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Keynote Lectures

Oleg Darintsev, Head of "Robotics and control in technical systems" Laboratory Mavlyutov Institute of Mechanics, Ufa Investigation Center, R.A.S., Professor Ufa State Aviation Technical University, Ufa, Russia

Lecture Title: The micro grippers: principle of operation, construction and control method

Abstract: The micromanipulation operations are a complex problem, so specific approaches are required in the development of microgripper designs and synthesis of its control systems. Different examples of microgrippers are given, ways to control them are discussed. The problem of performing micromanipulation operations, the main effects acting in the contact zone of parts and a gripper, as well as the features of the implementation of operations to grip objects with dimensions less than 1 mm are considered. The classification of microgripping devices of robots used in the assembly of microsystems or planned for use is given. Particular attention is paid to specific techniques for the design of microgrippers, original technical and technological techniques.

Vladimir Fetisov, Professor of Information and Measuring Technologies Department at Ufa State Aviation Technical University, Ufa, Russia

Lecture Title: Aerial Robots and Infrastructure of Their Working Environment

Abstract: Aerial robots (also known as UAVs – unmanned aerial vehicles) are increasingly being introduced into our life. Today we can see aerial robots in agriculture, building industry, delivery services, security and monitoring systems and so on. More frequently not single UAVs but their groups are used. And it would be reasonable to control such groups at all functioning stages, including on-ground maintenance, in automatic mode. Development of infrastructure for automatic service and maintenance of aerial robots has appeared on the agenda of many companies specializing in unmanned aerial systems. Some aspects of such infrastructure creation are discussed in this paper with special emphasis on charging stations for UAVs with electrical propulsion system.

Ilshat Mamaev, employee of the group of intellectual industrial robotics of the Institute of Anthropomatics and Robotics Karlsruhe Institute of Technology, Karlsruhe, Germany

Lecture Title: Towards human-robot collaboration

Abstract: Nowadays robots are shifting from highly structured industrial environment into human everyday life. This implies new requirements to the robot control, perception, cognitive abilities and safety. In this talk an overview of current research and industrial projects with a focus on human-robot collaboration will be given. Besides of control aspects of such systems, new proximity tactile sensor technology and its applications in robotics will be shown. Finally, some examples of AI/Machine Learning methods and it's applications in robotics will be presented.

	**Sergey Konesev,** Associate Professor of the Chair «Electrical Engineering and Electrical Equipment Enterprises», FSBEI HE "USPTU", Ufa, Russia **Lecture Title:** Multi-function integrated electromagnetic component for secondary power sources **Abstract:** The development of digital, intelligent energy, electromechanics, electrical engineering leads to the active use of secondary power sources, frequency converters, inverter technology, power electronics. The desire to reduce the mass and dimensions of electrical devices and systems, increase their specific power creates the need to use key (pulse) modes of electric energy converters. To reduce electromagnetic interference, as well as dynamic losses during switching, it is advisable to use the resonant modes of the inverter technology. A multifunctional integrated electromagnetic component (MIEC) has been developed, capable of performing the functions of inductance (inductor), capacitor and transformer at the same time.
	**Jesus Savage,** Professor of the Department of electronics and engineering of the National Autonomous University, Mexico City, Mexico **Lecture Title:** Robotics, AI and Machine Vision conjunction paradigm **Abstract:** A semantical reasoning analysis mechanism is discussed, based on symbolic AI methods and digital signal processing for VIRBOT robotic system, being used in service robot testing for RoboCup-at-Home competitions, where a robot has incomplete data and acquires missing pieces of data, interacting with users.
	**Robert Sattarov,** Professor of Electromechanic Department, Ufa State Aviation University, Ufa, Russia **Lecture Title:** Worm-like locomotion systems for in-pipe robots and its fuzzy sliding controller design **Abstract:** Worm-Like Locomotion Systems (WLLS) for a class of in-pipe robots is considered, and a novel fuzzy sliding mode controller is designed for the velocity tracking problem in the WLLS. Because of the strong nonlinearity, an estimator for a friction force is created and it is used into the construction of the sliding mode controller. A sliding mode surface is provided based on the tracking error of the longitudinal displacement and a center of mass velocity. Fuzzy rule is formed to tuning one of sliding mode designable parameters. Simulation results verify the effectivity of the presented fuzzy sliding mode control method
	**Lingfei Xiao,** Associate Professor and Deputy Director of Control Engineering Department, College of Energy and Power Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing, China **Lecture Title:** Intelligent sliding mode control and its application in mechanical & power systems **Abstract:** Sliding mode control (SMC) is an effective control method with strong robustness, intelligent optimization algorithms have good effects for SMC on attenuating chattering, facilitating the parameter tuning, enhancing the robustness to mismatched uncertainties and improving the fault tolerance. In this talk, several kinds of intelligent sliding mode control methods will be given, the steady and dynamic control performance, robustness and fault tolerance will be shown on some mechanical & power systems.

