SUMMARY OF THE MAIN RESULTS AND SCIENTIFIC CONTRIBUTIONS

of Assist. Prof. Dr. Eng. Plamen Vasilev Vasilev,

for participation in the contest for the academic position of "Assoc. Prof." in the field of higher education Technical Sciences, professional field 5.2. Electrical Engineering, Electronics, and Automation,

scientific specialty - "Automated Systems for Information Processing and Control", announced by UCTM in State Gazette issue No. 68/13.08.2024.

Scientific works include 28 publications, distributed as follows: 12 publications in issues, referenced and indexed in world-renowned scientific information databases (10 of them are presented as equivalent to a monographic work) and 16 in peer-reviewed journals or edited collective volumes. The most general publications, having the nature of research with a scientific, scientific-applied, and applied orientation, can be conditionally divided according to the subject of the research problems into the following main groups:

• Advanced approaches in the design and development of Manufacturing Operations Management systems.

• Formalization of the design and development stages of information systems.

• Design and development of supervisory control and data acquisition and visualization

• Design and development of mobile applications for virtual and augmented reality and their integration with information systems for different purposes

• Advanced approaches to system integration

• Production automation

• Cyber-physical systems

• Mathematical modeling and optimization of technological processes

• Robotics

I. Advanced approaches in the design and development of Manufacturing Operations Management systems.

The following publications are included in this direction: I.(9), II.(8), II.(9), II.(10), II.(13), II.(14)

Much of the research is related to the applicability and use of the IEC/EN BDS 62264 (ANSI/ISA-95) standard as a descriptive approach and framework for the design of information systems of different hierarchical levels. To the greatest extent, the design and development of functionalities

of the Manufacturing Operational Management Systems (MES/MOM) are advocated, through the use of the models and objects of IEC/EN БДС 62264, as well as the application of other related standards, such as ISO 22400 (II.(13)), RAMI4.0 (II.(10), II.(11), II.(12)), etc.

II.   Formalization of the design and development stages of information systems.

The following publications are included in this direction: I.(5), I.(8), I.(10), II.(15), II.(16)

Research is based on the formalization of design processes, through the use of standard UML models and diagrams and architecture development based on them (MDD, MDA).

III.   Design and development of supervisory control and data acquisition and visualization

The following publications are included in this direction: I.(3), I.(4), II.(1), II.(5)

Development of supervisory control systems at the second hierarchical level, solving specific tasks for changing and maintaining controller setups, and collecting data on process variables. Some of the publications are related to the development of a multi-functional operator station under the ICTinSES project.

IV.   Design and development of mobile applications for virtual and augmented reality and their integration with information systems for different purposes

The following publications are included in this direction: I.(6), II.(10)

The capabilities of mobile application development using the Unity PC game development platform and the Vuforia Engine to develop virtual and augmented reality applications are presented. The possibility of embedding additional functionalities was used, by writing C# scripts, in particular, extracting data from an external relational database, and presenting it on a mobile device.

V.   Advanced approaches to system integration

The following publications are included in this direction: I.(2), II. (1), II. (2), II. (7), II.(6)

Publications from this point are related to finding methods and means of implementing communication, using standard protocols, between devices and systems with different communication capabilities.

VI.   Production automation

The following publications are included in this direction: II. (3), II. (4)

The publications are related to finding the optimal control of operating modes of complex interconnected MIMO objects and installations and the study of the effect of the proposed solutions in specific examples.

VII.   Mathematical modeling and optimization of technological processes

The following publications are included in this direction: II. (11), II. (12)

Standards describing cyber-physical systems and their properties are discussed in this group of publications. A parallel is drawn with other existing standards and approaches for realizing the cyber-physical capabilities of assets without embedded intelligence are outlined.

VIII.   Cyber-physical systems

The following publications are included in this direction: I. (1), I. (7)

Mathematical models of complex multi-connected objects relevant to industry have been compiled. Mathematical models are used to solve optimization problems, the solution of which gives justified results, with scientific and scientific-applied dimensions.

IX.   Robotics

The following publications are included in this direction: II. (17), II. (18)

Robotic, wireless devices with proposed application in minimally invasive surgery (MIS) have been implemented. Test results of the devices are presented.

Contributions under indicator I:

I. (1) – Mathematical models have been developed, describing the statics of absorption columns for extraction of nitric acid. A software package has been developed for the simulation of column behavior in nitric acid production. Simulations were carried out and column profiles were taken. In conclusion, integration options between high- and low-pressure nitric acid production are given.

