





# CPS&C 2019 Programme & Abstracts International Conference Cyber-Physical Systems and Control St. Petersburg, Russia • 10-12 June 2019



Dear colleagues,

We are pleased to welcome you to the International Conference on Cyber-Physical Systems and Control (CPS&C'2019) in beautiful St. Petersburg, Russia – the city of palaces, museums and science – in Peter the Great St. Petersburg Polytechnic University that celebrates its 120th anniversary this year.

This conference draws upon the experience of previous research events that have focused on information technologies, system analysis, engineering and control and have been hosted by Peter the Great St. Petersburg Polytechnic University in partnership with leading European and Russian academic institutions. The most significant in series of these events were the International Conference System Analysis in Engineering and Control (since 1998), the Distributed Intelligent Systems and Technologies Workshop (since 2008), the International Scientific Symposium Automated Systems and Technologies (since 2014), the International Conference Network Cooperation in Science, Industry and Education (in 2016), each attended by hundred participants.

CPS&C'2019 is dedicated to the 35th anniversary of the partnership relations between Peter the Great St. Petersburg Polytechnic University and Leibniz University of Hannover.

Cyber-Physical Systems (CPS) are a new generation of control systems and techniques which help promote prospective interdisciplinary research. A wide range of theories and methodologies are being investigated and developed in this area to tackle complex and challenging problems. Therefore, CPS can be considered as a scientific and engineering discipline that is set to make impact on future industrial and societal-scale systems characterised by deep integration of real-time processing, sensing, and actuation across logical and physical heterogeneous domains.

CPS&C'2019 aims to bring together researchers and practitioners from all over the world and to reveal cross-cutting fundamental scientific and engineering principles that underpin the integration of cyber and physical elements across all application fields. The conference agenda includes keynote and plenary lectures, sessions and discussions.

# Conference Co-Chairs

Professor Michael Krommer, Vienna University of Technology, Austria Professor Dmitry G. Arseniev, Peter the Great St. Petersburg Polytechnic University, Russia Professor Ludger Overmeyer, Leibniz University of Hannover, Germany

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- Vyacheslav P. Shkodyrev Chairman
- Aleksandra V. Loginova
- Vyacheslav V. Potekhin
- Konstantin K. Semenov

# Monday, 10 June, 2019

Academic Building, Grazhdansky Pr. 28	βA
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09:00-10:00	Registration
10:00-10:30	<b>Open Ceremony</b> Professor Rudolf Pichler, Graz University of Technology, Austria Professor Vyacheslav P. Shkodyrev, Peter the Great St. Petersburg Polytechnic University, Russia Nikita A.Utkin, Technical Committee 194 Cyber-Physical Systems, Moscow, Russia Nikita M. Kuprikov, Academy of Standardisation, Metrology and Certification, Moscow, Russia
10:30-12:50	<b>Plenary Session</b> Chairpersons: Professor Rudolf Pichler, Graz University of Technology, Austria Professor Vyacheslav P. Shkodyrev, Peter the Great St. Petersburg Polytechnic University, Russia
10:30-11:00	<b>Keynote Lecture</b> SEAMLESS DATA INTEGRATION IN A CYBER-PHYSICAL PRODUCTION SYSTEM WITH HIGHLY HETEROGENEOUS FACILITIES – ARCHITECTURES AND USE CASES FROM A LEARNING FACTORY Professor Rudolf Pichler, Graz University of Technology, Austria
11:00-11:30	<b>Keynote Lecture</b> PHYSICS OF MIND - COGNITIVE APPROACH TO INTELLIGENT CONTROL THEORY Professor Leonid Perlovsky Harvard University, MA, USA
11:30-11:50	Coffee break
11:50-12:20	<b>Keynote Lecture</b> AN OVERVIEW OF PRACTICAL ONTOLOGY IMPLEMENTATION IN DECISION SUPPORT SYSTEMS Professor Tatiana A. Gavrilova and Ass. Professor Dmitry V. Kudryavtsev St. Petersburg State University, Russia
12:20-12:50	<b>Keynote Lecture</b> CYBER-PHYSICAL SYSTEMS AND CLAUSEWITZ PRINCIPLES Professor Alexander K. Belyaev Institute of the Problems of Mechanical Engineering of the Russian Academy of Sciences, Russia
12:50-13:40	Lunch

	Sessions					
13.40-15.40	Fundamentals 1 Room 220	Technologies 1 Room 220a	Applications 1	Education and Social Aspects 1 Room 217		
13:40-13:55	F1-1	T1-1	A1-1	E1-1		
13:55-14:10	F1-2	T1-2	A1-2	E1-2		
14:10-14:25	F1-3	T1-3	A1-3	E1-3		
14:25-14:40	F1-4	T1-4	A1-4	E1-4		
14:40-14:55	F1-5	T1-5	A1-5	E1-5		
14:55-15:10	F1-6	T1-6	A1-6	E1-6		
15:10-15:25	F1-7	T1-7	A1-7	E1-7		
15:25-15:40	F1-8	T1-8	A1-8	E1-8		
15:40-16:00	Coffee break					
	Sessions					
16.00-18.15	Fundamentals 2 Room 220	Technologies 2 Room 220a	Applications 2 Room 316	Education and Social Aspects 2 Room 217		
16:00-16:15	F2-1	T2-1	A2-1	E2-1		
16:15-16:30	F2-2	T2-2	A2-2	E2-2		
16:30-16:45	F2-3	T2-3	A2-3	E2-3		
16:45-17:00	F2-4	T2-4	A2-4	E2-4		
17:00-17:15	F2-5	T2-5	A2-5	E2-5		
17:15-17:30	F2-6	T2-6	A2-6	E2-6		
17:30-17:45	F2-7	T2-7	A2-7	E2-7		
17:45-18:00	F2-8	T2-8	A2-8	E2-8		
18:00-18.15	F2-9	T2-9	A2-9	E2-9		
18:30	Social Event by invitation of SPbPU					

# Tuesday, 11 June, 2019

Research Building, Polytechnicheskaya Str. 29

10:00-12:30	Ceremony dedicated to the <b>35th anniversary</b> of the partnership relations between Peter the Great St. Petersburg Polytechnic University and Leibniz University of Hannover
12:30-14:00	Lunch

# Academic Building, Grazhdansky Pr. 28A

14:10-15:40	Plenary Session Chairpersons: Professor Ludger Overmeyer, Leibniz University Hannover, Germany Professor Dmitry G. Arseniev, Peter the Great St. Petersburg Polytechnic University, Russia				
14:10-14:40	<b>Keynote Lecture</b> LAYOUT OPTIMIZATION FOR CYBER-PHYSICAL MATERIAL FLOW SYSTEMS USING GENETIC ALGORITHM Professor Ludger Overmeyer, Leibniz University Hannover, Germany				
14:40-15:10	<b>Keynote Lecture</b> CYBER-PHYSICAL SYSTEMS IN COMPLEX TECHNOLOGIES AND PROCESS CONTROL Professor Branko Katalinič, Vienna University of Technology, Austria				
15:10-15:40	<b>Keynote Lecture</b> MULTI-PARADIGM MODELLING OF CYBER-PHYSICAL SYSTEMS Professor Hans L. M. Vangheluwe, University of Antwerp, Belgium				
15:40-16:00	Coffee break & Gallery opening of artist Aleksandr Dudorov				
	Sessions				
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16.00-18.00	Fundamentals 3 Room 220	Technologies 3 Room 220a	Applications 3 Room 316	Education and Social Aspects 3 Room 217	
<b>16.00-18.00</b> 16:00-16:15	Fundamentals 3 Room 220 F3-1	Technologies 3 Room 220a T3-1	Applications 3 Room 316 A3-1	Education and Social Aspects 3 Room 217 E3-1	
<b>16:00-18:00</b> 16:00-16:15 16:15-16:30	Fundamentals 3 Room 220 F3-1 F3-2	Technologies 3           Room 220a           T3-1           T3-2	Applications 3 Room 316 A3-1 A3-2	Education and Social Aspects 3 Room 217 E3-1 E3-2	
<b>16.00-18.00</b> 16:00-16:15 16:15-16:30 16:30-16:45	Fundamentals 3 Room 220 F3-1 F3-2 F3-3	Technologies 3           Room 220a           T3-1           T3-2           T3-3	Applications 3           Room 316           A3-1           A3-2           A3-3	Education and Social Aspects 3 Room 217E3-1E3-2E3-3	
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<b>16:00-18:00</b> 16:00-16:15 16:15-16:30 16:30-16:45 16:45-17:00 17:00-17:15 17:15-17:30	Fundamentals 3 Room 220 F3-1 F3-2 F3-3 F3-4 F3-5 F3-6	Technologies 3         Room 220a         T3-1         T3-2         T3-3         T3-4         T3-5         T3-6	Applications 3           Room 316           A3-1           A3-2           A3-3           A3-4           A3-5           A3-6	Education and Social Aspects 3 Room 217E3-1E3-2E3-3E3-4E3-5E3-6	
<b>16.00-18.00</b> 16:00-16:15 16:15-16:30 16:30-16:45 16:45-17:00 17:00-17:15 17:15-17:30 17:30-17:45	Fundamentals 3 Room 220 F3-1 F3-2 F3-3 F3-4 F3-5 F3-6 F3-7	Technologies 3         Room 220a         T3-1         T3-2         T3-3         T3-4         T3-5         T3-6         T3-7	Applications 3           Room 316           A3-1           A3-2           A3-3           A3-3           A3-4           A3-5           A3-6           A3-7	Education and Social Aspects 3 Room 217E3-1E3-2E3-3E3-3E3-4E3-5E3-6	
16.00-18.00         16:00-16:15         16:15-16:30         16:30-16:45         16:45-17:00         17:00-17:15         17:15-17:30         17:30-17:45         17:45-18:00	Fundamentals 3         Room 220         F3-1         F3-2         F3-3         F3-4         F3-5         F3-6         F3-7         F3-8	Technologies 3         Room 220a         T3-1         T3-2         T3-3         T3-4         T3-5         T3-6         T3-7         T3-8	Applications 3         Room 316         A3-1         A3-2         A3-3         A3-3         A3-4         A3-5         A3-6         A3-7         A3-8	Education and Social Aspects 3 Room 217E3-1E3-2E3-3E3-4E3-5E3-6	

# **Keynote Lectures 1**

Chairpersons:

Professor Rudolf Pichler, Austria Professor Vyacheslav Shkodyrev, Russia

### SEAMLESS DATA INTEGRATION IN A CPPS WITH HIGHLY HETEROGENEOUS FACILITIES - ARCHITECTURES AND USE CASES EXECUTED IN A LEARNING FACTORY

Rudolf Pichler, Lukas Gerhold, Michael Pichler, Austria

Facing the principal challenges of a Cyberphysical System (CPS) in a manufacturing environment (CPPS) by establishing an appropriate universal and scalable architecture the paper shows two explicit use cases of successfully established communication lines (horizontal and vertical) that integrate facilities deriving from highly different domains, this all done at the Learning Factory at Graz University of Technology.

## PHYSICS OF MIND - COGNITIVE APPROACH TO INTELLIGENT CONTROL THEORY

Leonid Perlovsky, USA; Vyacheslav Shkodyrev, Russia

Intelligent control theory is based on learning surrounding world and adapting to changes in the process of reaching the defined goal. In this paper we consider a cognitive approach to learning developed following the human cognitive ability and a scientific method of physics.

### AN OVERVIEW OF PRACTICAL ONTOLOGY IMPLEMENTATION IN DECISION SUPPORT SYSTEMS

### Dmitry Kudryavtsev, Tatiana Gavrilova, Russia

Ontology has already rather long history in computer science. It helps to represent knowledge in the domain of interest and make it available both for human and machines. For many years ontologies were mostly considered as an object for academic research, but recently they are getting used in growing number of applications. The suggested paper provides a brief overview of practical ontology implementation in decision support systems. The typical knowledge-intensive tasks were used to organize the overview – one example of a system was provided for each task.