Section: Robotics and Automation

Mikhail Khachumov. **Tactical Level of Intelligent Geometric Control System for Unmanned Aerial Vehicles**

Abstract: This study considers the tactical level of the intelligent geometric control system designed to solve the cutting-edge scientific problem of controlling unmanned aerial vehicles (UAVs) in unstable conditions. Intelligent-geometric theory combines geometric control methods (methods of optimal control, complex motion control and stabilization, formation control, trajectory and target tracking, differential pursuitevasion games, etc.) with intelligent control methods using tools of artificial intelligence (productions, semantic networks, fuzzy logic, framebased behavioral microprograms, frame-based operations, machine learning, genetic algorithms, methods of knowledge acquisition, etc.) and provides reliable and high-performance control techniques for operating in uncertain environments under wind disturbances. Hierarchical architecture of intelligent geometric control system is designed for joint application of precise geometric and adaptive intelligent control methods as parts of a single robotic system. The solution to the problem of controlling a UAV group taking into account mathematical models of an aircraft and wind loads was simulated in MATLAB system.

Tagir Muslimov and Rustem Munasypov. **Three-Dimensional Consensus-Based Control of Autonomous UAV Swarm Formations**

Abstract: This paper presents a multi-agent approach to controlling a decentralized swarm three-dimensional (3D) formations of autonomous fixedwing unmanned aerial vehicles (UAVs). Cooperative control is analyzed within the framework of coordinated rectilinear path following. Focus is made on attaining a pre-specified geometric configuration and maintaining the resulting UAV formation vertically by controlling the altitude difference (distance between aircraft along the vertical). Consensus-based UAV interaction is used, i.e. there is no 'leader'. Each UAV is assumed to be equipped with a standard autopilot, in which a finite-state machine controls the flight altitude. Thus, an arbitrary preconfigured 3D formation can be attained by combining this strategy with the existing approaches in controlling a formation as projected onto a horizontal plane. The proposed control laws are adjusted to the input constraints arising from the vertical velocity limits of the UAVs. MATLAB/Simulink modeling used complete nonlinear 6 degree-of-freedom (DoF) 12-state models of fixed-wing UAVs equipped with tuned autopilots in two scenarios: a group following a horizontal path, and following a descending path. Modeling showed the proposed multi-UAV swarm controls were effective, as they could accurately attain and maintain a 3D formation of required shape.

Valeriia Izhboldina, Igor Lebedev and Aleksandra Shabanova. **Approach to UAV Swarm Control and Collision-Free Reconfiguration**

Abstract: In this paper the problem of unmanned aerial vehicle (UAV) swarm control is considered. As the most promising approach to UAV swarm control a composite one was chosen. The proposed conceptual model of the composite method includes operator, base station, and two communication networks: one between agents and another one between base station and agents. UAV trajectory computation is fulfilled on the land-based station using swarm reconfiguration algorithm. Two enhanced 3D reconfiguration algorithms were presented: eased and based on divide and conquer – which differ in used collision avoidance methods. Eased algorithm contains a method of parallel translation of target points, homothety and target coordinate exchange method. To ensure control of greater swarm size, algorithm based on divide and conquer was developed. Algorithm based on divide and conquer includes

parallel translation, delay allocation method, collision graph composition and divide and conquer algorithm. For evaluation algorithm performance tests in virtual environment were performed on swarms of different sizes (from 10 to 100 agents). Greater trajectory calculation time and swarm reconfiguration time are explained by the greater number of used methods. However, the total trajectory and the average number of collisions calculated using algorithm based on divide and conquer have smaller values compared to eased algorithm. Eased algorithm provides UAV movement without collisions with a swarm size of 70 agents, while algorithm based on divide and conquer has a limit of 90 agents. Therefore, for swarm reconfiguration with a large number of agents, algorithm based on divide and conquer is more preferable.

Egor Aksamentov, Konstantin Zakharov, Denis Tolopilo and Elizaveta Usina. **Approach to Robotic Mobile Platform Path Planning upon Analysis of Aerial Imaging Data**

Abstract: The research is focused on solving one of the main problems of robotic system navigation - building an energy-efficient trajectory. A method of trajectory planning is proposed, according to which images obtained using an unmanned vehicle camera are stitched into an orthomosaic image, on which the Mask R-CNN neural network detects all static obstacles. In addition to creating a map of the area, the resulting images are also used to create a 3D model of the area. The developed method enables the robotic to find all static obstacles, as well as to identify all terrain features. Based on the obtained data on the state of the terrain and the presence of static obstacles, the system finds the most energy-efficient path.

Peter Trefilov, Mark Mamchenko, Maria Romanova and Igor Ischuk. **Improving Methods of Objects Detection Using Infrared Sensors Aboard the UAV**

Abstract: The rapid development of unmanned aerial vehicles (UAVs) has contributed to a proliferation of multi-spectral aerial survey technologies and services. Aerial reconnaissance allows to obtain the detailed digital map of the area, including the geographical distribution of radiant temperatures. These temperature maps allow to find out the composition of the objects (figure out type of the material), their real dimensions and size. There are studies concerning processing of multi-spectral aerial survey images (both obtained in visible and infrared ranges) and selecting the UAV optimal flight altitude for detection, recognition, and identification of monitoring objects. However, the issue of developing an integrated algorithm of UAV multi-spectral aerial survey for classifying monitoring objects (taking into account the choice of optimal flight altitude and camera's resolution parameters) still remains open. This article considers the choice of the flight altitude of the UAVs based on Johnson's criteria for detection, recognition, and identification of monitoring objects. The integrated approach for conducting aerial survey based on mathematical relationship between optimal flight altitude of the UAVs and resolving power of its onboard camera is proposed.