I. (2) – A low-cost, fault-tolerant, distributed network architecture is implemented, taking into account best practices and recommendations for its construction at each hierarchical level.

I. (3) – An architecture of a multifunctional, platform-independent operator station based on a low-level programming language Tcl/Tk is proposed, the architecture of which consists of: a communication block, an interface block, a block for additional signal processing, a block for simulations and training, a database, a block with a knowledge base and a graphical interface with video signal integration capabilities. Possible applications are given in Supervisory Control Systems, operator station for operative treatment, and for using the graphical interface to receive video signals from various sources.

I. (4) – A virtual and augmented reality mobile application was developed as an upgrade to the proposed operator station in I. (3) for laparoscopy purposes. For this purpose, an additional database has been developed to store data from a laparoscopic instrument connected to the operating station. The database stores characteristics of various instruments, as well as tissues and organs. Upon receiving contact data with a surface and depending on the data on its characteristics, the mobile starts a training video giving data on the measured values of the touched organ. The created application is applicable in the training of medical personnel.

I. (5) – A model-based approach to design the architecture of a software system based on the multifunctional operator station presented in I. (3), I. (4) is presented. UML models and diagrams

describing the stages of design and development of the structure and functionalities of the system were developed.

I. (6) – The system described in I. (5) was implemented, and the mobile application for virtual and augmented reality was further developed and modified. Added a 3D model of human organs (liver) which is visualized when receiving signals from the laparoscopic instrument. The effect of touch and pressure on different samples with different physical characteristics by using different specially designed tips is described.

I. (7) – New properties of interconnected MIMO objects are defined that characterize and evaluate the change in behavior of these objects. A scientific experiment was conducted proving that the used linear models describing a system of interconnected reservoirs with relatively small dimensions show unsatisfactory results when describing large multi-connected reservoirs. Additional experiments were carried out, aiming to give satisfactory results in reducing the non-linearities by changing the design of the tanks.

I. (8) – UML class diagrams describing manufacturing resources in the field of electron beam technologies were developed. A domain model of an electron beam welding installation was made, describing the structure of the installation and various modifications of the functions depending on the operating mode used.

I. (9) – In the presented publication, the problem of non-uniform scheduling of small batches in a woodworking plant under progressive electricity prices after exceeding pre-ordered batches is considered. A solution to the formulated multi-criteria optimization problem is proposed by using the knapsack algorithm to be implemented in the constrained planning stage of the Operational Production Management System. UML diagrams of the interactions describing the planning stages were developed. A proposal is given for the use of an "elastic" knapsack where order scheduling continues as long as the progressive price of electricity is acceptable.

I. (10) – Conceptual development of an information health system is presented, aiming to process big data and the results to help the personal doctors in the Bulgarian health system. A conceptual model has been developed including the introduction of the Electronic Health Record, warnings of deterioration of patients' vital signs, through the submission of signals from portable devices, Remote monitoring of vital signs, preventive health analyses, telemedicine and combining big data with medical images. Particular attention is paid to data generated by portable devices. A model-based classification of objects was developed, and the personnel model from the IEC/EN 62264 standard was used as the basis of the classification.

Contributions under indicator II:

II. (1) - Integration between Distributed Control System (DCS) and Supervisory Control and Data Acquisition System (SCADA) MIK 5000Se with Matlab was implemented, through the use of OPC DA communication protocol and Matlab OPC Toolbox. Experiments were made to transmit data from simulation models from the Matlab Simulink environment to the Base Microprocessor

Station (BMS MIK-5000). Possibilities for personnel training and the use of simulations for control of complex objects are discussed.

II. (2) – A comparative analysis of blade servers from different manufacturers was made, and generalized selection criteria were selected. Benchmarking software products were used and a study was made between blade servers with equivalent performance from several leading manufacturers. By means of the evaluation criteria, advantages and disadvantages of the servers used in the study are indicated. Results are presented and conclusions are drawn.

II. (3) – Distillation column simulation models were developed using the software product UniSim Design Suite. Static and dynamic operating modes of the column were studied, based on which control parameters of regulators were selected and control was simulated by means of certain adjustable quantities.

II. (4) – A software product was developed and implemented as part of the second level of nitric acid production management at Agropolychim AD - Devnya. The program product SETPOINT, as part of COMSYS, was developed to solve an optimization problem with input data of 153 parameters, for the control of a nitric acid production plant by changing the setpoints of ten controllers. Technical and economic indicators are presented, showing the results of the operation of the optimization algorithm.