Room 220 10.30-12.50 Monday, 10 June, 2019

# CYBER-PHYSICAL SYSTEMS AND THE CLAUSEWITZ PRINCIPLES

### Aleksandr K. Belyaev, Vladimir A. Polyanskiy, A.S. Sukhanov, Russia; Michael Krommer, Austria

One of the important elements of cyber-physical systems is the interaction of automata with a person in the process of their functioning. This interaction was exactly the theme of the first book on cybernetics [1] and this book remains the only one addressing such a fundamental theory. There are two problems that prevent the use of methods already developed in the theory of automatic control: 1. Significant changes in human parameters during interaction with automata as part of an automatic control system; 2. Fundamental instability of the learning process. These problems are unsolvable in the framework of the notion that the controlled system must be formally stable with respect to the input and initial conditions. This stability is usually created by means of negative feedbacks. In this case, the accuracy and stability conflict with each other. When the internal properties of the controlled system are changing, the stability is lost even if the system had some margin of stability at the beginning of the process. Algorithms of learning, by themselves, tend to lose stability even in automatic systems with feedback. This is confirmed by the experience of developing the learning control for automated systems. Altogether these two problems create a barrier to the development and implementation of cyber physics in practice. Modern business approaches to management also make it impossible to construct a theory since they actually boil down to the fact that the gain of the open loop is reduced to the minimum for the sake of stability of the controlled system, and thereby the control errors increase. The qualitative theory built on the war principles by Clausewitz allows us to solve both problems however it requires formalization otherwise it is dangerous to use it in automata. The report provides one with an example of using the Clausewitz principles for modeling and control of distributed systems as the general structure of the applied approaches allows them to be widely used in cyber-physical systems.

# **Keynote Lectures 2**

Chairpersons:

Professor Ludger Overmeyer, Germany Professor Dmitry G. Arseniev, Russia

### LAYOUT OPTIMIZATION FOR CYBER-PHYSICAL MATERIAL FLOW SYSTEMS USING GENETIC ALGORITHM

### Nikita Shchekutin, Ludger Overmeyer, Germany; Vyacheslav Shkodyrev, Russia

Cyber-Physical Production systems are the main solution of the Industry 4.0 age. Still, the advantages of using them are not always easy presentable with numbers. In this paper, the task of arranging a Cyber-Physical material flow system is addressed as multi-objective optimization problem and the Genetic Algorithm is used for searching a Pareto-front of optimal layouts. As an example of such a material flow system, a decentralized modular conveyor, which was developed at the Institute of Transport and Automation Technology at the Leibniz University of Hannover, is used.

### CYBER-PHYSICAL SYSTEMS IN COMPLEX TECHNOLOGIES AND PROCESS CONTROL

### Branko Katalinič, Austria; Dmitry Kostenko, Vadim Onufriev, Vyacheslav Potekhin, Russia

In this article authors examine two main aspects of complex technological processes control done within the paradigm of a cyber-physical management system. These include controlled multiagent cooperation (such as smart grids) and identification of mathematical models connecting different key performance indicators.

Room 220 14.10-15.40 Tuesday, 11 June, 2019

# MULTI-PARADIGM MODELLING OF CYBER-PHYSICAL SYSTEMS

### Hans Vangheluwe, Joachim Denil, Belgium

The networking of multi-physics (mechanical, electical, hydraulic, biochemical, ...) with computational systems (control systems, signal processing, logical inferencing, planning, ...) processes, interacting with often uncertain environments, with human actors, in a socio-economic context, leads to so-called Cyber-Physical Systems (CPS). The CPS that are engineered today are reaching a hitherto unseen level of complexity. To date, no unifying theory nor systematic design methods, techniques and tools exist for such systems. Individual (mechanical, electrical, network or software) engineering disciplines only offer partial solutions. Multi-paradigm Modelling (MPM) proposes to model every part and aspect of such complex systems explicitly, at the most appropriate level(s) of abstraction, using the most appropriate modelling formalism(s). This includes the explicit modelling of the often complex engineering workflows. Modular modelling language engineering, including model transformation, and the study of modelling language semantics, are used to realize MPM. MPM is seen as an effective answer to the challenges of designing CPS. This presentation introduces a vision of complex CPS, in particular in the context of Industry 4.0. The causes of complexity of such systems and some of the challenges of their collaborative development are introduced, as well as possible multiparadigm modelling solutions such as (in-) consistency management and co-simulation.

# **Fundamentals 1**

Chairpersons:

Nataliia D. Pankratova, Ukraine Konstantin K. Semenov, Russia

# F1-1

# CREATION OF THE PHYSICAL MODEL FOR CYBER-PHYSICAL SYSTEMS

### Nataliia D. Pankratova, Ukraine

Creation of the physical model for cyber-physical systems (CFS) taking into account the concept, features and properties of CFS is proposed. The model is based on the general problem of multifactor risks, the margin of permissible risk, the prediction of the destabilizing dynamics of risk factors, principles, hypotheses, axioms that are directly related to the analysis of abnormal situations, accidents and disasters. This model is the foundation of the complex technical systems (CTS) operation. The communication with computational systems and different types of sensors is implemented online in real time. Joint actions of components of CTS at any moment of time determine the properties and features of the mode of functioning of a complex system. The example of the proposed model implementation is given using the example of a real complex technical system.

### F1-2

## THE CONSTRUCTION OF FUZZY INTERVAL REPRESENTING THE MEASUREMENTS RESULTS PERFORMED IN CYBERPHYSICAL SYSTEMS

# K.K. Semenov, Russia; L.K. Reznik, Vladik Kreinovich, USA

This paper is dedicated to the methods and rules of construction of fuzzy variables and fuzzy intervals that represent the measurements results obtained in cyberphysical systems. The derivation and explanation of the proposed algorithms are discussed. The constructed fuzzy variables and fuzzy intervals are used for further data processing and allow coordination of the objective information from gauges and sensors with subjective information or experts knowledge in fuzzy-logic control systems.

Room 220 13.40-15.40 Monday, 10 June, 2019

## F1-3

## METROLOGICAL ASSURANCE OF ENVIRONMENTAL ESTIMATION OF SOIL POLLUTION OF HEAVY METALS BY GEOINFORMATION SYSTEM

## Marina Meshalkina, Valerii Tcvetkov, Nadezhda Kryzhova, Russia; Elena Sokolova, The Netherlands

The article is devoted to estimation of the concentration of the heavy metals in soil. Geo-Information system was used to visualize the measurement results. The metrological assurance of the reliability of pollution boundaries selection has been evaluated.

# F1-4

## A COMPARISON OF TUNING METHODS FOR PID-CONTROLLERS WITH FUZZY- AND NEURAL-NETWORK CONTROLLERS

### Clemens Gross, Hendrik Voelker, Russia

Conventional approaches for control systems still present a reasonable solution for a variety of different tasks in control engineering problems. Controllers based on the PID approach are used in a wide range of applications due to their easy handling, realization and set up as well as their modest need of computational resources during the runtime. In order to heuristically find nearoptimal parameters for the controller design, different approaches for tuning PID controllers have been developed. The methods of Ziegler-Nichols are still popularly used despite being already long known, while modern methods such as the T-Sum method have emerged as well. In this work, a comparison of the so-tuned PID controllers with a Mamdani-Fuzzy-Logic controller and an adaptive Neural Network controller is given. To classify the performance of the controllers, a unified step response is used. It is shown that PID control can work just as well as Fuzzy-Logic or Neural Network control for easy applications with time-invariant parameters or in applications where the parameters only change slightly and no strict constancy of the plant output is necessary.

### PERFORMANCE ANALYSIS OF AVAILABLE SERVICE BROKER ALGORITHMS IN CLOUD-ANALYST

### Elena N. Desyatirikova, Almothana Khodar, Liudmila V. Chernenkaya, Russia; Iyad Alkhayat, Syria

Cloud computing is a kind of distributed computing with heterogeneous computing resources. Resource sharing, availability of resources according to requirements and much more are problems facing the cloud. Here, in this paper, Analysis and comparison of various existing algorithms of service brokers and load balancing algorithms in cloud computing are carried out. To test the implementation of existing algorithms, various modeling tools were developed, for example, a Cloud Analyst. The performance of the existing policies of the service broker is compared by considering the Overall response time and Data Center processing time.

### F1-6

# MEASURING THE GROWTH POTENTIAL OF A SEMANTIC MODEL OF THE DEFENCE-ORIENTED INDUSTRIAL ENTERPRISE THROUGH CPS

# Daria Iakovleva, Ermin Sharich, Russia; Igor Dyukov, Finland

Given that there are no methods of evaluating potential of a company within its management functions the article discusses the important problem of measuring the growth of the potential of a defense-oriented industrial enterprise. It presents an innovative multi-agent system of measuring the growth potential of the enterprise based on a semantic model which takes into account both the financial and production outcome of the company. It also focuses on innovative potential and human capital of the company, which is of great importance in contemporary economic environment. Without such a method, it is nearly impossible to diagnose, detect and mitigate the effects of the changing micro and macro environment. By estimating the growth potential and CPS-methods, it is possible to facilitate the process of resource management coordination and thus provide steady innovative development of the enterprise and its socio-economic environment.

# F1-7

# ROBUST DATA PROCESSING IN DIGITAL MEDICINE INCLUDING METROLOGICAL CHARACTERISTICS OF USED INSTRUMENTS ON EXAMPLE OF CRYOSURGERY STUDIES

### V.A. Suschnikov, K.K. Semenov, Russia

The modern state of medicine is characterized by wide use of digital technologies. It creates an opportunity for improving the numerical data processing methods and algorithms to make them more robust and adequate to the quality of data to be processed. The taking into account the information on precision and the accompanying the results with their uncertainty are the ways to perform more reliable decision-making. This paper illustrates these theses on the example of cryosurgery studies on all its stages: from data collection through data processing to decisionmaking and representing the final result in most reliable form for further using

### F1-8

# DEVELOPING OF KNOWLEDGE BASE FOR THE DECISION SUPPORT SYSTEM OF THE TRANSPORTATION OF THE OVERSIZED CARGOES

### Yu.M. Iskanderov, A.S. Svistunova, A.S. Chumak, Russia

This article reviews the important role of intelligent transport systems in the planning, organization and carrying out of oversized cargo transportation, highlights the peculiarities of transportation of these goods, outlines the approach used to build the knowledge base of the decision support system for oversized cargo transportation.

# **Technologies 1**

Chairpersons:

Igor Ilin, Russia Lev Stankevich, Russia Room 220a 13.40-15.40 Monday, 10 June, 2019

# T1-1

# CYBER-PHYSIC SYSTEM CONTROL BASED ON BRAIN-COMPUTER INTERFACE

### Filipp Gundelakh, Lev Stankevich, Nikolai Kapralov, Jaroslav Ekimovskii, Russia

The study describes approaches of direct and supervisory control of cyber-physic systems based on a brain-computer interface. The interface is the main component of the control system, performing electroencephalographic signal decoding, which includes several steps: filtering, artefact detection, feature extraction, and classification. In this study, a classifier based on deep neural networks was developed and applied. Description of the classifiers based on convolution neural network is given. The developed classifier demonstrated accuracy  $73 \pm 5\%$  of decoding four classes of imaginary movements. Prospects of using non-invasive brain-computer interface for control of cyber-physic systems, in particular, mobile robots for maintenance of immobilized patients and devices for rehabilitation poststroke patients are discussed.

# T1-2

# MODERN APPROACHES TO THE LANGUAGE DATA ANALYSIS. USING LANGUAGE ANALYSIS METHODS FOR MANAGEMENT AND PLANNING TASKS

Andrei Vinogradov, Natalia Vlasova, Evgeny Kurshev, Alexey Podobryaev, Russia

The article discusses modern approaches to the language data analysis in relation of solving new problems of management and planning.

### T1-3

# EFFICIENCY INDICATORS FOR COGNITIVE SYSTEMS OF DATA PROCESSING

### Man Tianxing, Nataly Zhukova, Ildar Baimuratov, Sergey Lebedev, Russia

This article proposes a system of indicators for data processing to esti-mate the evolution and representation of data at multiple levels. An ontology-based implementation of this system is presented.

## T1-4

# AUDIOVISUAL CONTENT FEATURE SELECTION FOR EMOTION RECOGNITION SYSTEM

### Dmitrii Malov, Olga Shumskaya, Russia

Cyber-physical systems provide a great number benefits for users, including information from different modalities: audio, video, text, images. It is very important to filter this information within such systems, as long as some destructive content can be met. In this paper we concentrate on detecting a potentially aggressive behavior in cyber-physical systems, in particular, within an audiovisual con-tent, using neural network technologies. The problem of feature selection of an audiovisual content using autoencoders are considered for finding the most informative latent feature space. The deep collective manifold meta-learning frame-work is proposed for solving this problem, that can be used for audiovisual content compression as well as training a classifier for emotion recognition task and in particular in potentially destructive behavior detection.

