and extinction coefficient were measured by spectroscopic ellipsometer. Optical transmission spectra of TiO2 thin films were investigated in wide T range. The films characteristics were measured including Urbach tail, T influence on optical properties and disordering process. XRD studies were performed for structural characterisation of TiO2 thin films with different thickness.

Carbon nanotube fibers were doped with iron via Fenton reaction. The reaction in presence of CNT does not result in addition of hydroxide group but in strong introduction of iron into the carbon structure. A new type of composite material is obtained. High concentration of iron gives new properties of the basic CNT material like magnetic properties – ferromagnetism. Carbon nanotubes with magnetic properties are under further research.

Graphene nano-flakes and carbon nano tubes were used to fabricate acetone gases detection sensors. The sensors were made by screen printing technology. The aim is to obtain non-invasive sensors replacing the blood glucose tests. The method bases on ketoacidosis accompanying diabetes. Acetone exhaled with air is measured. Thin film titanium oxide and CNT or graphene nano-flakes sensors are printed on a ceramic substrate. Sensitivity test were performed with the new family of sensors.

A combined technique of screen printing and laser sintering of a paste based on the mixture of silver nanoparticles and silver micro flakes was used as a good method for rapid prototyping or short series production of printed electronics devices. The tests were done with two different substrates, Polyethylene Terephthalate PET and Polyimide PI foils. The aim is to push the technologies of printed electronics PE forward. Screen printing method involves pressing high viscosity ink/paste through holes or not masked part of screen by squeegee. The advantage of PE is that the manufacturing does not require clean rooms and high vacuum systems, what makes it very cost effective in numerable applications.

Aerosol jet printing is a technology which is able to form a micrometre size patterns directly on the substrate. Microscale electronics is to be efficiently printed. The ink is atomized to form a mist or fog of very small droplets below 1 um. Ink mist is transported to the printing head. Shear gas in the printing head focuses the mist into a micrometre size stream. The head prints on 3D substrates. Achievable narrow line dimensions make this technology comparable with conventional flat multistage photolithography. There was used nano-silver ink with ultrasonic atomizer.

Inkjet printed structures were manufactured and tested for paper-based packages. The aim is to master low cost printing technology directly on thin paper based bags and boxes, which are popularly used in shops. Electro conductive and dielectric areas are to be printed. Peltier cell was used to increase the quality of printouts on plain porous paper used for common packaging. Key issue in this printing technique is wettability of the paper by the ink and its penetration into paper. Not penetrated or smeared ink leads to short circuits in the impedance combs. SU-8 hydrophobic dielectric was used as lower and upper layer for the printed sensors.

CuO nanowires sensors of gases were researched. CuO layers were obtained in different thermal conditions by PVD and thermal oxidation processes. PVD builds C-Ni layer on Cu, which was then annealed. Two kinds of sensors showed different electrical responses to hydrogen and ammonia gases which was caused by various topography of the layers. The adsorption desorption mechanism of reacting gases with developed surface of CuO layer influences on the electrical response. CuO nanorods below 100 nm were synthesized by PVD and oxidation for sensors of NO2, H2S, C2H5OH, HCHO, CO and NH3. The nanorods were characterized by SEM, HRTEM and XRD.

High speed camera was applied in the analysis of the chip flow direction during turning process of difficult to be cut materials. Several series of tests of roughing turning were done. Chip formation and movement, including direction, speed and acceleration, is recorded by the camera. Advanced image processing algorithms were applied. The process of chip formation was modelled. All steps of the cycle of the chip breaking favourable for longitudinal turning of the Inconel 626 alloy were investigated.

Metal – dielectric nanocomposite modelling was used for percolation process visualization. Model was based on high voltage discharge in air between metallic discs modelling the metallic phase. Disks distribution map the type of conductivity. A test stand was built to measure flashover voltage. A relationship between the changeover voltage and the concentration was formed and percolation threshold was estimated. Jump voltage decreases with the concentration of nanoparticles. Percolation channels were recorded during discharges.

MIS/IS FET (Metal Insulator Semiconductor/Ion Sensitive Field Effect Transistor) technology with DLC (Diamond-Like Carbon) and SiO2/DLC thin films as the gate dielectric were fabricated to check relevant fabrication methods. The obtained DLC films show good adhesion to SiO2 layers on silicon substrate. High values of the threshold voltage are a consequence of charge presence at the SiO2/DLC interface. A better control of the deposition process, optimization of deposition process parameters may significantly improve the film properties. The aim of research is to obtain better ion sensitive FET structures designed for chemical sensing.

Electrically conductive acrylonitrile butadiene styrene ABS/copper composite filaments for fused deposition modelling FDM were fabricated for tests of additive manufacturing. There is a common need to develop new materials that can broaden the applicability of 3D printing.

Addition of metal powders, nanomaterials and other relevant additives to thermoplastic polymers, composites with better magnetic, electrically conductive or heat conductive properties etc. are obtained. The tests were made with copper powders as the functional phase, to obtain electrically conductive filaments, with ABS as the matrix. Above 80 wt% of copper in the composite the resistivity is no longer significantly reduced.

Titanium comb capacitor was designed and manufactured to check the alternative possibility of using titanium electrodes instead of golden ones. Lithography techniques were used for processing the obtained layer of the material. Substrate samples with a titanium layer have been designed and manufactured. The structures allow the impedance of living cells to be measured.

