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ABSTRACTS

PhD Scientific Seminar

Faculty of Electronics and Automation
Technical University of Sofia, Plovdiv Branch

20 March 2024

Preface

The PhD Scientific Seminar of Faculty of Electronics and Automation is held annually since 2021. It has become an expected place for meetings between PhD students, young scientists and leading researchers at Technical University of Sofia, Plovdiv Branch. Over the years, the seminar gives the chance to the PhD students of the faculty to show and share their most interesting and significant results.

This book of abstracts presents the essence of progress which the PhD students of Faculty of Electronics and Automation gained in the period of March 2023 - March 2024. As a result it contains 11 resumes, which have been extended by presentations and demonstrations during the seminar.

We would like to thank all PhD students who have contributed to the seminar. To thank all those attendees who showed to the PhD students that they are important part of the scientific community of Technical University of Sofia, Plovdiv Branch.

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Table of Contents

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ALGORITHMS AND PROGRAMS DEVELOPMENT TO ENSURE PRODUCTION SYSTEM OPERATION WITH NETWORK COMMUNICATION

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The field of information and communication technologies is defined as one of the current areas of development of science and innovation in the world. Modern industrial automation is based on the integration of achievements in the fields of information, control, and communication technologies. In this meaning, the work is focused on developing solutions, algorithms, and programs to ensure the operation of intelligent production systems with network communication. The tasks are aimed at designing specialized modules for data collection and processing for diagnostics and notification in the maintenance and management of production processes. The research and analysis provided in the dissertation are focused on developing a comprehensive system for predictive support to help operators to make adequate decisions based on the accumulated, summarized and stored in a special database experience. It is planned to analyze in detail the existing methods for maintenance of technological facilities and sites, and their positive and negative sides will be analyzed. Existing software systems and standards for predictive diagnostics and maintenance will be thoroughly researched and analyzed. Based on the requirements for the predictive support system, the aim of this dissertation will be formulated. A widely used approach is based on data from previous developments and the current state of the forecasting process to determine how

much time is left before failures occur. The time remaining until the failure occurs is called "Remaining Useful Life (RUL)", which means "remaining useful time". Predictive maintenance is based on the condition, performed as a result, of a prognosis obtained from the analysis and evaluation of significant parameters of degradation of an element of the facility. It is planned to develop a software module to support decision-making on the condition, using intelligent methods for predictive diagnostics. The idea is to develop a module for analyzing production and reducing losses by using various algorithms and methods. The prognosis development for of the RUL, the ways of decision-making in the presence of alternatives and proposals for a model will be goal finding solutions and applying to the industrial system. The requirements for automated systems are becoming higher, and their performance is improved through the methods of self-optimization, self-configuration, self-organizing logistics, adaptive diagnostics.

So far the recent work is presented and published in three papers:

1) A. Petrov, A. Taneva, Network Design for Gathering Data in Manufacturing Process, International Conference AUTOMATICS AND INFORMATICS`2022, October 06 - 08, 2022, Varna, Bulgaria (ICAI'22) , **DOI:** 10.1109/ICAI55857.2022.9960027, 978-1-6654-7625-6/22/$31.00 ©2022 IEEE,
Electronic ISBN:978-1-6654-7625-6, **Print on Demand (PoD) ISBN:**978-1-6654-7626-3

2) A. Petrov, A. Taneva, Process Inspection and Data Collection for Manufacturing, International Conference AUTOMATICS AND INFORMATICS`2022, October 06 - 08, 2022, Varna, Bulgaria (ICAI'22) **DOI:** 10.1109/ICAI55857.2022.9960000 , 978-1-6654-7625-6/22/$31.00 ©2022 IEEE,

3) A. Petrov, A. Taneva, Algorithm for Pneumatic actuator control and diagnostics, 2023 INTERNATIONAL CONFERENCE AUTOMATICS, ROBOTICS & ARTIFICIAL INTELLIGENCE, June 16 - 19, 2023, Sozopol, Bulgaria **DOI:** 10.1109/COMSCI59259.2023.10315855

and a seminar to Control Systems Department on 26.11.2023.