### T1-5

# EXPERT SYSTEM AS A TOOL FOR MANAGING A TECHNOLOGIES PORTFOLIO

### Alla Surina, Danila Kultin, Nikita Kultin, Russia

The technology portfolio possessed by the company is the basis of its competitiveness. When developing an development strategy, the right choice of priorities, which are embodied in projects for the development and implementation of innovative technologies, is of great importance. Decisions on the development or introduction of technology relates to the field of strategic management. Strategic decisions are characterized by a high degree of uncertainty, which often does not allow the use of analytical methods. The analysis shows that under the conditions of uncertainty and a dynamic external environment, the portfolio approach to the development of a strategy for the technological development of an enterprise is the most promising. Technology portfolio management is an essential component of an enterprise management strategy. In practice, the most simple models and methods of technology portfolio management are used. Involving the involvement of experts reduces management efficiency. As part of the management system of the technological portfolio of the enterprise, it is proposed to use an expert system. With the help of an expert system, a possible, for example, assess the commercial potential of a technology as part of an portfolio. Knowledge in the expert system should be organized in the form of inference rules, which makes the system flexible, making it easy to adjust the accumulation of know-ledge in the process of using the system.

### T1-6

### DYNAMIC CONTAINER VIRTUALIZATION AS A METHOD OF IOT INFRASTRUCTURE SECURITY PROVISION

### A. Iskhakov, A. Iskhakova A., R. Meshcheryakov, Russia

The given article proposes an approach to security provision of one of the key bases of digital transformation - the technology of the Internet of things (IoT). The effective technology of carrying out the information security audit with application of Honeypot systems is the cornerstone of article and the offered method. The main advantages of use of container virtualization unlike application of traps on the basis of virtual machines are formulated by the author. The method of protection of a similar infrastructure by means of integration of dynamic container virtualization of network traps is considered. The article contains information on implementation of the offered method, results of comparison with existing solutions, the summary table about the actual results of carrying out an experiment. The detailed flowchart of functioning of the offered method is also provided in work.

### T1-7

### IIOT IN SMART CITIES' UTILITY SYSTEMS: FROM PROTOTYPE TO PRODUCTION

### Igor Ilin, Daniil Bolobonov, Aleksandr Frolov, Igor Korolev, Russia

Smart Cities, Industrial Internet of Things (IIoT), Smart Grids and etc. are products of Industry 4.0 that are on verge on becoming mass-implemented after years in development by different companies and startups. While these technologies are nowhere from being completely novel, they have significant undiscovered potential. Companies invest millions into research and development and often fail to achieve desired outcome due to blurred vision, prolonged development and other reasons. This paper analyzes errors during system modeling cycle while also proposing framework for developing IIoT system in Smart City that enables companies to accelerate development of new products while also reducing costs. IIoT system developed by the authors of this paper is an end-to-end solution for Smart Cities that mainly focuses on gathering data of housing sector's utility systems such as water pressure and temperature, voltage and others. During development several working prototypes had to be scrapped due to not meeting requirements of potential and real customers. Over time an approach that allowed rapid incorporation of customer requests into the solution was developed. It includes modular hardware coupled with microservice-based cloud software and agile software development. Application of this approach allowed to satisfy needs of increasing number of customers.

# T1-8

# THE ANALYSIS OF CYBERSECURITY PROBLEMS IN DISTRIBUTED INFOCOMMUNICATION NETWORKS BASED ON THE ACTIVE DATA CONCEPTION

# S.V. Kuleshov, A.Y. Aksenov, I.I. Viksnin, E.O. Laskus, V.V. Belyaev, Russia

This paper consider the problems of cybersecurity for distributed infocommunication networks, related to the violation of the access rights of the executable code of active data to network node resources (shared memory, radio channel reconfiguration, motion control functions, onboard node sensor).

# **Applications 1**

Chairpersons:

Alexandra A. Zaytseva, Russia Sergey G. Redko, Russia

## A1-1

# SITUATION AWARENESS IN MODELING INDUSTRIAL-NATURAL COMPLEXES

### A.Ya. Fridman, B.A. Kulik, Russia

The concept of situation awareness (SA) is adapted and concretized for the previously developed situational conceptual model of an industrial-natural complex. The features of the presented approach consist in quantitative assessing of the three main levels of achieving SA and taking into account the possibility of transferring the modelling object from the normal operation mode to an abnormal or emergency situation. Analysis of SA is performed in a discretized state space of this object with an expertly synthesized metric. The research allows to objectify measuring their SA level for decision makers involved in managing the complex's components.

### A1-2

# THE DEVELOPMENT OF SOFT DEFINED DISTRIBUTED INFOCOMMUNICATION SYSTEMS ARCHITECTURE BASED ON THE ACTIVE DATA TECHNOLOGY

### Sergey V. Kuleshov, Alexandra A. Zaytseva, Andrey L. Ronzhin, Russia

The active data technology allows developing the architecture of soft defined systems based on the new principals. The most interesting implementation is to build the self-organized networks that consist of UAV and robots complexes.

### A1-3

## ORGANIZING CYBER-PHYSICAL HOMOGENEOUS PRODUCTION ENVIRONMENTS

### O.A. Konovalova, Yu.R. Nurulin, S.G. Redko, Russia

A promising direction of development of modern production systems is the creation of cyber-physical homogeneous production environments (CPHPE) based on new structural and organizational principles. The stationary, semi-stationary and non-stationary environments with simultaneous and preliminary setting is described in the article. The concepts of stationary, semi-stationary and non-stationary environments with simultaneRoom 316 13.40-15.40 Monday, 10 June, 2019

ous and preliminary setting of elementary production modules are introduced. Such environments use the mechanisms of artificial intellect with adaptive behavior, including self-organization, based on the creation by a system of causeand-effect relationships to achieve the target functions of management and development in real time. Parameters that are common for all types of CPHPE, as well as those related to a particular class of environment and its configuration are considered

### A1-4

### CLOUD SYSTEM FOR DISTRIBUTING MULTIMEDIA CONTENT IN CYBER-PHYSICAL SYSTEMS

### Dmitriy Levonevskiy, Anton Saveliev, Ilya Duboyskiy, Pavel Drugov, Russia

This paper considers building a cloud system for distributing multimedia content in cyber-physical environments. The paper describes overall system architecture, gives detailed description of the users, involved in content distribution. Their typical actions are defined in use case diagrams. UML-diagrams are given, describing modules for content management and transmission. Distributed data storage and management is also thoroughly described here. Various output channels and display modes are compared here in terms of client-server interactions to be considered when displaying multimedia content. An essential part of the cyber-physical system, described here, is mobile device management and data coordination among such devices. The presented systems can be easily implemented with Unity engine (C#) and GraphQL query language. The paper ultimately gives a high-level perspective of content delivery networks in modern enterprise.

### A1-5

# STATIC FORCE ANALYSIS FOR VERSATILE GRIPPER

Ivan I. Borisov, Sergey A. Kolyubin,

Viacheslav P. Shkodyrev, Alexey A. Bobtsov, Russia

This paper presents a novel approach of a static force analysis of a versatile gripper used as an adaptive tooling for flexible manufacturing robotic solutions. The mechanism consists of 8 links, which can be separated only into an input link and a system of 6 links which can not be divided into smaller parts. The mechanism is used to implement a finger of a versatile bio-inspired industrial gripper, which is able to change a degree of freedom (DOF) in order to change a mode of grasping. It is possible to change DOF via breaking/reconnecting a kinematic chain of the finger. When the mechanism is intact it has only 1 DOF and it represents a fully kinematically defined structure, that allows performing a precision grasp. When the kinematic chain is broken the finger got underactuated, thus in this case it has 2 DOF and an underactuated power grasp can be performed. The finger represents different types of a mechanism in precision and power grasps. Force analyses of the finger in both modes were carried out in order to get information about the relationship between torque applied to a driving link and forces applied to surfaces of phalanges. The paper is concerned with the force analysis and a design of the prototype of the gripper.

### A1-6

### OPEN SOURCE FILE SYSTEM SELECTION FOR REMOTE SENSING DATA OPERATIONAL STORAGE AND PROCESSING

# Andrei N. Vinogradov, Evgeny Kurshev, Sergey Belov, Russia

The article discusses the shortcomings of the exploited remote sensing processing complexes, conceptual approaches for a modern universal high-performance computing complex development, justifying the choice of open-source system software to create a system based on performance testing under various conditions, experience of real projects solutions.

### A1-7

# DIGITAL TWINS OF OPEN SYSTEMS

### B.F. Fomin, T.L. Kachanova, O.B. Fomin, Russia

This report is devoted to new direction of Physics of Open Systems. Under this direction, the methods and technologies were created to provide cognition, scientific understanding and rational explanation of states and properties inherent in open systems. In doing so, these systems can be represented by hundreds, thousands, and tens of thousands of variables. On this basis, a multidimensional knowledge-centric analytics of open systems being considered at their natural scale and real complexity has arisen. At this time, the formation of a new cyber-physical paradigm of system research and development goes on. The report includes a review of possibilities for applying this paradigm to automatic generation of digital twins of open systems in complex subject matter areas.

# A1-8

# SYNTHESIS OF THE COORDINATED CONTROL ALGORITHMS FOR MANIPULATOR

# Valeriy Liubich, Aron Kurmashev, Russia

Objectives: Synthesize the coordinated control algorithm and the reduced coordinated control algorithm for the biaxial manipulator and for the typical (a straight line and a circular arc) and non-typical (a parabola) trajectories. Synthesis: We synthesized the coordinated control algorithm (the CCA) based on Kurmashev A.D. algorithm and proposed the reduced coordinated control algorithm (the RCCA) for the biaxial manipulator model. Experiment: Using mathematical modeling we compared the two synthesized algorithms and the uncoupled system on different trajectories - a straight line, a circular arc, and a parabola - and different contour speeds. Results: Using of the coordinated control algorithms depending on the trajectory and the contour speed – leads to increase in the minimal quality factor and may lead to decrease in contour speed error in comparison to the uncoupled system. Conclusion: We successfully synthesized the coordinated control algorithms for the manipulator moving along the typical and non-typical trajectories. The synthesized algorithms eliminate contour and contour speed errors better than the uncoupled system. Implication: The RCCA allows us to control manipulator by using the information only from position and speed sensors. Therefore, it is possible to implement the RCCA on existing equipment without its significant modification adding additional sensors, loops, etc.

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Leonid Chechurin, Finland Nadezhda A. Tsvetkova, Russia	Monday, 10 June, 2019		

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### E1-1

## BLENDING TRADITIONAL AND MODERN APPROACHES TO TEACHING CONTROL THEORY

### Inna Seledtsova, Leonid Chechurin, Finland

Control Theory serves as a fundamental background for a number of popular paradigms, including the cyber-physical one. The contents have been standardized over the decades of teaching, but new digital technologies and market's practical skills demand raise the questions on how the course is to be taught. The goal of the report is to share the results of 3 years (2015-2018) of experimenting on the transition from classical to project-based blended design of Modern Control and Automation course. The course is the part of curricula of SPbSPU MSc degree programme "Management of Innovative Processes (Innovatika)", 75 students were taught. Now the course is represented by online and offline studying of the basic theoretical aspects and hands-on development of a hardware device in a project group. Each element of the course, its three years evolution, analysis of collected data, results of surveys and recommendations for adaptation of the used tools for the Control Theory teaching in frames of another educational program or university are described in the article.

### E1-2

# SYSTEMATIC APPROACH TO EDUCATION OF SPECIALISTS FOR NEW TECHNOLOGICAL PARADIGM

# S.G. Redko, N.A. Tsvetkova, I.A. Seledtsova, S.A. Golubev, Russia

The world is about to enter a new technological evolution with cyberphysical systems in its basis. One of the vital questions is exploring of new approaches to training specialists capable to develop, contribute and maintain corporate and industrial infrastructure in the new technological framework. The main goal of this research is to show approach to complex training of qualified specialists in the upcoming economic and technological paradigm in terms of three aspects: whom to teach, what to teach to, and how to teach. Interrelation and the impact of these three aspects on preparation of highly in-demand professionals in the field of cyber-physical systems and control are shown in the article. The main emphasis is made on the question "How to Teach?"