Elena Efremova and Vladimir Soldatkin. **Integrated Sensor System for Controlling of Altitude-Velocity Parameters of Unmanned Aircraft Plane on the Basis of Vortex Method**

Abstract: The paper considers the original scheme, algorithms for the formation and processing of time-frequency primary informative signals and determination of the altitude-velocity parameters of unmanned aircraft planes in channels of integrated sensor system with one receiver of primary information. The competitive advantages of the offering sensor system for controlling the altitude-velocity parameters are provided, which determine the prospects for its use on unmanned aircraft planes of various classes.

Andrey Trifonov, Sergey Filist, Sergey Degtyarev, Vadim Serebrovsky and Olga Shatalova. **Human-Machine Interface of Rehabilitation Exoskeletons with Redundant Electromyographic Channels**

Abstract: A method for controlling an exoskeleton by means of instructions obtained by decoding an electromyography (EMG) signal is considered. The method allows to minimize errors when positioning the exoskeleton in the verticalization mode. The EMG signals are segmented into intersecting or nonintersecting windows and for each segment obtained in the previous step, they receive many signs of the EMG signal (vector of informative signs). The vector of informative features is fed to the neural network classifier, which controls the controller of the exoskeleton servomotors. The vector of informative features is obtained through a multilevel comparator, the number of levels of which determines the dimension of the vector of informative features. The EMG classifier includes a comparator unit, a multiplexer, an informative feature calculation unit, a first neural network, a memory unit and a second neural network, the outputs of which control the servo motor controller. In order to adapt the exoskeleton control system to the patient, additional channels for classifying EMG signals are introduced into the human-machine interface. Each channel of the EMG signal is associated with a specific muscle or group of muscles that control the movement of the same limb joint. The servo motor controller uses a third neural network to aggregate these signals into a single control signal. The neural network control method with redundant EMG channels has been tested on the exoskeleton at the moment of controlling the verticalization of the patient.

Haci Mehmet Guzey. **Neuro Sliding Mode Control for Exoskeletons with 7 DoF**

Abstract: In this paper, a novel neuro sliding mode controller (SMC) is developed for a 7 degree of freedom (DoF) upper exoskeleton. RBF-like neural network control is used to estimate the exoskeleton dynamics in the configuration of the sliding mode control. Stability of the neuro-SMC is derived on the basis of Lyapunov stability criteria. To validate our theoretical claims, simulation results are given at the end of the paper.

Andrey Karlov, Ekaterina Saveleva, Andrey Yatsun and Aleksey Postolny. **Modeling of the Exoskeletal Human-Machine System Movement Lifting a Load**

Abstract: The mechanization and automation are introduced in various industries for loading and unloading operations. However, the manual labor continues to be widespread in a number of industries. One of the ways to improve the quality of working conditions due to the transition from extreme to comfortable conditions is using of exoskeletons. The technological operations of lifting and transfer of goods implementation by a person can be considered in two aspects: from the point of view of the workload performed by a person with this type of work, and, on the other hand, the functional stress of the body as an integral response to the load. The study of the human-machine system (HMS) elements interaction allows us to identify new opportunities for providing a cooperative solution to technological problems by obtaining the exoskeleton's links movement given accuracy. The article is devoted to the HMS motion kinematic model development, as well as the determination of the dependence of the linear gravity compensator (LGC) length change on the magnitude of the exoskeleton's back rotation angle for various geometric dimensions that determine the position of the LGC. The determination of this dependence allows us to construct an algorithm for the HMI, including the LGC functioning. For this, the vector method of mathematical modeling is used.

Sergey Jatsun, Andrey Malchikov, Andrey Yatsun and Ekaterina Saveleva. **Mathematical Modeling of Load Lifting Process with Industrial Exoskeleton Usage**

Abstract: The article is devoted to investigation of the opportunity of exoskeleton usage in industrial conditions, which can partially compensate the load during carring out of the technological operations. Such devices can significally reducie human fatiguability, improve operations quality, reduce the injury risk and the professional diseases development. The article presents a mathematical model describing the lifting load process with the use of industrial exoskeleton. A mathematical apparatus, which makes it possible to obtain load lifting kinematic parameters and evaluate the exoskeleton joints forces, is presented in the work. The paper presents the numerical modeling results, and analyzes them. The values of the device hinges torques were obtained. The knees and ankle joints turned out to be the most loaded during lifting process. The necessity of additional external devices usage to compensate these efforts is mentioned.

Dmitriy Blinov, Anton Saveliev and Aleksandra Shabanova. **Deep Q-Learning Algorithm for Solving Inverse Kinematics of Four-Link Manipulator**

Abstract: This paper presents deep Q-learning algorithm designed to solve inverse kinematics problem of four-link manipulator. This algorithm uses dynamic exploration coefficient instead of a constant value, which allow to avoid convergence of the neural network to a local optimum. In addition, a method for generating a Q-table has been developed to avoid the bottleneck effect when neural network constructing. This in turn leads to reduction of training time and lower hardware requirements. To evaluate the effectiveness of the proposed algorithm, three environments were developed and for each of them specific neural networks model were used. Three different environments allow to evaluate the algorithm performance for solving inverse kinematics of varying complexity: with one initial and one target points, with several initial and one target points, and, conversely, with one initial and several target points. Obtained dependency graph of rewards on the number of training episodes shown successful training of agents in all environments. Successful training of the Q-learning algorithm in the third environment suggests that the algorithm can be used for solving the inverse kinematics for all points of the manipulator working space. The main advantage of the developed algorithm is the possibility of its application for solving inverse kinematics problems of varying complexity. In addition, this algorithm can be used to solve inverse kinematics of manipulator with a different number of links.