II. (5) – By using the software product UniSim Design Suite, the processes and control systems in an ethanol-water mixture rectification column were modeled. An environment has been developed for training in modeling and management of technological objects at UCTM.

II. (6) – The working principle of two communication protocols OPC and CAN is reviewed. Heterogeneous communication environment for data transmission between devices supporting CAN protocol to devices and systems supporting OPC communication is realized.

II. (7) – A communication interface module enabling web communication using traditional OPC technologies has been implemented. To achieve the goal, an integration solution for communication between SCADA systems with different capabilities has been developed. The web-based Ignition SCADA system was used. The integration results and architecture of the developed connection are presented.

II. (8) – A concept for the development of Manufacturing Operational Management Systems in the context of the Industry 4.0 paradigm and accompanying new technologies is presented. Cyber-physical systems, the decentralization of computing capabilities depending on the level of production assets, vertical and horizontal integration, the use of the Internet of Things, Cloud technologies and the statistical processing of Big Data are listed as the main drivers of change. MOM4 Manufacturing Operational Management Systems is examined as a basis for the design and development of solutions, part of the paradigm for Industry 4.0.

II. (9) – The publication reconciles two dissimilar standards, on the one hand ANSI/ASHRAE/ACCA Standard 180-2008 Standard Practices for Inspection and Maintenance of Building Ventilation, Heating and Air Conditioning Equipment, and on the other hand IEC/EN BDS 62264. The recommended procedures for maintenance of building facilities were used to

develop Maintenance Definitions, which were subsequently used to plan preventive maintenance of building facilities in a shopping center.

II. (10) – The relationship between the RAMI4.0 and IEC/EN BDS 62264 standards at the Equipment Model level and what role the equipment plays in an organization is presented. The Definition of Operations model is presented, which was used as a basis for the development of an informational, augmented reality mobile application to present information about the service and maintenance procedures of a facility when it is identified.

II. (11) – Areas of overlap between the RAMI4.0 and IEC/EN BDS 62264 standards are presented. The examined correspondences between the standards aim to prove the concept that the two standards are focused on the same subject presented from a different perspective.

II. (12) – Continuation of II. (11), which presents a solution for developing an administrative shell of the I4.0 component models without built-in intelligence. Means and mechanisms are presented that can be used for any kind of asset depending on what role from the architecture axis of the Reference Framework Architecture Model (RAMI4.0) they fulfill.

II. (13) – A rationalization of an existing architecture based on the Production Capability Model of the IEC/EN BDS 62264 standard is proposed, which takes into account the multidimensional nature of production schedules, the interrelationships between production capacities and their continuous change. Examples are given of assessing the overlap between planning and execution using Key Performance Indicators and their use in taking corrective action on production schedules.

II. (14) – Models and diagrams of electron beam welding processes based on IEC/EN BDS 62264 have been developed, aiming to be used in the construction of an Operational Production Management System. A sequence diagram has been developed for performing emergency stop procedures in case of deviation from set parameters for different operating modes of the plant.

II. (15) – The planning processes are modeled, according to the standard IEC/EN BDS 62264, taking into account the characteristics of a woodworking SME. Through UML diagrams, the use cases in the planning process are described, and as a result, a model described through an activity diagram for the phasing of production order planning is proposed.

II. (16) – A model-driven approach to the development of Manufacturing Operational Management Systems is presented. A model-driven architecture is proposed to develop concept-independent models -> Platform-independent models -> Platform-specific models leading to automatically generated code. An example of the development of IEC/EN BDS 62264 models for a woodworking SME is given, in which they are gradually supplemented with specific details, in the process of gathering requirements, subsequently a diagram of the interactions between the objects (databases) is generated from them.

II. (17) – The development of a wireless robotic device as part of a minimally invasive and laparoscopic surgery tool that detects sudden abnormal changes in heart rhythm and can provide an alert to the personnel performing the procedure is presented. The proposed device has the

possibility of connection with smart glasses, through which additional information from the robotic device can be presented.

II. (18) – A group of intelligent robotic devices for minimally invasive surgery are presented, including: A robotic diagnostic device that takes into account the reaction of tissue formations to mechanical microcontacts; A robotic therapeutic device for microwave irradiation of tissues by means of a specialized manipulator determining the duration and intensity of radiation. A block diagram of the architecture is presented, including the microcontroller with a "fast" ADC and communication channels; A robotic wireless device for monitoring tissue formations by monitoring ECG changes; A manipulation tool for squeezing, holding and moving irregularly shaped objects. The stand-alone wireless module is described and experimental performance of the instruments is shown.