# E1-3

# USAGE OF MOOCS PLATFORMS FOR PRACTICAL STUDIES

### S.D. Minnebaeva, N.A. Tsvetkova, Russia

This article examines the applicability of MOOCs platforms for teaching practical studies. As an example, the course "Basics in project-based activities", developed at Moodle-platform is observed. The processes of projects (initiative and on given topics) assignment and project work under mentor supervision are described. Thus, article gives a comprehensive and clear idea how such platforms can be used for practical learning.

### E1-4

# SERVICE FOR AGGREGATION OF EDUCATIONAL EVENTS AND MAKING RECOMMENDATIONS FOR "VKONTAKTE" USERS

### Vasily Vasilev, Igor Konovalov, Igor Nikiforov, Kirill Kobyshev, Vitaly Monastyrev, Russia

In recent years, the available information volume has grown dramatically. Humanity is faced with the problem of information redundancy and excess. For example, a person who is looking for educational activities on the Internet finds thousands of options and it is a challenge to choose the most suitable and appropriate one. Such a situation is not good and creates few benefits for event organizers and end users. The article provides a solution to the problem with the help of service with a built-in recommendation system. The recommendation system is built on top of neural networks and implements easy horizontal scaling approach be able to handle huge amount of data. In addition, the service can aggregate information from third-party information sources in single consolidated data storage in order to automate providing of recommendations. The software service reduces user's time to find, for example, an appropriate and suitable educational event. The implemented service has been tested on the users of "Vkontakte" social network. Social network data is used by the neural network to determine the educational event that is interesting to the user. In this paper, we consider existing implementations of recommender systems, highlight their features and drawbacks, and suggest an approach to developing a service that allows aggregation of sites with educational events and select recommended activities based on neural networks using user social networks. Distinctive features of the proposed approach are: the use of a neural network in model building, the use of a social network to collect information, web-scraping pages for data aggregation, the use of an architecture that assumes horizontal scalability.

### E1-5

# SOME RESULTS OF THE ANALYSIS OF 3 YEARS TEACHING OF THE MASSIVE OPEN ONLINE COURSE

### Sergey A. Nesterov, Elena M. Smolina, Russia

The paper describes the results of MOOC «Data management» on the Russian platform of Open Education openedu.ru. Some approaches to the analysis of the results of distance learning, including data mining, are discussed.

### E1-6

# THE RELEVANCE OF THE GAME IN THE EDUCATIONAL PROCESS

Victor Baranov, Marina Bolsunovskaya, Natalia Ezhova, Evgeniy Ezhov, Russia

The article describes the methods and means of gaming pedagogical technologies, implemented when teaching students of the St. Petersburg Polytechnic University. The efficiency and prospects of using such methods in teaching mathematics and computer science are shown. The corresponding statistics is given.

### E1-7

# CRITERION OF STABILITY OF LINEAR SYSTEM WITH ONE HARMONIC TIME-VARYING COEFFICIENT BASED ON A FORMALIZED FILTER HYPOTHESIS

### Anton Mandrik, Russia

Stability criterion for linear time-varying (LTV) system with one harmonic time-varying coefficient in a feedback is suggested. The found criterion is based on a hypothesis that the LTI part of the system is a lowfrequency filter. The criterion is simple and suitable for calculation of stability borders for LTV systems. The suggested criterion is compared to numerical experiment, Bonjiorno criterion, Stationarization method.

### E1-8

## FLIPPED CLASSROOM DESIGN: SYSTEMS ENGINEERING APPROACH

### Iuliia Shnai, Leonid Chechurin, Finland

Flipped or inverted classroom is one of up-side down pedagogies, which combines different learning theories. Its earning design constitutes already well-known components : video lecture and activities, both structured in a novel way. The proposed research targets to increase the understanding and scalability of flipped classroom implementation. It is an attempt to plan the course transition in the more effective way. To achieve this goal the 9 window design approach and Flipped Classroom Design Approach (FCDA) are used. The preliminary results describe the initial flipped classroom model with its connections, impacts and list of parameters for one element. The model is adapted to transition the course of System Modelling from Traditional to flipped form. Further it can be used by the teachers as an algorithm on the stage of flipped classroom planning, design, development and implementation. Practically, the current results appear in a guided FCDA approach with the template and supporting online learning materials.

# **Fundamentals 2**

Chairpersons:

Elena A. Yakovleva, Russia Artem A. Efremov, Russia

# F2-1

## PARAMETRIC CONTROL OF OSCILLATION

# Leonid Chechurin, Finland; Sergej Chechurin, Anton Mandrik, Russia

Any oscillating system is described by certain parameters and very often these parameters can be dynamically changed in a certain way to reach control goals. We overview a number of designs in which periodic variation of parameters in linear time-variant and non-linear systems is the main control paradigm. We use frequency analysis and one frequency approximation as the mathematical instrument. The approach that is also known as stationarization uses equivalent transfer functions for each time-variant and nonlinear element and reduces the stability analysis to classical Nyquist plot. The study presents in the unified framework several problems that have been solved in the last decades and new ideas, such as parametric synchronizing of oscillation. As the approach uses simple mathematics, it can be used by field engineers for inventive oscillation control design for cranes, ships, rotors and many other vibrating systems.

### F2-2

# PILOT INDUCED OSCILLATIONS AND THEIR PREVENTION

### Boris Andrievsky, Dmitry G. Arseniev, Nikolay V. Kuznetsov, Iuliia S. Zaitceva, Russia

In the paper, the pilot induced oscillations are considered. The ways to prevent long uncontrolled irregular oscillations that occur as a result of the efforts of the pilot to control the aircraft are discussed.

### F2-3

# QUALITY ASSESSMENT IN CYBER-PHYSICAL SYSTEMS

### S.G. Redko, A.D. Shadrin, Russia

The article considers the subjective side of quality as the degree to which a set of characteristics of objects and subjects of a cyber-physical system fulfils the requirements of all parties concerned. The authors suggest an interpreta-tion of the term «cyber-physical system» with consideraRoom 220 16.00-18.15 Monday, 10 June, 2019

tion of its performance quality assessment. The study proves that an adequate assessment model requires the development of special algorithms and significant computational resources. Its practical implementation is possible via digital models, or digital twins.

### F2-4

# METROLOGICAL SELF-ASSURANCE OF CYBER-PHYSICAL SYSTEMS' SOFTWARE AS THE PERSPECTIVE OF METROLOGY IN THE XXI CENTURY

### K.K. Semenov, G.N. Solopchenko, Russia; V.Ya. Kreinovich, USA

The Industry 4.0 paradigm supposes widespread use of cyber-physical systems that are inconceivable without computational tools. This article discusses the possibility of self-assurance of software used in cyber-physical systems that provide the confirmation of its full compliance with acting metrological regulatory documents and automatically produces the estimation of uncertainty of each result generated by computational component of system during mathematical processing the measurements results obtained by physical component. The proposed technology can be easily included in software of cyber-physical systems as its integral part and will improve its functionality. Such a cyber-physical-oriented software tools are the perspective of future metrology.

### F2-5

## UNIFORMITY OF ADAPTIVE CONTROL OF SOCIO-ECONOMIC AND CYBER-PHYSICAL CHANGES USING THE LINGUA-COMBINATORIAL MODEL OF COMPLEX SYSTEMS

# T.S. Katermina, E.A. Yakovleva, V.V. Platonov, A.E. Karlik, Russia

This paper presents the conceptual framework of methodology for recognizing the importance of subject-object relations using modern advances in the theory of complex systems and methods of system engineering, artificial intelligence, decentralized platforms, and other methods of expert systems for supporting management decisions. The questions reviewed in this research include such matters as the impact of the global sociocultural cycle on the development of society, the issue of sustaining a stable state of infrastructure, the dynamism of homeokinetic equilibrium when managing innovations during the formation of a basic strategic plan, keeping the system in a zone of adaptation maximum in a flow of change. This paper also presents the risks and threats of anticipating problematic situations, which were identified in line with the cognitive approach and based on the positions of the adaptive control theory. The guidelines for the integrated integrity of systems and the cyber-physical interactivity in technological ecosystems were revealed using a lingua-combinatorial model and distributed registry technology, with a commitment to social and economic security.

### F2-6

### FUZZY CONTROL UNDER UNCERTAINTY

#### V.I. Abliazov, V.N. Tisenko, Russia

This report addresses the aspects of decisionmaking problems during asset management in cases when there is an uncertainty of the situation that can be caused by complexity of an asset or insufficient information about it. In last decades, the fuzzy logic proposed by Lotfi Zadeh has been successfully used in such cases. This report also considers positive and negative aspects of this form of logic and proposes using fuzzy converse logic (antonyms-related) which is free from weaknesses of fuzzy-related concepts proposed by Zadeh. We outline the basic axioms of converse logic and its application for decisionmaking problems during asset management under uncertainty.

### F2-7

### DATA SHUFFLES MINIMIZING APPROACH FOR APACHE SPARK PROGRAMS

### Maksim Popov, Pavel Drobintsev, Russia

This article discusses a way to optimize the Apache Spark program by reducing the number of transformations with wide dependencies and, as a result, the number of data shuffles. This achieved by combining sequential data processing algorithms in chains based on common key fields, as well as grouping the data itself, which is stored in resilient distributed structures – Spark SQL Datasets, according to the keys by which the processing takes place.

### F2-8

# PREDICTORS OF KNOWLEDGE MANAGEMENT SYSTEM EFFICIENCY IN THE CONTEXT OF INFORMATION OVERLOAD

### Elvira Grinberg, Russia

Technology acceptance model (TAM) predicts system success based on design features through such variables as perceived ease of use and perceived usefulness. Acceptance and use of Knowledge Management System is complicated by organizational and personal barriers and aggravated by information overload. Perceived ease of use, "the degree to which a person believes that using a particular system would be free of effort" (Davis 1985), comes to the fore in that context. Present paper makes an overview of Knowledge Management Systems from the TAM perspective considering the mentioned limitations. It identifies gaps in the existing stream of research and focuses on three external variables which predict the perceived ease of use: 1) visualization, 2) underlying ontology, 3) employees' ability to structure and generalize knowledge.

### F2-9

## OPERATORS OF BOUNDED LOCALLY OPTIMAL CONTROLS OF DYNAMICAL SYSTEMS

### Vladimir N. Kozlov, Artem A. Efremov, Russia

The problems of locally linear and quadratic optimal stabilization in finite-dimensional and functional spaces based on the projection method were studied in a number of papers [1, 2, 4, 5], as well as in a series of other studies. In this paper, the problem of quadratic locally optimal program stabilization in functional space is formulated, from which follows the problem of quadratic locally optimal stabilization of the equilibrium state of a dynamical system.

# **Technologies 2**

Chairpersons:

Toni Kuronen, Finland Pavel Drobintsev, Russia

T2-1

# THE PLATFORM OF THE INDUSTRIAL INTERNET OF THINGS FOR SMALL-SCALE PRODUCTION IN MECHANICAL ENGINEERING

Igor Chernorutsky, Pavel Drobintsev, Vsevolod Kotlyarov, Alexey Tolstoles, Alexey Maslakov, Russia

The paper deals with the problem of creating an industrial Internet of Things (IoT) platform for a small-scale machine-building site, which is important because this type of production is characterized by an imbalance between the time of technological preparation of production and the production process itself. The developed platform is focused on wide applicability by adapting to technological routes for creation of the details of varying complexity, to different structures of production equipment and to varying resources. The platform concept allows a several times reduction of the complexity of the design work of small-scale production and creation of technological processes for small-scale or individual production based on promising directions of the development of modular technologies.

## T2-2

# 3D HAND MOVEMENT MEASUREMENT FRAMEWORK FOR STUDYING HUMAN-COMPUTER INTERACTION

### Toni Kuronen, Tuomas Eerola, Lasse Lensu, Jukka Häkkinen, Heikki Kälviäinen, Finland

In order to develop better touch and gesture user interfaces, it is important to be able to measure how humans move their hands while interacting with technical devices. The recent advances in high-speed imaging technology and in imagebased object tracking techniques have made it possible to accurately measure the hand movement from videos without the need for data gloves or other sensors that would limit the natural hand movements. In this paper, we propose a complete framework to measure hand movements in 3D in human-computer interaction situations. The framework includes the composition of the measurement setup, selecting the object tracking methods, post-processing of the motion

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trajectories, 3D trajectory reconstruction, and characterizing and visualizing the movement data. We demonstrate the framework in a context where 3D touch screen usability is studied with 3D stimuli.