Sergei Savin, Oleg Balakhnov and Alexander Maloletov. **Linearization-based Forward Kinematics Algorithm for Tensegrity Structures with Compressible Struts**

Abstract: This paper presents a new local linearization method for elastic forces in tensegrity structures, which can be used to solve forward kinematics problems. Forward kinematics problems are often solved as a part of inverse kinematics algorithms and trajectory planning in robotics, and it is often desirable to be able to perform those algorithms online. The proposed method allows to solve forward kinematics as a quadratic program, which makes it fast and reliable, and allows us to take advantage of the existing convex programming software. The paper demonstrates the work of the proposed method using a three link tensegrity structure.

Sergey Jatsun, Boris Lushnikov, Oksana Emelyanova and Andres Santiago Martinez Leon. **Synthesis of SimMechanics Model of a Quadcopter using SolidWorks CAD Translator Function**

Abstract: Currently, computer modelling is one of the most important scientific tools for investigating the behavior of complex dynamic systems. The choice of an algorithmic language depends on the simplicity of programming, the form of presentation of the simulation results, and different advantages provided by programs such as MATLAB, libraries of which includes SimMechanics Visual Modeling Tool. This article discusses modern approaches to computer modeling of unmanned aerial vehicles (UAVs), described the integration process of SolidWorks and MATLAB/Simulink environments by implementing a CAD model, created previously in SolidWorks and exported to MATLAB/Simulink, an algorithm for modeling a dynamical model of an UAV type quadcopter based on PID control strategies has been implemented, a software for modeling and testing control algorithms for a UAVs type quadcopter has been performed, creating automatic navigation systems, and planning the trajectories of a quadcopter UAV.

Aleksandr Nikitin, Vyacheslav Soldatkin and Vladimir Soldatkin. **Technology for Constructing Multifunctional Controlling System of Motion's Parameters of Unmanned Single-Rotor Helicopter**

Abstract: The article views the technology of construction of the controlling sensor system of motion's parameters of unmanned single-rotor helicopter based on the use of the information about position resulting velocity vector of incoming air flow of vortex column of rotor using original fixed multifunction receiver of primary information. The transformation of informative signals is proposed to provide according with two-channel scheme with ion-mark and aerometric channels. The algorithms of processing of informative signals and determination of air parameters of motion of an unmanned single-rotor helicopter in the channels of a multifunctional sensor system built according to the one fixed multifunctional receiver with ion-mark and aerometric channels are presented.

Vinh Nguyen, Quyen Vu and Andrey Ronzhin. **Mathematical Modeling of Stable Position of Manipulator Mounted on Unmanned Aerial Vehicle**

Abstract: The stability of the manipulator is important issue especially in the domain of unmanned aerial vehicle (UAV). Any movements of manipulator greatly affects UAV stability. In particular, the horizontal shift of the center of gravity requires of the UAV the powerful controller, that change forced the propellers of quadrotor to bring the UAV to a stable state. In this paper we have studied the movements of manipulator and its center of gravity at least horizontally when UAV is in hover mode. As a result, we developed mathematical model and software for calculation of deflection angles between successive links of the manipulator, which provides deviation of the center of mass (COM) of the UAV horizontally less than 1 mm.

Denis Milyakov, Vladimir Verba, Vladimir Merkulov and Andrew Plyashechnik. **Active Phased Antenna Arrays for Long-Range Mobile Radars Based on Quadcopters**

Abstract: Strengthening the role of unmanned aerial vehicles (UAVs) for various purposes due to their group use allows obtaining a number of advantages in solving a wide class of tasks. At the same time, the new advantages of group use of UAVs are due to: the difficulty of separate observation of the group members and, accordingly, the difficulties of tracking and target distribution; the inability to serve the entire large group with the number of participants exceeding the capacity of the information control system of the opposing side; the increase in the behavioral complexity of the UAV in solving various problems through the use of artificial intelligence; random change of the spatial position of individual UAVs within the group,

preventing their detection and selection of virtually all types of information systems. The noted advantages of the UAVs groups are especially pronounced in the implementation of such a new task as the formation and use of temporary active phased antenna arrays (APAA) of large sizes based on multicopter for the implementation of long-range radar systems. In this regard, the purpose of the paper is to present a variant of the algorithm for the formation and functioning of such a APAA. On the example of solving the task of maintaining an air object, the features of the operation of a radar with a APAA based on a group of UAVs are illustrated.

Youshaa Murhij and Vladimir Serebrenny. **Hand Gestures Recognition Model for Augmented Reality Robotic Applications**

Abstract: Augmented Reality (AR) is a research promising field. Its main idea is to integrate and merge the virtual world with the real world. Augmented reality could improve or enhance our perception of the real world by integrating virtual objects. The existing hand gesture applications related to augmented reality can detect hand motion or track it in addition to the ability to construct a 3D model of tracked hand using markers and motion sensing devices like Kinect, Leapmotion and AR/VR instruments. In this paper, a hand gesture recognition model based on deep convolutional neural network is proposed to be used in 3D virtual environments for robotic teleportation. This model is tested on HTC VIVE Pro AR/VR instruments using the VIVE eye and on a Kinect v2 to control an industrial manipulator in real time using only the hand movements in both online and offline control modes.