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RESEARCH, MODELING AND CREATION OF SIMULATION MODELS OF INTERFERENCE STRUCTURES

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The computation of the parameters and values of optic interference systems is a very valuable and very laborious and time consuming work. With that in mind it is of essential importance to find ways and techniques to optimize it. With the addition of semi-modern technology in the face of multi-core and multi-thread CPUs and GPUs it is possible to research and explore millions of possible configuration faster than ever. With enough resources it is even possible to create a supercomputer which will find and create thousands of useful models from a both scientific and practical standpoint.

It is possible to look at a electromagnetic wave, which are both the sound and the light waves as a series of points in a 3D environment. Each of them having a value for its current power. When we add a fourth dimension, which in our case is the time, these values start to change. Terms like amplitude and phase gets added to the equation. When we include the fifth dimension, which is space, we can combine multiple waves, who begin to interfere with eachother. This phenomenon results in a single new wave – superposition of all the interfering waves. Apart from that there is also implied variety. Our world is not perfect and there are outside factors that need to be accounted for. Vibrations, temperature expansions and other imperfections of the materials, air pressure and humidity fluctuations are just to name a few.

All this complexity showcases the need of parallel computation techniques and big powerful computational machines. In par, specialists are also needed to program and operate them.

Although light and lighwaves have been heavily researched for a very long time we strongly believe that there are still some unknowns that deserve some proper attention, especially in laser technology. With each day we try to expand our knowledge on physics and combine it with what we know about parallel computing to create faster and better ways to find useful patterns.

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SECURE HETEROGENEOUS ARCHITECTURE

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Embedded processors are the core of smart and IoT devices. For the last two decades, they were primarily ARM instruction set based but since the RISC-V instruction set was introduced 14 years ago, things came to a state where RISC-V challenges ARM supremacy. Due to the open nature of this instruction set, it became popular for both industry and academic studies, as it enables freedom of design, implementation and scalability.

Along with the benefits, RISC-V becoming mainstream technology leads to an increased risk of cyber attacks, necessity for data protection and execution security. Many solutions to these challenges are ported from other platforms, new approaches were introduced and advanced researches are being conducted to handle the ever-existing security threads.

The latest technology and future development direction of RICS-V security research is still to be defined.

A common tendency in computer security especially implementing Root-of-Trust is isolation in terms of hardware resources and access to these resources. Best results can be achieved if there is a complete isolation, even between the execution flows of user programs, kernel and security targeted code, which naturally leads to the use of multi-processor systems.

Based on the security level of each processor it might or might not have access to the other processor resources thus defining one of the processors as a security core. These processors perform different computations and algorithms. To optimize the device means that these processor cores should not be identical but have the minimum functionality to perform their tasks. As RISC-V base instruction set includes just 47 instruction it means that we can have very small cores perform different tasks which minimizes chip size and power consumption.

Cyber-security faces constant attempts to exploit previously undiscovered security holes. While software can easily be patched and misbehavior detected by the user, hardware security issues can only be partially fixed by software resulting in performance degradation and can also go unnoticed by the user. Hardware implemented mechanisms can spot unauthorized code on very low level. Having a separate RISC-V RoT core which is able to identify security threads can significantly improve the reliability of a RISC-V base heterogeneous computer system.

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PARALLELIZING THE NEEEDLEMAN-WUNCH ALGORITHM USING GRAPHIC ACCELERATORS

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Bioinformatics is poised to play a critical role in future scientific discoveries due to the exponential amount of data generated in recent years. Bioinformatics aims to take advantage of all new technologies, including advances in computing power, new graphics cards and new algorithms, and apply them to large data sets generated by biological systems to answer questions that were previously impossible to answer. Bioinformatics has helped to revolutionize the sequencing that has occupied biologists for the last decade. New advances in this field have given scientists access to the genomes of hundreds of organisms. This has allowed them to gain a deeper understanding of how genetic material behaves in different species. But fully understanding these data requires biological knowledge, making bioinformatics and its interdisciplinary approach of particular importance.

The Needleman–Wunsch algorithm is an algorithm used in bioinformatics to align protein or nucleotide sequences. The algorithm was developed by Saul B. Needleman and Christian D. Wunsch and published in 1970.The algorithm essentially divides a large problem (e.g. the full sequence) into a series of smaller problems, than optimizes the results. The algorithm is widely used for optimal global alignment, especially when the quality of the global alignment is of the utmost importance. The algorithm assigns a score to every possible alignment and his

purpose is to find all possible alignments having highest score.