### T2-3

# FUNCTIONAL MODELING OF AN INTEGRATION INFORMATION SYSTEM FOR BUILDING DESIGN

### Alexander Bukunov, Russia

The processes at the construction stages are characterized by considerable complexity due to the large amount of information contained in the design and construction documentation, and its mutual influence. Information management requires engineering data management systems and an object information model. The technology of building information modeling is based on the development and use of a virtual model of a construction object in the form of a three-dimensional information model and related documents. The article analyzes the Polterovich-Tonis evolutionary model as applied to information modeling processes in Russia. The functional approach to the modeling of complex project management systems in construction and visual modeling of construction objects is considered. The links between various design and calculation systems, estimated systems, scheduling and resource management systems are revealed. A formal description of the conceptual model of an integration information system for design decisions in construction and a data exchange strategy between the system for automation of accounting and control and the BIM-system of visual presentation have been developed.

### T2-4

# EEG-BASED BRAIN-COMPUTER INTERFACE FOR CONTROL OF ASSISTIVE DEVICES

### N.V. Kapralov, J.V. Ekimovskii, V.V. Potekhin, Russia

The study describes an approach of supervisory control of a imb prosthesis and a mobile robot based on a non-invasive brain-computer interface. Key applications of the system are the maintenance of immobilized patients and rehabilitation procedures. An interface performs imaginary hand movement decoding using electroencephalographic signals. The decoding process consists of several steps: (1) signal acquisition; (2) signal preprocessing (filtering, artifact removal); (3) feature extraction; (4) classification. The study is focused on obtaining the best accuracy of decoding by comparing different feature extraction and classification methods. Several methods (Riemannian geometry-based) were tested offline. Furthermore, online testing of control capabilities using in-house data was performed.

### T2-5

## PROACTIVITY AND SUBSIDIARITY AS BASIC PRINCIPLES OF DIGITAL TRANSFORMATION OF STATE INTERACTION WITH CITIZENS AND BUSINESS

# G.S. Tibilova, A.V. Ovcharenko, A.V. Potapova, Russia

The present paper describes two stages of the digital transformation of state interaction with citizens and business. The first stage is the construction of e-government, conversion of interaction to electronic form; the second stage is human-centered digital transformation based on proactivity and subsidiarity.

### T2-6

# ARTIFICIAL INTELLIGENCE IN THE MANAGEMENT OF INNOVATION PROJECTS

### Nikita B. Kultin, Russia

A characteristic feature of an innovation project as an object of management is a high degree of uncertainty in the types and timing of work, time and financial costs. The project manager is usually forced to make decisions in the context of incomplete or unreliable information, which makes it impossible to use analytical methods to select the optimal or best solution. Experts from relevant subject areas are usually involved in solving the problems of analysis, selection and justification of decisions. Examination of solutions requires considerable time and financial costs. It is possible to reduce the cost of the examination, to improve the quality of the decisions made by using the expert system as a decision-making tool. With the expert system, you can assess the commercial potential of innovation, evaluate the effectiveness of investments, evaluate the risks of a project. Knowledge in the knowledge base of the expert system should be presented in the form of a set of rules of logical inference. The use of an expert system as a tool to support decision-making in managing an innovative project will reduce

the time and financial costs of conducting examinations and improve the quality of project management.

### T2-7

## NEURAL NETWORK COMPENSATION OF DYNAMIC ERRORS IN A ROBOT-MANIPULATOR PROGRAMMED CONTROL SYSTEM

### Yan Zhengjie, Ekaterina Rostova, Nikolay Rostov, Russia

The subject of consideration in this paper is a programmed control system of a robot-manipulator. Mathematical description of the control system was presented taking into account the nonlinear dynamics of the robot and its drives. Synthesis of multivariable compensators of dynamic errors for a prototype control system was carried out. A computer model of the control system with synthesized compensators was developed using MATLAB package. The results of teaching of neural network compensators are given for different programmed trajectories of the robot gripper and joints. Comparative analysis of dynamic errors in the prototype system and the system with neural network compensators was conducted.

### T2-8

## CREATION OF REAL-TIME DIAGNOSTIC TEST BENCHES FOR MONITORING AND CONTROL IN ENERGY SYSTEMS USING SOFTWARE AND HARDWARE MODELING

Mikhail Gushchin, Stanislav Popov, Svetlana Solovyova, Russia

Software and hardware research technologies are increasingly used in practice and further improvement of research and diagnostic complexes are precisely associated with them. The combination of digital and analogue and analog-to-digital converters of virtual and physical modeling with the inclusion of real devices in the test circuits provides a number of new advantages.

### T2-9

# A FRAMEWORK FOR THE ANALYSIS OF RESOURCE-FLOWS IN THE EXTENDED MANUFACTURING NETWORK BASED ON CYBER-PHYSICAL INFRASTRUCTURE

### Alexander Karlik, Vladimir Platonov, Elena Iakovleva, Russia

The paper deals with the cyber-physical system as an infrastructure that enables extended interorganizational networks connecting manufacturing facilities of many independent firms (of network nodes) in the production process up to a global scale. It presents a basic analytical framework that allows to study such network as a system of the highest complexity that enables the heterogeneous resource-flows between nodes and emerges from the interaction of the cyberphysical and anthropogenic systems. In the focus of attention is the following: the equipment and inventory flows of the digitally enabled physical objects that can be fully automated in the cyberphysical system; the information and knowledge flows which involves the challenge of extracting information from big data; resource allocation between the manufacturing facilities of different firms connected via the network. Besides, the article considers the anthropogenic system as another key regulator of the manufacturing network necessary not only to deal with cyber-physical effects but also to regulate the idiosyncratic resource flows: those of human capital and trust.

# **Applications 2**

Chairpersons:

Zhao Yanan, China Galina Malykhina, Russia Room 316 16.00-18.15 Monday, 10 June, 2019

# A2-1

# MULTIPLE PARAMETERS ESTIMATION OF SHIP ROLL MOTION MODEL WITH GYROSTABILIZER

### Mikhail A. Kakanov, Fatimat B. Karashaeva, Oleg I. Borisov, Vladislav S. Gromov, Russia

A problem of parametric identification in marine applications, namely, surface vessels equipped with gyrostabilizers is discussed. Three approaches are considered in this work, which are the gradient method, Kalman filterbased method and dynamic regressor extension and mixing (DREM) method. All of them are applied to the ship roll motion model with unknown parameters. Simulating the system two types of input signals are injected in order to test the sensitivity of the each approach to the persistency of excitation condition. Simulation results show advantages of the DREM method in the considered application, in particular, with regard to the convergence rate of the multiple parameters estimation.

# A2-2

# ALGORITHM FOR SEARCHING SEMANTICALLY RELATED JIRA ISSUES TO AUTOMATE CUSTOMER REQUESTS RESOLVING

### Artem Kovalev, Semen Sheremetov, Igor Nikiforov, Russia

The software sustaining phase is one of the essential stages of the software development life cycle. At this stage, customers can contact support and software engineers to solve any problems or issues arising during the operation of the software. The work is devoted to research in the field of software sustainment automation. An automated approach to solving customer requests is proposed, which consists in using the Doc2Vec algorithm to search for semantically similar resolved requests, as well as to find competent software engineers in the Jira issue tracking system. The proposed approach is implemented in a software tool for the automated analysis of unresolved customer requests and providing recommendations to help in solving each of them. The results compare the manual and automated approach to analyzing customer requests. The advantages of using the tool in the process of software product support are listed.

# A2-3

### COMPARISON OF ANALYTICAL BP-FBP AND ALGEBRAIC SART-SIRT IMAGE RECONSTRUCTION METHODS IN COMPUTED TOMOGRAPHY FOR THE OIL MEASUREMENT SYSTEM

### L. Zarour, G. Malykhina, Russia

Imbalance between the produced oil entering the pipeline and the oil received by the consumer is a real problem. To solve the problem, we propose to use methods of computed tomography. The article is devoted to investigate methods for reconstructing a section of a pipeline to determine time intervals over which there are no gas inclusions in the oil flow. Computed tomography is based on image reconstruction methods. We made comparison between analytical reconstruction techniques: Back Projection (BP) and Filtered Back Projection (FBP) and iterative reconstruction techniques: Simultaneous algebraic reconstruction technique (SART) and Simultaneous Iterative Reconstruction Technique (SIRT), the simulation was performed using Astratoolbox an open source image reconstruction tool for tomography, then the reconstructed images were compared using the relative root mean square error and a conclusion is achieved. The results demonstrate that the SIRT and SART method has given the closest reconstructed images.

### A2-4

# DYNAMIC DESIGN OF AN IMPROVED-ACCURACY INNOVATIVE COMPENSATORY FLOWMETERS OF VARIABLE PRESSURE DIFFERENTIAL

### A.I. Nagorny, V.S. Nagorny, V.N. Tisenko, Russia

The problem of high-precision measurement of the flow of natural gases becomes increasingly important over time. Along with oil, natural gas is one of the fundamental energy resources of the planet today. Significant amounts of natural fuels are transported around the world. Even small errors in gas flow measurement (within 2-3%) lead to significant financial losses for suppliers during their transportation through gas pipelines every day. This article researches the usage an electrodynamic automatic control systems in the development of an innovative flowmeter device. This document focuses on the description of a fundamentally new device: a flowmeter of a variable pressure drop that measures the flow of liquids and gases with increased accuracy and the sensitivity. The article describes the physical principles of building electrohydrodynamic inverters and considers the dynamics of working (changing parameters of the system over time) of the compensation inverter. To choose the optimal combination of transfer coefficients, which are included into the converter's compensation circuit, there are transfer functions (W) of all basic elements from structural scheme being defined. Making a search of boundary of the flowmeter's compensation circuit that means the limit of flowmeter's operability.

### A2-5

### CONTROL OF SOLAR PV/WIND HYBRID ENERGY SYSTEM IN GRID CONNECTED AND ISLANDED MODE OF OPERATION

# A.L. Loginov, B. Mukhambedyarov, D.V. Lukichev, N.L. Polyuga, Russia

Hybrid energy system which includes photovoltaic (PV) arrays and wind turbine with synchronous generator (WT/SG) is considered in this paper. Structure of the system was designed according with the most popular and efficient scheme. It includes generation sources, DC bus, power converters, storage battery, load and stiff grid. Maximum power point tracking algorithms (MPPT) were developed to increase power generation of PV array and wind turbine. MPPT algorithm based on fuzzy logic controller shows efficient performance for PV arrays. Perturb and observe algorithm gives opportunity to achieve maximum power from wind turbine. Boost converter and active rectifier (AR) were used for power conversion with PV arrays and wind turbine accordingly. Novel control strategy for active rectifier was introduced in article. Here active rectifier was implemented with synchronous generator behavior and this approach is called virtual synchronous machine (VSM). Concept of virtual synchronous machine is alternative method of grid feeding. The model of VSM can emulate properties such as damping and inertia. Virtual synchronous machine allows smooth synchronization in grid tied mode and shows high operation speed and accuracy. In this paper energy system is designed for 10 kW and all essential points such as reliability, optimal control strategy and high efficiency are inherited our system. Modelling was held in MATLAB/Simulink software package.

### A2-6

### TOWARDS THE PROBLEMS OF GREEN ENERGY MARKETS DEVELOPMENT

Yury Nurulin, Inga Skvortsova, Elena Vinogradova, Russia

The article is devoted to analysis of the current state and prospects for development of the renewable (green) energy market. The achieved level of technologies and equipment for production of renewable energy and the main trends in development of these issues is analyzed. The demand of green energy is analyzed from the point of view of free market niches for this type of energy. The main focus in the study is made on the organizational and economic mechanisms for connection of new suppliers to existing grids. The accessibility of energy systems is considered as a key factor for development of the green energy market. The technical, organizational and economic problems of ensuring the accessibility of energy systems are ana-lyzed. The barriers that prevent the level of grids accessibility, which is necessary for the formation of an effective market for green energy, are analyzed. Getting electricity index as a component of the Doing Business rating is used for comparative analysis of availability of electricity grids in the world economies and Russia. The Smart Grid concept is analyzed from the point of view of development the grid's availability.