Denis Ivanko, Dmitry Ruymin and Alexey Karpov. **An Experimental Analysis of Different Approaches to Audio-Visual Speech Recognition and Lip-Reading**

Abstract: In this paper we have analyzed different approaches to audio-visual speech recognition. We mainly focused on testing different modalities fusion techniques, rather than other parts of AVSR (e.g. feature extraction methods). Tree audio-visual modalities integration methods were under consideration, namely GMM-CHMM, DNN-HMM and End-to-end approaches, defined as the most promising and commonly found in scientific literature. The testing was performed on two different datasets: on GRID corpus for the English language and on HAVRUS corpus for the Russian. Obtained results once again confirms the superiority of neural network approaches compared to the others in conditions when we have enough data to effectively train NN models, which was demonstrated by our experiments on the GRID dataset. On a more compact in size HAVRUS database, the best recognition results were demonstrated by the traditional GMM-CHMM approach. This paper presents our vision on current state of audio-visual speech recognition field and possible directions for the further research.

Maxim Kolomeec, Ksenia Zhernova and Andrey Chechulin. **Unmanned Transport Environment Threats**

Abstract: Unmanned private and public transport may be susceptible to attacks through various interfaces including networks and physical sensors. With the spread of smart transport and the urban environment that can interact with vehicles, such threats will become increasingly relevant. The paper presents the overview of current cases of attacks on the connected unmanned transport environment that includes smart cars and smart city infrastructure. The paper includes the overview of implementation and classification of such environment components: smart vehicle components and smart city components that can

interact with each other. Based on the implementation of components and what technologies they are used, paper overview attack cases. The attack cases are based on the current reports of security incidents in the past and related research. The paper discusses the most urgent threats for such smart city environment based on the analysis of found attacks and classes of interfaces. The work highlights that today the most serious threat remains the problem of cyber-physical and network security.

Alexander Denisov and Oleg Sivchenko. **Conceptual and Set-Theoretic Models of Wireless System for Information Exchange**

Abstract: Conceptual and set-theoretic models of wireless data transfer network for static and dynamic systems, particularly, for robotic devices, including radio modules, which use repeaters for communication with remote network nodes are described. These models are intended for agricultural applications. Radio modules, sensors and robotic devices, connected using repeaters to the distributed wireless network, are described. The design problem of wireless data transfer network completed with static and dynamic radio modules is a complicated one. Certain specifics deals with how to maintain data transfer speed above the specified threshold by varying distance between radio modules and robotic device motions. Increased data transfer reliability, specific robot interaction patterns and groundwork for IoT paradigm implementation are of particular importance here.

Eugene Larkin, Tatiana Akimenko, Alexey Bogomolov and Konstantin Krestovnikov. **Mathematical Model for Evaluating Fault Tolerance of On-Board Equipment of Mobile Robot**

Abstract: The approach to simulation of a mobile robot on-board equipment fault tolerance based on the theory of semi-Markov processes is presented. At the first stage of proposed approach a simulation the lifecycles of equipment units is considered and for every unit ordinary semi-Markov model is determined. Formulae for unit lifetime calculation in the general case are obtained. At the second stage, the model of competition between units for the fault is considered. To simplify the simulation, the digital approach to the competition analysis is worked out. Digital model is obtained by means of sampling densities described units lifetimes. It is shown, that digital approach to analysis of competition permit, rather simply, calculate a lifetime of fault tolerant assembles and/or onboard equipment as a whole. So it is shown, that number of sampled in histogram, presented unit lifetime allows to control both accuracy and computational complexity of mobile robot reliability parameters calculation. Example of calculation of fault tolerant actuator control system reliability is presented.

Elvira Chebotareva, Kuo-Hsien Hsia, Konstantin Yakovlev and Evgeni Magid. **Laser Rangefinder and Monocular Camera Data Fusion for Human-Following Algorithm by PMB-2 Mobile Robot in Simulated Gazebo Environment**

Abstract: The paper presents a human-following algorithm for an autonomous mobile robot, which is equipped with a 2D laser rangefinder (LRF) and a monocular camera. As a rule, quality of a human tracking by a LRF is reduced in cluttered environments. We used a monocular camera to increase a human tracking reliability. In contradiction with popular human tracking algorithms that apply only a 2D LRF, our algorithm does not impose any restrictions on a type of humans clothes, and our approach does not require a human head and an upper body to be located within a monocular camera field of view. Several human trackers and variations of our algorithm were compared in the Gazebo virtual experiments within a free corridor and an office

room environments. The virtual experiments demonstrated that our method successfully improved a human tracking quality being employed with the human-following virtual PMB-2 robot.

Ramil Safin, Roman Lavrenov and Edgar Alonso Martinez-Garcia. **Evaluation of Visual SLAM Methods in USAR Applications Using ROS/Gazebo Simulation**

Abstract: The problem of determining the position of a robot and at the same time building the map of the environment is referred to as SLAM. A SLAM system generally outputs the estimated trajectory (a sequence of poses) and the map. In practice it is hard to obtain groundtruth for the map, hence only trajectory ground-truth is considered. There are various works that provide datasets to evaluate SLAM algorithms in different scenarios including sensor configurations, robots, and environments. Dataset collection in a real-world environment is a complicated task, which requires an elaborate sensor and robot configuration. Different SLAM systems demand various sensors resulting in the problem of finding an appropriate dataset for their evaluation. Thus, in this paper, a solution that is based on ROS/Gazebo simulations is proposed. Two indoor environments with flat and uneven terrain to evaluate laser range and visual SLAM systems are created. Changing the sensor configuration and the environment does not require an elaborate setup. The results of the evaluation for two popular SLAM methods – ORB-SLAM2 and RTAB-Map are presented.