The DNA sequences are available in FASTA format, which are stored in NCBI (The National Center for Biotechnology Information). The structure of one FASTA file is presented by a thousand rows – a nucleotid sequences. A large computing resource is required for comparing and searching for matches. The graphical accelerators are suitable for this problem. GPUs (Graphical Processing Units) have thousands of cores,which can be used for parallel comparison. In 2006 appears the CUDA (Compute Unified Device Architecture) architecture, which can be used for parallel programming, using languages like FORTRAN/C, ACC, C++.

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APPLICATION OF AI IN MANAGEMENT INFORMATION SYSTEMS AND BUSINESS ANALYTICS

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Management information systems (MIS) are information systems used for decision-making, and coordination, control, analysis, and visualization of information regarding the processes, people and technology employed within an organizational setting. The field of MIS increasingly often relies on the implementation and integration of AI tools to transform aggregated organizational and business data into insights for improving business decisions as well as for development of process automation solutions.

Our previous reserch revolves around the implementation of intelligent robotic process automation (iRPA) for document extraction and information extraction within the most widely distributed ERP system SAP Business Technology Platform with the goal of reducing human workers' involvement in time-consuming low value tasks. A use case scenario quantifying the business value of integrating iRPA bot chains in small and medium-sized enterprises was developed. The research was summarized in two papers and presented at the International Conference Automatics and Informatics (ICAI 2022):

- Intelligent Robotic Process Automation for Small and Medium-sized Enterprises, Stoykova, S., Hrischev, R., Shakev, N., **DOI:** 10.1109/ICAI55857.2022.9960077
- Bot Development for Intelligent Automation in ERP Systems, Stoykova, S., Hrischev, R., **DOI:** 10.1109/ICAI55857.2022.9959995

Recently our research efforts were focused on preparing a comprehensive literature review on the topic of application of AI in MIS with the aim of identifying opportunities, challenges and future directions for development in this field. Within the review the following were identified: types of AI tools utilized in and developed for MIS, types of platforms for AI deployment, as well as business categories that most benefit from the introduction of AI in terms of value generated. The study recognized gaps in previous research efforts in the field and offered future research directions that can bridge these gaps:

- Artificial Intelligence for Management Information Systems: Opportunities, Challenges, and Future Directions, Stoykova, S., Shakev, N., Algorithms 2023, 16, 357, **DOI:** 10.3390/a16080357

Two of the research directions identified in the prepared literature review have been further explored: process and workflow automation, chatbots for automation of operator training and customer interaction.

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New Algorithms And Models For The Work Of Intelligent Assistant Agents In a High-Risk Environment

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The goal of the dissertation work is to develop and research new models and algorithms for the operation of intelligent assistant agents in a risky environment. Research is focused on the modeling of a virtual 3D simulator and virtual 3D intelligent agents to be assistants in an electric substation or an object of the electric power system for medium and/or high voltage.

An overview has been made of the most wide-spread and widely used types of agents in artificial intelligence and in different environments, including goal-based agents, belief-desire-intention (BDI) agents, conversational agents, and others. The various types of agents possess their own unique features and capabilities, which make them suitable for different tasks and applications within this chosen field of work. Understanding the characteristics of each kind of agent is crucial, in order to make correct decisions about which agent is best suited to the specific needs.

The goal of this overview is to go over some of the currently most widely used classifications of intelligent agents as well as their architectural solutions and their range of applications. There are different types of classifications which are discussed – such as the methods in which the agents interact with their surrounding environment; their capabilities of learning, retaining and using information; based on a goal or utility; the process by which they determine their decisions and chosen actions or based on the way they communicate with the user.

Radoslav Furnadzhiev is a PhD student at the Technical University Sofia branch Plovdiv, Faculty of Computer Systems and Technologies. He has experience with development of data-intensive applications where large volumes of data need to be processed, analyzed, and stored. His PhD research interests and activities are in exploring Orchestration and Coordination architecture patterns for achieving scalability and availability in modern containerized applications. Radoslav holds an MSc degree in Computer Science from the same university.