# A2-7

## DIGITAL TWIN ANALYTIC PREDICTIVE APPLICATIONS IN CYBER-PHYSICAL SYSTEMS

Anton P. Alekseev, Vladislav V. Efremov, Vyacheslav V. Potekhin, Russia; Zhao Yanan, Du Hongwang, China

Abstract. The article shows the relevance of the use of predictive models of digital counterparts for the formation and analysis of time trends obtained from the sensors of the automated control system. The requirements for the predictive model are shown, machine learning algorithms, regression for time series forecasting are described, analysis and comparison of algorithms based on RMSE, MAE, R2 error readings are presented. Also, in the article the methods of automatic determination of emissions and novelty in time series are shown, the methods of detection of dependencies between parameters are given. The authors give an example of integration of the predictive model into the infrastructure of a digital double, describe the life cycle and full functionality of such a system. In conclusion, the prospects of using the predictive model in systems where it is difficult to read the necessary parameters with a given low frequency are shown.

### A2-8

## THE ASSESSMENT OF THE SUCCESS MEASURES AND CHALLENGES OF THE AGILE PROJECT MANAGEMENT

#### T. Kovaleva, Russia

Since every project is unique, there is no ideal project management system suitable for each type of project. However, during the existence of the project management, many effective approaches, methods and standards have been created. One of these methodologies is Agile, which was originally created for software development. That is why this methodology is most often used in the IT industry. However, this does not prevent the usage of Agile by many non-technical teams. Non-IT companies quickly discovered the benefits of using flexible thinking and some Agile practices that can help businesses achieve more. The most important advantage of Agile is its flexibility and adaptability. It can be adapted to almost any conditions and processes of the organization. That is what determines its current popularity and explains why so many systems for different areas have been created on its basis. At the same time, the results of transformation do not always coincide with the expectations. This paper sets out the success measures with the Agile projects. The challenges that companies most often encounter are evaluated and the dependence of the trend in the popularity of Agile techniques on the success of the methodology implementation is studied, based on the largescale surveys of Agile at companies in Russia and worldwide.

# A2-9

## APPLICATION OF A\* PATHFINDING ALGORITHM MODIFICATION WITH THE USE OF R-TREE FOR INDOOR NAVIGATION

### Leonid Borisevich, Sergei Molodyakov, Russia

In this paper a modification of A\* pathfinding algorithm is described, which is adapted for a coordinate plane filled with rectangular obstacles. Each obstacle is described with an enumeration of vertices. With a large number of obstacles in place or high dense of points on a map being used, the task of determination of random point belonging to an obstacle becomes computationally complex. A comparison of data structures for storing information about obstacles is listed in this paper, as well as experimental results. Advantages of using R-Tree structure are presented.

# Education and Social Aspects 2 Roo

Chairpersons:

Leonid Chechurin, Finland Aleksandra Loginova, Russia

E2-1

# ANALYSIS OF STUDENTS' PERFORMANCE IN ONLINE DISCUSSION FORUM: SOCIAL NETWORK APPROACH

# Arnob Islam Khan, Vasilii Kaliteevskii, Iuliia Shnaic, Leonid Chechurin, Finland

In the new era of digitalization, education sector is experiencing changes in terms of learning design, teaching methods, engagement of the learners and integration of technology. Flexibility of online courses attract more students and online Learning platforms provide access to the enormous amount of data. Practically every click can be traced and described. Most of the active learning are taking place in the form of online discussion. Therefore, in order to measure the students' performance in an online course, it is essential to evaluate the communication channels. However, the assessment methods for online discussion remain limited. The objective of the work is to provide a ranking of students based on their participation in the online discussion forum. It provides an opportunity for the teachers' to automatically assess students' performance quantitatively based on systematic approach. In this work, network centrality measures are employed to rank the students based on their interactivity. Text analytics is applied in association with sentiment analysis to assess meaningfulness of each student's communication. The method was tested on the online course data of "Systematic Creativity and TRIZ basics" at LUT University, Finland. In general, these metrics can provide better means to the online educators to assess students' participation in any discussion forum.

### E2-2

# THE ROLE OF HUMAN FACTORS IN CYBER-PHYSICAL SYSTEMS

### Aleksandra V. Loginova, Anton D. Potsulin, Russia

In the paper the role of people in cyber-physical systems is discussed. It should be noted that people play roles of the decision makers in cyberphysical systems, particularly they design and manage these systems. Therefore, human-machine interfaces design is critical in the developRoom 217 16.00-18.15 Monday, 10 June, 2019

ment of CPS, and it should be acknowledged that the possible operation efficiency of CPS highly depends on the approach that takes into account that the system design has to be adapted to human capabilities.

### E2-3

# TERMINAL UNITS INTEGRATION IN MODERN ALERT SYSTEMS

### N. Belov, L. Chernenkaya, Russia

The article describes the integration of alert terminal modules into the modern Russian alert systems. In addition, there is data-reporting model is presented for the subsystem in the integrated operational-dispatch alert system.

### E2-4

# MODELLING COMPLEX PROJECTS' MANAGEMENT SYSTEMS IN THE FIELD OF INFORMATION TECHNOLOGIES

### Marina Bolsunovskaya, Svetlana Shirokova, Aleksandra Loginova, Russia

The paper is dedicated to the methods of complex projects' management, and mainly is based on the paradigm of system analysis. Among others the following methods are proposed to use in complex projects' management system: methods and models based on structural (target-oriented) approach; methods of project management; methods and models based on the personnel approach; methods of organizing complex expertise, etc. The example of a project management system composition based upon the project of development a software complex is given.

### E2-5

### HARDWARE AND SOFTWARE SYSTEM FOR COLLECTION, STORAGE AND VISUALIZATION METEOROLOGICAL DATA FROM A WEATHER STAND

### Pavel Pankov, Igor Nikiforov, Russia

In the modern world, the use of measuring sensors and microcontrollers is growing every year. Their application ranges from household appliances to industrial automation. The article describes the process of developing and creating a software and hardware system designed for collection, storage and visualization meteorological data. The system includes a stand with weather sensors, a microcontroller and a software. It allows user to receive data from the stand with a microcontroller and to interact with the MongoDB database. As a result of the research and the work, a prototype of a hardware and software system was developed, which provides the tracking of atmospheric environmental indicators, their processing, storage and visualization. In addition, the possibilities for further project development are described.

# E2-6

## CONCEPTUAL MODEL OF IT-INFRASTRUCTURE FOR DIGITAL ENTERPRISE: TARGET VISION AND DEVELOPMENT APPROACH

## Anastasia I. Levina, Sofia E. Kalyazina, Maxim A. Sinelnikov, Russia

A modern digital enterprise is able to quickly respond to the changing needs of the market and consumers. Timely and properly conducted business anal-ysis of the enterprise allows to make a plan for the formation of a manufacturing company as a digital enterprise. The article considers the methodology and detailed example of the development of the target model and the automation program of the manufacturing company.

### E2-7

# THE MODEL OF IT COMPANY MANAGEMENT SYSTEM

### Xenia V. Lisovodskaya, Aleksandr D. Shadrin, Russia

The proposed model bases on: Scrum proses framework, Project management standards that solves Scrum fragmentation problem, System and software engineering, that allows to develop more consistent management system of IT company.

# E2-8

# THE 120TH ANNIVERSARY OF METROLOGICAL EDUCATION IN RUSSIAN FEDERATION

### N. Kuprikov, A. Ekimov, M. Polishchuk, Russia

In 2019, the Russian Federation celebrates the 120th anniversary of metrological education. On June 4, 1899, Emperor Nicholas II approved the "Regulations on Weights and Measures" devel-

oped by the Russian scientist Dmitry Ivanovich Mendeleev, the founder of Russian metrology. In accordance with the Provision, the creation of testing institutions and the training of qualified specialists performing verification were envisaged. For the first time in Russian history the foundations for training of specialists in metrology were laid. This reform initiated by D.I. Mendeleev became the basis for the transition of Russia to the normative and legislatively fixed system of metrology, and also served as the beginning of the national metrological education. Today the Academy of Rosstandart which is in the system of the Federal Agency for Technical Regulation and Metrology continues the process of specialists in the field of metrology training begun by D.I. Mendeleev. According to the Order of Rosstandart of March 14, 2018 No. 477, the Academy is the organization that provides additional professional education, training and retraining of the personnel of Rosstandart and subordinate organizations in the field of technical regulation, standardization and metrology.

# E2-9

# TRANSFORMATION THE PLM-SYSTEM INTO THE CYBER-PHYSICAL SYSTEM FOR THE INFORMATION ENSURING OF MANAGING THE ENTERPRISE

### V.N. Volkova, A.E. Leonova, V.I. Karpov, Yu.Yu. Chernyy, Russia

The article proposes the concept of transforming the existing PLM-system (product lifecycle management) into a Cyber-Physical System for the production and management of an enterprise (in the extended understanding of this term). The concept is based on the study of the interaction of product development systems and making decisions about the feasibility of transferring the relevant processes to an automated digitalization mode. When do the Transformation the PLM-System into the Cyber-Physical System. It is necessary to investigate the business-processes of an enterprise by developing appropriate models, briefly described in the article. Tuch a transformation based on the introduction of emergent technologies can be the basis for creating a cyber-physical system for managing all the life cycle processes of an enterprise - from receiving an order and organizing production to delivery to the customer and product support.

# **Fundamentals 3**

Chairpersons:

Boris Sokolov, Russia Vyacheslav Shkodyrev, Russia

# F3-1

### OPEN CYBER PHYSICAL SYSTEM CONCEPT

Yury S. Vasiljev, Violetta N. Volkova, Vladimir N. Kozlov, Russia

The purpose of this article is the concept substantiation of the Cyber-physical system (CPS) as an open system with active elements. The development take place due to the exchange with the environment of material objects, energy, information (system openness) with the environment and due to the presence of active elements, which: 1) initiate the implementation and interaction structure of industrial (advanced industrial) and modern information (digital) technologies, resulting in a new quality, there is arises a law of emergence, which is the basement of negentropic tendencies, do opposing the law of increasing entropy in closed systems (ie, the second physical law of thermodynamics), which ensures the development in the open systems theory of L. von Bertalanffy, and 2) maintaining of stability, ability to resist to undesirable results, that may arise from the simultaneous implementation of heterogeneous innovative technologies. The possibility of using of the proposed concept of the CPS as a means for sustainable development of an enterprise is ensured by the fact that CPS is developed not as a separate introduction of technologies, but as a system in which digital technologies have to be included in the enterprise life cycle (in the technological process and organizational management system) and the task is to preserve on control functions for the active elements that are part decision makers, on the selection and implementation of innovations. Developing of models for analysis and control the choice of innovative technologies on creating cyber-physical systems for concrete enterprises and organizations, we is proposing to use systems theory and systems analysis methods.

### F3-2

# DISTRIBUTED KNOWLEDGE BASE OF INTELLECTUAL CONTROL IN SMART GRIDS

D. Kostenko, D. Arseniev, V. Onufriev, Russia

The article proposes solution for low efficiency and inadequate power distribution in zero-energy **26** 

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building grids. Distributed knowledge base application enables power grid segments self-sustainability and amplification of zero-energy buildings efficiency. Proposed methodology of smart grids development is headed towards optimal power generation and consumption control, adjusted power spike handling and improvements in operational reliability. Key performance indicators of various levels and hardware restrictions are taken into account. The system is able to function on already existing equipment with minor adjustments. According to the proposed algorithm a computer model is written. The model creates randomly-generated power grid segments consisting of zero-energy buildings, non-producing buildings and supportive equipment. Each individual building receives its own power consumption and production levels. Those parameters are measured and analyzed within two series of experiments. The tests conducted show efficiency of the proposed logic and measure potential power savings within different the worst- and the best-case scenarios and use-cases.