Dmitriy Levonevskiy, Evgenii Karasev and Egor Aksamentov. **Architecture and Algorithms of Geospatial Service for Navigation of Robotic Complexes**

Abstract: This paper considers the problems of robotic device navigation for performing various agricultural tasks. The proposed approach for map building ensures automated establishment of 3D terrain models, based on snapshots, taken from unmanned aerial vehicles. The presented method of route planning employs such 3D models effectively enough. The techniques of edge weight calculation facilitate selection of the smoothest areas for route planning, therefore, reducing energy consumption. The suggested software architecture relies on a service bus for data transfer. This solution reduces the dependence of software modules, enables integration of heterogeneous data sources and allows controlling data flows and system processes more efficiently. Decent usability of the developed systems is achieved by means of cross-platform implementation of the front-end application.

Ayrat Migranov. **Cloud-Based Task Distribution System Infrastructure for Group of Mobile Robots**

Abstract: One of the possible approaches to the construction of control systems for groups of mobile robots using distributed cloud technologies is considered, for which a scheme of access to information resources and a mechanism for distributing resources of a cloud computing system with linear decomposition are developed: the solution to the problem is divided into a series of smaller, simpler, subtasks in a hierarchical tree based on the linear distribution method. The specifics of the workspace model are shown, the goals of the functioning of robots are formalized, and the optimal energy evolutionary algorithm for solving the problem of distributing tasks in the team is proposed taking into account the initial and current levels of battery power, the energy consumption of each robot and the energy needed to perform individual tasks. Parameters for evaluating the effectiveness of the obtained solutions are determined, genetic algorithms are synthesized, for which a coding form of the solution in the

form of a chromosome is proposed and specific fitness functions are compiled. An algorithm has been developed for calculating the fitness function, implemented taking into account the specifics of its work in the cloud. Experimental results were obtained when checking the operability of the algorithms on the available on-board computing means of mobile robots, and the effectiveness of using distributed computing resources of a group of robots was estimated when implementing cloud services on their basis.

Nikolay Teslya, Alexander Smirnov, Artem Ionov and Alexander Kudrov. **Multi-robot Coalition Formation for Precision Agriculture Scenario based on Gazebo Simulator**

Abstract: Nowadays the study of interaction models of intelligent agents is one of the main research directions in the field of collaborative robotics. It includes studies of coalition formation principles, tasks decomposition and distribution, winnings sharing, and implementation of proposed techniques and models. This work focuses on presenting environment and robots states in smart space during joint task solving as well as modeling and visualizing the interaction process using open software Gazebo and Robotic Operation System. The ontology of robot is presented, that combines description of the robot equipment and physical characteristics. To provide variability in robot interaction some of the concepts are evaluated with fuzzy sets. The architecture of modelling approach is presented based on the combination of smart space concept for ontologybased information exchange between robots, Robotic Operation System for robot control, and Gazebo simulator for modelling and visualizing robot actions in 3D environment. The example of interaction is presented based on precision agriculture scenario.

Petr Neduchal and Milos Zelezny. **Environment Classification Approach for Mobile Robots**

Abstract: The type of environment plays an essential role in mobile robotics. Autonomous robots usually work in static and single type environments. Unfortunately, in the real world, there are many situations when the type of the environment change. This paper deals with the design of the system for environment recognition working in real-time on a mobile robot. Once the environment is recognized and classified, the parameters of the robot can be adapted. Consequently, the robot can handle operations in multiple environments. The paper contains information about previous related work in the environment classification, description of the proposed system, and experiments. Experiments are focused on change detection and environment classification using visual and non-visual sensors. Moreover, two non-visual change detection approaches are proposed in the experiment section.

Rinat Galin and Roman Meshcheryakov. **Collaborative Robots: Development of Robotic Perception System, Safety Issues and Integration of AI to Imitate Human Behavior**

Abstract: The development of collaborative robotics as a research area is based on the study of safety and machine vision issues. The process of integrating artificial intelligence into robotic systems is gradually taking place. The process of intelligent robotic automation is based on a combination of machine learning of robots and high vision technologies on the way to interactive intelligent collaborative robotics. Given the lack of barriers for modern robots that work with humans, the issues of safety interaction remain the basic basis, which is considered an integral part of any implementation of new technological solutions. Such intelligent robotic solutions aimed to provide complementing and augmenting human capabilities, not replacing them. To take full advantage of this collaboration between robots and humans we must

understand how humans can most effectively augment robots and how robots can enhance what humans do best.