SCHEDULING AND RESOURCE ALLOCATION OF CONTAINERIZED APPLICATIONS

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Cloud computing has gained a major foothold in information technology in recent years. It has allowed for easy on-demand access to computational resources and provides many advantages to its users like automatic scaling, ease of management, and dynamic resource pooling. Several architectural styles have been developed that leverage these technologies for developing and deploying complex software solutions.

Container-based microservice architectures are an increasingly popular technique for packaging and deploying cloud-based applications. It involves encapsulating an application and its dependencies into a container image that can be run consistently across different environments. Wide adoption of containerization technologies like the container orchestration platform Kubernetes that enables the deployment, scaling, and management of containerized applications in a cloud environment. The process of scheduling containerized applications on a Kubernetes cluster is a complex and challenging task that requires advanced algorithms and techniques. Scheduling can be designed to be reliable and predictable, ensuring that workloads run smoothly and without disruption. Resource fragmentation and scheduling inefficiencies due to over-provisioning for peak loads can exacerbate issues of low resource utilization, and high operational costs. Overall, resource fragmentation and non optimal scheduling can have detrimental effects on performance and reliability of cloud systems, highlighting the importance of effective resource management and scheduling algorithms in cloud computing environments.

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Artificial Intelligence Systems in Robotics

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In the era of Industry 4.0 and the dawn of Industry 5.0, the advancement of artificial intelligence systems and industrial robotics is developing at an extremely fast pace. The main users of industrial robots in recent years are the electrical and electronic industries. Seek for new artificial intelligence algorithms for better human-robot collaboration is of increasing interest to engineers and researchers. Robotic systems with collaborative functions, the so-called cobots are a new generation of robots that have been developing steadily in recent years. The International Federation of Robotics (IFR) reports a 50% increase in collaborative robots deployed in industry for 2021.

Collaborative robots are the result of the successive development of industrial robotics. Their main advantages are expressed in the need for a small space for installation and operation, easy programming and adaptation to a specific production, without the need for special qualification of the programmer, the possibility to replace people in boring and repetitive operations, as well as to overcome many challenges related to with the ergonomics of work spaces. Apart from the economic advantages, last but not least is the possibility of safe collaboration in the shared workspace with minimal risk of occupational accidents for the workers.

Not every robotic system that makes independent decisions has artificial intelligence. The using of artificial intelligence algorithms allows the system to "sense" the surrounding external environment and determine the best way to interact with this environment when performing a specific task. Autonomous operation of the robotic system can be enabled with a high level of artificial intelligence algorithms. The process of human-robot communication and programming approaches increasingly easy to use. Modern communication technologies include hand gestures, face tracking, voice commands and tactile sensors, etc.

There is no still generally accepted definition of artificial intelligence, as well as specific limits of technical requirements and basic characteristics. For example, The European Commission define AI as "systems that exhibit intelligent behavior by analyzing their environment and — with some degree of autonomy — taking action to achieve specific goals.” The lack of a clear definition of the concept of artificial intelligence, as well as technical requirements and parameters regarding the components of an AI system, also leads to discussions about which algorithms and methods should be classified as such. The main goal of applying artificial intelligence in robotics is to achieve better control in the dynamic and undefined environment in real-time or offline, as well as in large variations in the work cycle.

Future development directions are probabilistic algorithms and high AI, through which a higher level of cognitive and semantic intelligence can be achieved. Using the knowledge of the human operator and the collaborative capabilities of the robots, the production lines will take a new direction for further technical improvements.

In conclusion, the main challenges facing researchers are in searching and finding solutions to create robotic systems working in human-robot collaboration, guaranteeing unambiguous two-way communication, with the aim of the highest degree of human safety, improved energy efficiency, easy reprogramming, adaptability, intuitive interface, which in turn will lead to improved economic indicators, as well as new areas of application and implementation.

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VISUAL SERVOING IN DOOR OPENING TASK FOR OMNIDIRECTIONAL MOBILE MANIPULATOR

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The general door opening task takes special place among the mobile robot operation challenges. Research interest in the topic grows in various directions, from mathematical modelling to energy saving solutions. Still, door recognition and locating, and further robot/manipulator approaching algorithms are the main and must tasks have to be solved.