### F3-3

### METHODOLOGY OF COMPLEX OBJECTS STRUCTURAL DYNAMICS PROACTIVE MANAGEMENT THEORY AND ITS APPLICATION

Boris Sokolov, Vyacheslav Zelentsov, Nikolay Mustafin, Vadim Burakov, Russia

Methodological and methodical fundamentals of the complex objects (CO) proactive management and control theory based on the fundamental results obtained in the interdisciplinary field of system knowledge are proposed. The paper provides information on the developed innovative multiple-model complexes, combined methods, algorithms and techniques to solve various classes of problems of operational structural and functional synthesis and management of the development of the regarded classes of CO. The tasks of controlling the structural dynamics of CO belong to the structural and functional synthesis class of problems and the formation of appropriate programs for managing and control their development. The main difficulty and feature of the solution of these regarded problems is as follows. Determination of optimal control programs of the basic elements and subsystems of the CO can be performed only after all functions and algorithms of information processing and control, which should be implemented in these elements and subsystems, become known. In turn, the distribution of functions and algorithms on the elements and subsystems of CO depends on the structure and parameters of the control laws of these elements and subsystems. The difficulty of resolving this controversial situation is exacerbated by the fact that under the influence of various reasons, the composition and structure of the CO at different stages of its lifecycle changes over time. The gives examples of solving practical problems for such subject areas as spacecraft, logistics, and industrial production.

### F3-4

### "MOMENT" REPRESENTATION OF "FAST DECREASING" GENERALIZED FUNCTIONS AND ITS APPLICATION IN SEVERAL APPLIED STOCHASTIC PROBLEMS

### Andrei N. Firsov, Russia

This paper describes the process of building special space of generalized functions, its properties and applications. Presented applications are: constructive solution of Kolmogorov-Feller type equation with polynomial drift coefficient; proof of exponential nature of equilibrium establishment in rarefied gas, described by Boltzmann equation of kinetic theory of gases.

# F3-5

# KNOWLEDGE PROCESSING METHOD WITH CALCULATED FUNCTORS

### Alexey Kuvaev, Vasily Meltsov, Nataly Zhukova, Russia

Intellectual inference methods are one of the convenient tools for solving certain classes of knowledge processing tasks. One of the current areas in which the application of logical inference methods and engines can lead to new results is the field of cyber-physical systems that has been actively developing in recent years, including the control of unmanned vehicles and aircraft, intelligent mechatronics and robotics. But for this it is necessary the operations of processing numerical information to enter into the logical conclusion procedure. The high-performance method of parallel output based on the disjunct (clauses) division is selected as the basic method of logical inference. To implement arithmetic operations, this method is proposed to be

supplemented with a special mechanism of calculated functors. The developed modified inference method differs from the known methods by a number of important advantages. Firstly, it will significantly expand the use of artificial intelligence methods in cyber-physical systems. Secondly, inference and arithmetic operations can be performed in parallel. And thirdly, it is an opportunity to use for the arithmetic calculations the available special processors of logical inference on the FPGA for autonomous intelligent

### F3-6

### GRAPH MODEL APPROACH TO HIERARCHY CONTROL NETWORK

### Dmitry Arsenjev, Dmitry Baskakov, Vyacheslav Shkodyrev, Russia

In this paper, we propose to consider the possibility of using graph models for control and monitoring systems. The central element of the control system is a neural network, which will be built using the Directed Acyclic Graph. The novelty of the approach lies in the fact that the proposed software implemen-tation of this approach using deep learning packages, for example, TensorFlow1 or Keras2. In this case, it is useful to use the mathematical apparatus of the Di-rected Acyclic Graph to construct such complex multilevel hierarchical models of deep learning.

### F3-7

# APPLICATION OF METHODS FOR OPTIMIZING PARALLEL ALGORITHMS FOR SOLVING PROBLEMS ON DISTRIBUTED COMPUTING SYSTEMS

### Shichkina Yulia, Kupriyanov Mikhail, Al-Mardi Mohammed Haidar Awadh, Russia

Today, various researchers have developed a set of methods for optimizing parallel algorithms for systems with distributed memory. These methods are optimized for various parameters and taking into account various properties of the algorithm. A distributed computing system has its own characteristics, such as heterogeneity of computing nodes, network bandwidth and others. The studies conducted by the authors of this article show that these characteristics do not interfere with the application of these methods to solving problems in a distributed computing environment. The article shows that there is no need to modify and adapt optimization methods for use in distributed computing systems. But, taking into account the properties of such systems contributes to the emergence of iteration in the application of optimization methods and increases the complexity of the process of analysis and optimization of the initial parallel algorithm. The article also describes ways to solve the problem of reducing the time complexity of the iterative application of optimization methods to the initial parallel algorithm. The results of the research of the authors is a method for constructing a special type of graph for a parallel algorithm taking into account the properties of a given computing system and approaches to constructing the schedule of the algorithm.

### F3-8

### COMPLEX SYSTEM AND VALUE BASED MANAGEMENT AND CONTROL: MULTIATTRIBUTE UTILITY APPROACH

#### Yuri P. Pavlov, Rumen D. Andreev, Bulgaria

Inclusion of the personal human knowledge and intuition or even the social needs and understanding in the system modeling is a challenge and put a new level of challenges. The utility theory is the mathematical approach to measurement and utilization of qualitative, conceptual in-

formation and permits the inclusion of the decision maker (or the technologist, manager) in complex model like "Technologist - dynamical model" in mathematical terms. The subject of this paper is the design of a methodology and algorithms for evaluation of expert utility (value) function and that permit development of value driven control in systems where the individual human choice is decisive for the solution. It is presented a methodology and machine learning algorithms for evaluation of expert utility function used in development of value driven control where the human preferences are basis or important part for solution. This approach is illustrated by modeling of exhaustible forest resource management and timber production based on the optimal control of exhaustible forest resource. The principles of rationality and market efficiency need economically effective resource management. A multiattribute utility function is included in the dynamical model and by this way the optimal control solution is synchronous with the consumers' preferences.

# **Technologies 3**

Chairpersons:

Anton Kvasnov, Russia Svetlana Shirokova, Russia

# T3-1

# ESTIMATING THE ACCURACY INCREASE DURING THE MEASURING TWO QUANTITIES WITH LINEAR DEPENDENCE

### V.A. Garanin, K.K. Semenov, Russia

Increasing of measurement accuracy is always relevant goal. One of methods to achieve this is to use relations between quantities to be measured - if such relationships exist and are known at least approximately. At present there are not so many published articles that describe metrological applications which use this kind of information about measured quantities to get better accuracy. It seems that small amount of practical realizations is because of necessity to use rather sophisticated mathematical approaches based on the probability theory and mathematical statistics and numerous simulations to make a conclusion about potential increase of accuracy. This paper presents the simplified approach producing a set of clear enough formulas and indicators, which are helpful for engineers during preliminary estimation of the potential increase of accuracy from the known interconnections between measured quantities. A case of linear dependency between measured quantities is analyzed to show how the approach works.

### T3-2

### A NEW APPROACH TO FEATURE GENERATION BY COMPLEX-VALUED ECONOMETRICS AND SENTIMENT ANALYSIS FOR STOCK-MARKET PREDICTION

### Dmitry Baryev, Igor Konovalov, Nikita Voinov, Russia

Theory of complex-valued econometrics makes it possible to generate gualitatively new features that can be used in machine learning algorithms. Our study reveals the task of determining the long-term dependence of future companies' stocks prices on a time-generated feature - a calculated tonality coefficient gained by methods of semantic analysis of texts from social networks. Data was gathered from Twitter platform with the use of Big Data ETL-scenarios. The resulting data sets were used to train machine learning algorithms designed to work with Big

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Data technologies. A semantic coefficient was calculated on the basics of aggregated estimates for each day, with the further application of the methods of complex-valued econometrics. To demonstrate the new approach of feature generation a complex-valued linear regression model based on the semantic coefficients and stock markets data was constructed. The outcome obtained by new approach was compared to existing solutions in terms of accuracy and. Finally, we demonstrate a possible route for impact in improvements of the existing algorithms for trading strategies using the complex-valued regression.

### T3-3

## FLEXOGRAPHIC PRINTING OF OPTICAL MULTIMODAL Y-SPLITTERS FOR OPTICAL SENSOR NETWORKS

### Keno Pflieger, Ludger Overmeyer, Germany

Flexographic printing on Polymethylmethacrylat (PMMA) substrates is a promising technology for the cost effective production of large-scale optical networks. It allows for numerous applications in the fields of data transmission, sensing and point-of-care systems. This article introduces the flexographic printing of optical multimode ysplitter as a fundamental element for these networks. It is printed with an optical grade acrylic polymer on flexible PMMA substrates. We investigated geometric and optical properties of splitters with angles up to 20° and achieved attenuations below 1.3 dB at 638 nm.

### T3-4

## COMPLEX EXPERT ASSESSMENT AS PART OF FAULT MANAGEMENT STRATEGY FOR DATA STORAGE SYSTEMS

### Olga Mamoutova, Svetlana Shirokova, Mikhail Uspenskij, Vladimir Zhvarikov, Russia

A fault management strategy for a data storage system usually employs the methods of error and anomaly detection, fault diagnosis, root cause analysis and failure prediction. There is a variety of methods in the field of reliability and fault tolerance that are applicable for fault management of enterprise data storage. However, current implementations of fault management strategies lack automated support to incorporate a particular expert knowledge. Informational approach as an element of a complex expert assessment is one of the ways to engage an expert knowledge in a fault management strategy. Presented methodology provides a new comprehensive approach to the problem of fault management with a data storage system as an application use case.

### Т3-5

# ABNORMAL ACTIVITY DETECTION IN CROWDED SCENES USING VIDEO SURVEILLANCE

### Wassim Assi, Russia

Abnormal activity detection is a challenging problem in video surveillance for security purposes and protection system. We presents a new approach for abnormal activity detection in videos surveillance with crowded scenes which is important for many daily purposes. Our approach based on three types of features for detecting anomaly events. First type is motion features based on optical flow calculation, second type is the size of moving individuals along frames, and third type is motion magnitude. We will use many training approaches in supervised and semi-supervised and unsupervised learning to choose the best method. We will use UCSD Anomaly Detection dataset. Aim is to identify anomalies in video feeds using Machine Learning techniques and many types of learning algorithms to build an effective classifier, evaluate and compare between these algorithms to choose the best performance.

### T3-6

## CYBER-PHYSICAL SYSTEM AS THE DEVELOPMENT OF AUTOMATION PROCESSES AT ALL STAGES OF THE LIFE CYCLE OF THE ENTERPRISE THROUGH THE INTRODUCTION OF DIGITAL TECHNOLOGIES

#### Arina Kudriavtceva, Russia

Nowadays the complexity of automation processes is increasing. As a result, there is a need for distributed automation systems that are necessary for work in conditions of limited control in real time and communication in production processes. Cyber-physical systems imply a fully synergistic integration of computing and control with physical devices and processes. Furthermore, the introduction of the cyber-physical system into the enterprise's automation systems will help to combine automation process control and automation production control and the enterprise as a whole, will help create a controlled system, from order to implementation. In this paper, a cyberphysical approach to the design of a distributed automation system is considered. This approach allows integrating control, communication, and calculations at all stages of the product life cycle. The basis of the cyber-physical system is the introduction of digital technologies, as all innovations are provided and improved by computing power and data analytics. To assess the usefulness of introducing technologies for creating a cyber-physical system, it is proposed to use informational assessments by A.A. Denisov.

#### T3-7

### CLASSIFICATION METHOD OF FIXED GROUND OBJECTS BY RADAR IMAGES USING ARTIFICIAL NEURAL NETWORKS

#### Anton Kvasnov, Russia

The article considers a recurrent Bayesian algorithm for recognition of object classes in conditions of radio-electronic control and monitoring of the surrounding space. Mathematical model of an algorithm are given. The conditions allowing to use the received expressions for lighting systems of the environment are proved. An application example of the algorithm for a iterative model is considered.

### T3-8

### INTELLECTUAL COGNITIVE TECHNOLOGIES FOR CYBER-PHYSICAL SYSTEMS

#### Galina V. Gorelova, Russia

The paper presents information on the cognitive modeling of complex systems and provides considerations on its place within the framework of research and development of cyber-physical systems. Theoretical and practical results of the application of cognitive modeling of complex systems can be attributed to the intellectual decision support systems in the socio-economic and industrial areas. Mathematical and software apparatus of cognitive modeling of complex systems is designed to describe the structure and behavior of a complex system in the face of uncertainty, implements an interdisciplinary approach to decision making problems. For the future can be recommended for use in the direction of «Cognitive city». A number of results of cognitive modeling of a regional socio-economic system are presented. The cognitive map of the system, the results of the study of its structural and dynamic properties, the results of scenario modeling and recommended management decisions are presented.