Mark Mamchenko, Pavel Ananyev, Alexander Kontsevoy, Anna Plotnikova and Yuri Gromov. **The Concept of Robotics Complex for Transporting Special Equipment to Emergency Zones and Evacuating Wounded People**

Abstract: Ministry of the Russian Federation for Civil Defense, Emergencies and Disaster Management (EMERCOM of Russia, EMERCOM) devotes special attention to equipping subordinate units with advanced robotics. Despite this, EMERCOM of Russia lacks robotics complex capable of transporting special rescue equipment to emergency zone, bringing medicines to the wounded, and evacuating them to safe areas. This fact reduces efficiency and increases duration of emergency operations: if special vehicles are not able to reach the emergency zone, Russian EMERCOM employees will have to deliver rescue equipment and tools manually, and evacuate the wounded using stretchers on their own. This article proposes a concept of advanced robotics complex capable of carrying out the aforementioned tasks. We do not seek to provide full and detailed technical description of the whole complex. Only its composition, requirements, and peculiarities of power/communications systems, cargo delivery and safe evacuation mechanism, and possible electronic components shall be described.

Sergey Kharchenko, Roman Meshcheryakov, Yaroslav Turovsky and Daniyar Volf. **Implementation of Robot-Human Control Bio-Interface When Highlighting Visual Evoked Potentials Based on Multivariate Synchronization Index**

Abstract: The introduction part the main ways of integration of humanmachine control systems integration of systems as well as the ways of visual evoked potentials extraction in electroencephalograms (EEGs) are described. The article includes researches of electroencephalogram (EEG) signals with steady state visual evoked potentials for various photostimulation frequencies basing on the method of the multivariate synchronization index. Influence of length of window being processed on recognition accuracy of frequency of the signal being studied is explored. Ratio of the correctly recognized states is considered in the function of accuracy metric. Examined necessity of original signal pre-processing by way of the signal band-pass filtering. In addition, application of the multivariate synchronization index in multichannel mode is reviewed. The result of the authors' investigation is a number of recommendations on parameters used for extraction of steady state visual evoked potentials in the method of the multivariate synchronization index. Results obtained are of considerable practical importance as they can be used for brain-computer interface producing on the basis of visual evoked potentials and later can be taken for building of control theory of robot systems of different application and for implementation of decisions on man-machine interoperability within narrow practical tasks.

Dinar Bogdanov. **Continuum Manipulator Motion Model Taking into Account Specifics of its Design**

Abstract: The paper discusses the kinematics model continuum of the manipulator of the original design, as well as the issues of its application in the synthesis of the control system. The links of the manipulator are built on the basis of solid-state elements in contact with each other on the surface of a spherical shape and connected with the help of flexible cables. The

operational characteristics of the manipulator (size and shape of the workspace, service and manipulation factors) are easily adjusted to technical requirements by changing the geometric parameters of the elements and their number in the links, as well as changing the number of links themselves. The complexity of controlling such a manipulator is determined by the need to obtain and process a significant amount of information about the state of the manipulator and its components. Due to the impossibility of obtaining explicit information about the position of the link elements relative to each other, it is proposed to compensate for this drawback by synthesizing an exact kinematic model. The authors propose such a link model, which takes into account rolling friction between link elements and the preliminary tension of the cables to ensure structural integrity in the entire range of motion. The results of the calculations revealed the peculiarities of the link movement in its entire range.

Eldar Mingachev, Roman Lavrenov, Evgeni Magid and Mikhail Svinin. **Comparative Analysis of Monocular SLAM Algorithms Using TUM and EuRoC Benchmarks**

Abstract: Stable and robust path planning and movement in ground mobile robots require a combination of accuracy and low latency in their state estimation. However, state estimation algorithms must provide these qualities under the computational and power constraints of embedded hardware. Simultaneous Localization and Mapping (SLAM) algorithms are the best choices for state estimation in these scenarios, in addition to their ability to operate without external localization from motion capture or global positioning systems. Moreover, a single camera setup is the most common solution for robotic platforms, which reduces our domain of interest to the specific SLAM algorithms type – Monocular SLAM. Yet, it is still not clear from the existing literature, which monocular SLAM algorithms perform well under the accuracy, latency, and computational constraints of a ground mobile robot with onboard state estimation. This paper evaluates an array of the most recent publicly available monocular SLAM methods: ORB-SLAM2, DSO, and LDSO. The evaluation considers the pose estimation accuracy (alignment error, absolute trajectory error and relative pose error) while processing the TUM Mono and EuRoC datasets on the specific hardware platform with a balanced amount of computational resources and power consumption. We present our complete results as a benchmark for the research community.

Section: Electromechanics and Electric Power Engineering

Nikolay Lopatkin. **Quarter-Wave Symmetric Space Vector PWM with Low Values of Frequency Modulation Index in Control of Three-Phase Multilevel Voltage Source Inverter**

Abstract: The paper deals with the three-phase multilevel voltage source inverter (MLVSI) load current quality issue, which is important, in particular, for the MLVSI application to adjustable-speed AC drive. Here the problem of MLVSI control is solved by the use of the low-frequency space-vector PWM with the quarter-wave symmetric output voltages (QWS-SVPWM), based on the approach operating with the integer and fractional parts of the reference delta voltages relative values. The specified technique has low dynamic losses in power semiconductor switches. QWS-SVPWM is applied to control MLVSIs of any arbitrary numbers of the equal levels and any arbitrary topologies. Comparisons of dependences on a modulation depth for the THD and the first three orders' integrated voltage harmonics factors (IHF) of the simulated MLVSI output voltage waveforms are carried out between the three lowest appropriate values of frequency modulation index. To obtain the most appropriate voltage waveform for the best quality MLVSI load current, the amplitude modulation index ranges for preferable use of each

of the three considered frequency modulation index values, under the terms of minimization of the appropriate orders' IHF values (depending on the particular kind of the load) are revealed.