VIII. Advanced Applications

Video system integrator VSI is under development. It is a complex hybrid system consisting of hardware, firmware and software. It can integrate and distribute video signals from many different sources. Video concentration device VSD, a part of the VSI is a portable capturing video signals in various formats from a variety of sources and transmitting them to the VSI server. Due to high complexity, VCD is equipped with a diagnostic system providing the possibility to remotely manage it. Its functions include the update of the firmware and software, starting the special diagnostic version of the firmware and the software, low-level expert access. The VSD was realized on Zynq Ultra Scale+ MPSoC containing Kintex UltraScale+ FPGA and six ARM MPs. The MPSoC is connected with multiple DDR4 memories used by the video encoder and by the main multicore 64-bit ARM CPU running under Linus OS. The configuration of MPSoC is loaded from QSPI Flash chip or SD card. The video streams, stored in large database, are served on demand to different destination places.

The growing number of distributed energy sources connected to the low voltage network causes changes in the network operation conditions. The proper response to these changes from the distribution system operators is necessary to maintain the required power quality indicators without the need to limit the ability to connect new sources to the network. Photovoltaic systems, with the variability of meteorological conditions, are quite unpredictable. This implies the need to forecast not only daily and annual power consumption, but also generation of the prosumers. When the local production exceeds the consumption, power flow changes its direction, from the load upstream to the feed. In most cases, networks are designed for unidirectional power flow. A large share of dispersed generation can cause a change in this area – the power flows will become bidirectional. Exploitation phenomena were observed in LV networks with large share of distributed generation and their impact on the voltage profile in the network.

A non-invasive method to determine the technical state of passenger car wheel rims is researched. The method consists of a series of vibration and dimension measurement on a rim mounted in a diagnostic station. The measurements are taken on four positions of the rim of rotation versus constant excitation point angular position. The wheel rim natural frequencies distribution versus time and rotation angle are examined as diagnostic tool of rim fit for use classification from materials fatigue point of view. Joints of rim components are estimated to identify potential cracks or loss of integrity in the wheel rim structure. Performed experiments show that the natural frequency values of rim, the damping factor of natural rim vibration and rim diameters grouped in a spider chart allows an effective visual classification of car rim fit for use.

Evaluating energy consumption in wireless sensor networks is an issue researched by the designers of the IoT edge systems. Wireless sensor networks WSN are used in many domains related to industry, infrastructure protection, civil and military monitoring, scientific explorations, etc. Typically, the used WSN nodes are powered from batteries with limited energy. Hence, an important issue is to assure long lifetime of the network. Data transmission is the major energy consumer in IoT edge. Various energy usage schemes are applied to optimize energy consumption. One of the major methods, wherever it is relevant, is to bring the nodes into a deep sleeping mode and waking them periodically. Analysis was performed in detail concerning time and power components influencing energy consumption profiles. The derived original parameters are helpful to create power consumption models for specific applications.

UAV was used as a measurement tool in several applications in engineering and environmental protection. Remotely controlled flying models was equipped with different types of data gathering equipment like cameras, scanners, gauges, humidity sensors, pressure, air temperature, particulate pollution sensors, CO_2, PM10, PM2.5, formaldehyde, nitrogen monoxide, ozone, etc. There were built tools for semi-automatic or automatic processing of the collected data and computation of derivative results as: maps of air pollutants distribution, ortho-photo-maps, cloud of points or numerical models of terrains coverage NMTC or altitude maps of measured parameters distribution or pollution. Multi-parameter sensor head was integrated with the fixed wing drone hull. One of the aerially measured object was the municipal sewage and wastewater treatment plant. The use of drones for air pollution mobile monitoring, including the assessment of greenhouse gas emissions from sewage treatment facilities, as well as measurements of dust and gas pollution resulting from low emissions, brings many benefits, but unfortunately has also some limitations. The benefits include: relatively low purchase and operating costs, time saving in obtaining information, safety for the operating personnel, flexibility of equipment specifications, routine flights, the ability to carry out measurements in a radiologically, biologically, chemically contaminated areas.

Domestic usage of energy follows certain standard schemes. Nonintrusive appliance load monitoring system NILM enables real-time identification of currently used appliances by their profiles of energy consumption. The measured values are changes in the voltage and current consumed by a house. Electric meters with NILM technology are used by utility companies to survey the specific uses of electric power in different homes. NILM is considered a low-cost alternative to attaching individual monitors on each appliance. Several series of experiments were performed on houses to research on the method efficiency. The aim is to optimize the house energy usage and fit it to the global energy usage profiles, with the purpose to lower the costs. Verification algorithms are to be used like Random Forest and Rule Induction. Significance measures taking into account nonlinear relations between observed features are to be considered.

A method of matching generation graph of photovoltaic electric stations and consumers was implemented. Characteristic feature of this method is the application of morphometric analysis for assessment of non-uniformity of the integrated graph of energy supply, optimal coefficients of current distribution, that enables by mean of refining the powers, transferring in accordance with the graph, to provide the decrease of electric energy losses in the grid and transport task, as the optimization tool.

A solution to automatic vehicle counting and classification was implemented. Hybrid system consists of a set of remote measurement units connected to a central computing network node. Software package deployed for the system is based on digital video acquisition, processing, image recognition, and NN algorithms. The vehicles are detected and classified. The aim of work is to contribute to a wider project of building local structures for inteligent transortation system. The tested system is deployed on several parking lots adjacent to major motorways providing dense trafic.

IX. Conclusions, Wilga 2018, WILGA 2019

During its 42nd edition Wilga Symposium gathered nearly 400 participants during the first week of June 2018. Around 300 papers were presented in oral and poster forms, mainly by young scientists and Ph.D. students. Wilga Symposium worked out a positive tradition for free and friendly technical meeting of young science. Wilga 2019 will be organized traditionally in two editions Winter and Spring, in January 31 – February 02 and during the last week of May 25 – 02 June. Wilga Symposium data is available on the web: wilga.ise.pw.edu.pl. Young scientists active in electronics, photonics, telecommunications, mechatronics, robotics, ICT technologies and physics are warmly welcomed.

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