# **Applications 3**

Chairpersons:

Gennady I. Korshunov, Russia Vladimir A. Polyanskiy, Russia

# A3-1

# POWER MANAGEMENT IN OPTICAL AUTONOMOUS SENSOR NODES

### Uliana Dudko, Ludger Overmeyer, Germany

Solar cells are the most common energy scavengers due to their ease of use, eliability and wide range of applications wherever the light is present. One of such applications is wireless autonomous sensor network, where each sensor node tends to be as small as possible. In this paper, we describe a way to optimize the optical energy harvesting process using as an example a power management IC BQ25570. We introduce an approach to calculate the minimal solar cell area and storage capacitance, which are necessary to supply the module in the active mode for a defined time period and to minimize the charging time.

### A3-2

# THE MODEL OF CYBER-PHYSICAL SYSTEM FOR HYBRID RENEWABLE ENERGY STATION CONTROL

### Dmitriy G. Arseniev, Vyacheslav P. Shkodyrev, Kamil I. Yagafarov, Russia

Cyber-Physical System (CPS) is a modern engineering system class based on a synergy of software and hardware components. In CPS, embedded computers and networks monitor and control physical processes using feedback loops where physical processes have an impact on calculations and vice versa. The present paper is devoted to the CPS development to control the process of energy production.

### A3-3

# LINEAR DIRECT DRIVE FOR LIGHT CONVEYOR BELTS TO REDUCE TENSILE FORCES

Ludger Overmeyer, Malte Kanus, Alexander Hoffmann, Bernd Ponick, Germany

Due to improving requirements of the mass flow and transport lengths, the use of intermediate drives for continuous conveyors for both packaged and bulk materials is constantly increasing. Intermediate drives allow the transmission of Room 316 16.00-18.00 Tuesday, 11 June, 2019

drive forces along the conveyor and thus lead to a reduction in the maximum belt tensile force. This paper presents a new drive concept for light conveyor belts. To reduce the belt tensile force, intermediate drives in form of linear direct drives are allocated over the transport distance. In the first part, a new belt design is presented which enables the implementation of the linear direct drive rotor elements. On the one hand, this is characterised by the low additional weight of the rotor elements. On the other hand, the conveyor belt has only a slightly higher bending stiffness compared to conventional conveyor belts, whereby small pulley diameters can be achieved. In the second part, the drive concept in the form of an Integrated Linear Hybrid Flux Modulating Motor (ILHFM) is explained more detailed. In particular, possible problems and the developed solutions, which were implemented and verified in a demonstrator, are presented. The results of the research show the high potential of the new drive concept especially in various application scenarios.

### A3-4

# CYBER-PHYSICAL SYSTEM FOR THE TECHNICAL CONDITION MONITORING OF HEAT NETWORKS

### G.I. Korshunov, A.A. Aleksandrov, A.R. Tamvilius, Russia

The issues of creating a new generation of heat pipe monitoring systems using the method of pulse reflectometry are considered. The control conductors built into the thermal insulation layer along the thermal conductor ensure the detection and localization of an ongoing or forecasted accident during the thermal insulation dampening. The introduction of technological innovations in the primary basic structure has led to a reduction in equipment and an increase in system reliability. New hardware and software tools have created the conditions for in-depth analysis of the technical condition of heating networks and solving new control tasks. The proposed approach and its development correspond to the concept of cyber-physical systems. The physical process of wetting insulation is an indirect but

significant accident factor. Control of wetting in the prescribed tolerances fixes a sign of an accident when going beyond the tolerance field. However, the value of the parameters of a pulse reflected from the place of moistening, the dynamics of its changes carry important additional information for a possible forecast of the technical condition and energy efficiency of pipelines and heat networks in general. The formation, transmission, processing of information from many objects of heat networks using knowledge bases, the Internet of things and other elements of the Industry 4.0 concept ensures the generation of near-optimal solutions and the achievement of high energy efficiency.

### A3-5

# APPLYING THE DESIGN THINKING APPROACH TO DEVELOPING NEW DIGITAL PRODUCTS

### Sofia E. Kalyazina, Oksana Yu. Iliashenko, Alexandra D. Borremans, Russia

Design thinking approach currently is a very promising method of product development as it allows to increase the consumer's orientation of the new product, to increase product satisfaction. The article analyzes the existing literature on the subject of Design thinking, reveals the main stages and methods of product development based on this approach. Based on this, an example of product development in the field of the Internet of Things in Medicine is considered.

### A3-6

# MEASUREMENTS OF QUALITATIVE SIMILARITY IN CYBER-PHYSICAL SYSTEMS

### V.S. Zaborovskiy, A.A. Lukashin, V.A. Polyanskiy, L.V. Utkin, Russia

An important aspect in human and machine communication is the ability of a man to distinguish not equivalent, but similar objects. For example, in a cyber-physical production system, a person may use bolts that are different in length from the one described in the documentation for assembly. At the same time, the automatic acquisition system should be able to replace the standard bolts with similar ones without human intervention. Similar tasks often arise in the selection of components of complex systems. For machine control systems, it is necessary to quantify the degree of similarity, since otherwise infinite numbers will be chosen. An important problem is also the search and selection of similar models when registering the rights to an industrial design and in general any search for analogues. A

typical approach to solving this problem is the decomposition of the material into parts and the compilation of a feature tree or a tree of connectedness of individual parts of an object. Facial recognition done by this algorithm occurs. However, such a decomposition does not reveal the overall shape of several related parts. The authors of the report propose the method of chords as the basic algorithm invariant to rotation and small changes in shape. The results of applying this approach to the automatic detection of oncological formations and related three-dimensional models are given. The results of testing software products and the long-term prospects for using similarity detection methods in cyber-physical systems are discussed.

### A3-7

# ENHANCING THE PERFORMANCE OF RESERVATION SYSTEMS USING DATA MINING

Elena N. Desyatirikova, Alkaadi Osama, Vladimir E. Mager, Russia; Ahmad Saker Ahmad, Syria

This paper is dedicated to applying data mining techniques to obtain knowledge from large databases of online resource reservation systems such as air travel, post office, hotels, hospitals and many more. The acquired knowledge is used to predict customer behavior and improve resource planning through improved overbooking management. Overbooking is a common trick, for example, in the area of tourism or hotels, where the consumer is completely expected to be denied services that have been pre-ordered. In other terms, such cases are referred to as «nonattendance».

### A3-8

### CREATION OF CYBER-PHYSICAL SYSTEMS BASED ON BASIC STRUCTURES IN CONDITIONS OF UNCERTAINTY

#### Gennady Korshunov, Russia

The article describes the processes of transformation of the basic structures of technical systems into cyber-physical systems based on the introduction of innovations. A distinctive feature of cyber-physical systems is the direct penetration of methods and means of cybernetics into controlled physical processes in order to intellectualize the system and minimize the influence of the «human factor». The introduction of innovations occurs in conditions of insufficient information and is always associated with different types of uncertainty. Uncertainty disclosures are based on probabilistic models, fuzzy sets or using knowledge bases. The phased introduction of innovations allows for the reasonable allocation of resources. Basic structures are fundamental technological innovations, represented by functionally necessary and functionally sufficient structures of systems that control physical processes. The article describes the processes of transformation of the basic structures of systems into cyber-physical systems used in various physical environments - solid, liquid and gaseous. As examples, the automatic assembly line of printed circuit boards, the locating system for monitoring thermal networks by the method of monitoring insulation dampening, the system of catalytic neutralization of vehicle exhaust gases are considered. In these examples, the objects of activity are primary physical processes. An in-depth study of primary physical processes made it possible to obtain new informational possibilities for analyzing, interpreting and regulating the key parameters of the above systems based on computing resources.

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Chairpersons:

Nguyen Hoang Sy, Vietnam Svetlana Ye. Shsepetova, Russia

# E3-1

# REFERENCE MODEL OF SERVICE-ORIENTED IT ARCHITECTURE OF HEALTHCARE ORGANIZATION

## Igor V. Ilin, Anastasia I. Levina, Aleksandr A. Lepekhin, Russia

The healthcare system nowadays rapidly moves towards digital transformation: digital technologies influence not only technical support of medical processes, but changes business models of healthcare organizations. Implementation of new technologies into the architecture of healthcare system requires clear under-standing of all the elements of the existing IT architecture and its relations in order to combine effectively the requirements of medical processes and possibilities of digital technologies. The IT architecture is a set of application components that realize a set of IT-services, which in turn supports the system of business processes of a healthcare organization. The paper describes the transparent and coherent reference model of the IT architecture and reference list of IT-services based or the functional structure of the healthcare organization. The reference model can be adapted to further detailed design of the applications of a particular healthcare organization.

### E3-2

## IT-ARCHITECTURE DEVELOPMENT APPROACH IN IMPLEMENTING BI-SYSTEM IN MEDICINE

### Oksana Yu. Iliashenko, Victoria M. Iliashenko, Alisa Dubgorn, Russia

One of the main key aspect of management in medical organizations is information support by different analytical systems. For this reason, the number of medical organizations that decide on the implementation of Business Intelligence class systems increases. BI-system allows for the data operational monitoring on the medical organizations management, simplifies the entire process of forming analytical reports in the company. BI system is the most complete source of information on current activities in the medical organizations. The BI-systems implementation in the enterprise IT architecture involves the modRoom 217 16.00-18.00 Tuesday, 11 June, 2019

ernization of the business processes system, services architecture, the development of IT architecture and information exchange model. One of the important tasks in the information-analytical system implementation is its integration into the existing enterprise architectural solution. This paper provides the development of the medical organization's IT architecture and a corresponding the information exchange model when solving problems of integrating BI system into the general enterprise IT architecture.

### E3-3

## DESIGN AND DEVELOPMENT OF AN ALGORITHMIC-PROGRAMMED SOFTWARE OF THE AUTOMATED INTELLIGENT LIGHTING SYSTEM FOR INDUSTRIAL PREMISES

#### Farah Yousef, Russia

With the growth of implementation in lighting systems devices, increasing the demand for tools to manage them. There are currently several standardized lighting control protocols on the market, like 0-10 V, DALI, KNX, DMX512, etc. These devices are quite expensive and usage it in industrial plants is limited. so, in this paper we work on developing a lighting system of industrial premises. The system is similar to standard lighting devices and cheaper than it and based on microcontrollers (Atmega) and Labview interface that monitors and supervise the system. Protocol, exchanging the data is «RS-485» (based on UART) which correspond working in industrial environment.

### E3-4

# DATA MANAGEMENT IN THE BUSINESS PROCESS SYSTEM

### Dmitry Yu. Mogilko, Victoria M. Iliashenko, Sergei G. Svetunkov, Russia

The paper reveals the opportunities of business intelligence in the enterprise business process management system in the era of digital transformation. Data management is presented from positions of the system approach on the basis of functional and time decomposition that promotes the increase of digital infrastructure designing efficiency of designing digital infrastructure designing for their storage and processing. At the same time, the performance of various process tasks and the work of projects is evaluated separately at the operational level.

### E3-5

# THE ROLE AND PLACE OF CYBER-PHYSICAL SYSTEMS IN THE LIFE OF SOCIETY: A SYSTEM MODEL OF CONTROL AND MANAGEMENT

### Svetlana Ye. Shsepetova, Russia

The development of techniques and technology at present time is moving the human community to a new level of organization of activities. However, the opening opportunities are accompanied by appearance of the serious risks for the individual, organizations and society as a whole. That how cyber-physical systems will affect on all stakeholders depends on the systemism/nonsystemism of the actors' worldview. Understanding each of them of the system principles of the organization of the society vital-activity by cyberphysical systems becomes decisive at this stage.

#### E3-6

### NETWORK CHALLENGES FOR CYBER PHYSICAL SYSTEMS IN TRAINING PROGRAMMES

Dmitry G. Arseniev, Victor I. Malyugin, Vyacheslav V. Potekhin, Russia; Cso Viet Hieu, Nguyen Hoang Sy, Nguyen Ngoc Tan, Vietnam

Joint educational programmes offer opportunities to integrate partner universities in the fields of research, development and education in order to solve such questions as improving the quality of teaching, search for new forms of effective interaction between scientific and educational schools of partners, introduction of innovative educational technologies. The most sought now is organisation of educational programmes that implement practical-oriented online courses, shortand long-term skills training, implementation of such technologies which realised in educational process in School of Cyber-Physical and Control Systems. A very important step in the development of interaction between Peter the Great St. Petersburg Polytechnic University and Binh Duong University is the creation of a unified educational environment and laboratory of intelligent control systems and further development of Synergy project.

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