The task of manipulator/robot door opening evolves the collaborative functions of service, industrial and military robots. Many examples of its implementation into various applications could be found in the literature. Such manipulators take part in risky form human rescue operations at nuclear power plants, dangerous buildings, in the military army, supporting soldiers in their missions (for example Boston Dynamics's SpotMini).

Problems also differ, but they could be grouped as follows: i) difficulties caused by construction limitations; ii) visual data reading and processing; iii) ensuring autonomous control and stability.

The research presents an initial stage of autonomous control of an omnidirectional mobile manipulator based on visual information. An algorithm of door opening task is proposed and implemented on a custom configuration, which is assembled for this purpose. Thus, it relies on two types of sensory information – distances, measured by a LiDAR and visual information gathered by a smart camera. The accent is put on giving a simple solution of door/door handle recognition and its coordinates extraction as very important subtasks of the overall autonomous door opening task by a mobile manipulator.

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Hand Gesture based Concept of Human - Mobile Robot Interaction with Leap Motion Sensor

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A precise gestural control interface of a four-wheel mobile robot is presented. The introduced hand gesture based concept of human - mobile robot interaction is inspired by the approaches of Cyber-physical systems, which combine cyber and physical world solutions. The goal is to create an effective human-machine interface that will allow more intuitive interaction between the operator and the robot. Thus, a human operator can initiate and control various maneuvers via specific hand gestures. A KUKA youBot omnidirectional mobile platform and a Leap Motion Sensor (LMS) have been used to implement and evaluate the proposed gestural control strategy.

Implementation: The proposed approaches are evaluated in an indoor environment, using a four-wheeled mobile robot platform KUKA youBot. ROS network with relevant nodes is designed. ROS messages are published/subscribed over a local network between the KUKA youBot (the master node) and the other equipment (sensors).

The proposed hand gesture based concept of human - mobile robot interaction with LMS could be easily implemented to other mobile robots or even to robot-manipulators. It could be used as a base for other algorithms, which investigates the human-machine interaction and collaboration in shared workspace.

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Methods and Means for Remote Measurements of Atmospheric Air Parameters

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Measuring different parameters of atmospheric air is important for air pollution control, monitoring of CO2 in the light of global warming, weather forecasting, environment monitoring for public safety and etc. Air quality is one of the most important factors for human life. It is vital to monitor indoor and outdoor air parameters and to do appropriate measures. In the recent years the technology advances increasingly and that makes possible to produce many types of low-cost sensors and microcontrollers that have low power consumption.

Poor air quality is one of the key factors that contribute to low quality of life and also to number of diseases, including cardiovascular and pulmonary. The pollutants that contribute to poor air quality in cities are mainly from on-road vehicles and can be classified in two groups – primary and secondary. The first group are produced directly by pollution sources like gases from combustion, some of which are Nitrogen Oxides NO2, Sulfur Dioxide SO2, CO and CO2, or particulate matter (PM) with various sizes, for example fine particles PM2.5. PM in atmosphere are complex mixtures of elemental carbon (EC), organic carbon (OC), mineral dust and water aerosols. Within this group are organic compounds, classified as Volatile Organic Compounds VOC. Some of them are benzene, toluene, ethylbenzene, and xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and

polychlorinated dibenzo–p–dioxins and dibenzofurans (PCDD/Fs). They are mutagenic and possibly carcinogenic. The other group – secondary pollutants are produced not directly but as a reaction in the atmosphere from the primary contaminates. One example is Ozone O3, which is toxic. So, it's important to monitor outdoor as well as indoor air quality in order to take appropriate measures such as frequent ventilation, managing traffic in big cities or increasing green spaces in urban areas.

Sensors that are examined are of different types – from the metal oxide class as well as low-cost particulate matter sensors. Meteorological parameters of atmospheric air are of interest because of their link with air pollution. The system under development uses heterogenous LPWAN wireless protocols like LoRaWAN, 802.15.4 for different use scenarios – stationary and mobile measurements. The results from the measurements are stored in database and presented to the user in the form of web page.