Vladimir Bocharov, Alexander Danilov, Viktor Burkovsky, Konstantin Gusev and Pavel Gusev. **Analysis of Resource Availability of Production Enterprise Based on Fuzzy Neural Network**

Abstract: Before launching a new product into production or when changing the production program of an aviation enterprise, you must clearly determine whether there are enough production resources to complete the new production program. The paper presents the use of modern intellectual technologies and methods. A workshop for the production of parts made of polymer composite materials is considered as the system under study. An up-to-date set of data describing the operation of the production unit was obtained. The analysis of the obtained data was carried out. The development of a fuzzy neural network is described and the results of forecasting for a test data set are presented.

Vladislav Shishlakov, Elizaveta Vataeva, Nataliia Reshetnikova and Dmitriy Shishlakov. **Synthesis of Nonlinear Impulse Systems**

Abstract: The problem of synthesizing the parameters of the laws of control of continuous and pulsed automatic control systems with polynomial approximation of nonlinearities is considered. As a mathematical apparatus for solving the problem, the method is used that is the inverse of the direct variational analysis method - the generalized Galerkin's method, which allows you to completely algebraize the solution of the problem for the class of automatic control systems under study, the dynamics of which are described by nonlinear differential equations of arbitrary order. The generalized Galerkin method is extended to a new class of systems - impulse nonlinear systems. Recurrence expressions defining Galerkin integrals for this type of approximation are also given.

Yuriy Obzherin, Mikhail Nikitin and Stanislav Sidorov. **Hidden Markov Model Based on Signals from Blocks of Semi-Markov System's Elements and Its Application for Dynamics Analysis Energy Systems**

Abstract: For modeling systems for various purposes, in particular, energy systems, semi-Markov processes are often used. During the functioning of the system for which the semi-Markov model is built, it is not always possible to get all the information contained in the status codes when changing its states, but you can only get the signal (information) in which block of system elements the state changed (failure, renewal and etc.). In this case, the states of the semiMarkov model can be considered hidden (unobservable). There are problems of analyzing the dynamics, predicting the states of the elements of the simulated system based on the received vector of signals from blocks of system elements. To solve these problems, the apparatus of the theory of hidden Markov models can be used. The paper considers the possibilities of applying this approach by the example of independent renewal processes superposition.

Sergej Solyonyj, Oksana Solenaya, Aleksandr Rysin, Vladimir Kuzmenko and Evgeny Kvas. **Robot for Inspection and Maintenance of Overhead Power Lines**

Abstract: Problems such as the destruction of insulators, the slope of the poles of power lines, a small layer of icing, will go unnoticed and can lead to serious consequences, such as a break in power lines and falling poles. If an accident occurs on the line, the repair team must drive

along the entire path of the power line from the beginning to the point of the accident, if the terrain allows transportation. Provided that some power lines can be hundreds of kilometers long, troubleshooting can take several hours or even days. Using robotic systems will speed up the search and repair processes. This article discusses the types of damage that occur on overhead power lines, modern solutions to these problems.

Igor Lebedev, Anton Ianin, Elizaveta Usina and Viktor Shulyak. **Engineering Solution of a Base Station for UAV Maintenance Automation**

Abstract: This paper proposes a construction of a land-based base station for automated UAV (Unmanned Aerial Vehicle) maintenance. The station is intended for UAV storage, protection from poor weather conditions, battery replacement and information transfer. UAV data transfer at the station allows to reduce UAV energy consumption in flight. The base station has two levels: the top one and the bottom one. The construction of base station allows to store UAVs with large dimensions, weighting up to 12 kg. The top level of the station consists of a retractable roof and meteo-sensors. The roof design provides for solar panel installation on it, what allows reducing base station energy consumption from batteries. Materials for the roof were chosen with intention to minimize roof weight and reduce load on drives. The bottom level of the base station contains the landing site, the battery replacement mechanism, the landing site lifting mechanism, the base station control system, as well the energy distribution system. The landing site features an ArUco-marker with backlight and includes mechanisms for UAV centering and fixation. The marker with backlight includes a plexiglass sheet, light emitting diodes (LEDs), a reflective substrate and an opaque scatterer. The outline lighting ensures marker detection in low light conditions. In cases, when the marker cannot be detected by active lighting, dependency of the required photosensitivity of the camera from the UAV flight altitude is presented.

Konstantin Krestovnikov, Ekaterina Cherskikh and Eldar Zimuldinov. **Combined Capacitive Pressure and Proximity Sensor for Use in Robotic Systems**

Abstract: Circuit solution and primary transducer of combined capacitive pressure and proximity sensor are described. Principle of operation of the developed interface circuit is shown, its principal electrical circuitry is explained. Design and structure of a primary capacitive transducer is considered for further use within the combined sensor. The dependence of the output signal from the force, applied to the prototype sensor, is empirically obtained and shows linear pattern in the working range of the sensor from 0 to 2.6 kg, whereas the sensitivity to the applied pressure was 2252 value/kg in output values of ADC. Graphical dependences of output signal are obtained from the distance between the sensor and the things being observed and consisting of different types of stuff. Mean value of interface circuit sensitivity to approaching object is 6.7 value/mm on the decreasing span of the characteristic curve in the range between 0 and 10 mm. The presented sensor can be employed in manipulators to control object grip, as well in feet of humanoid robot for zero moment point calculation and detection of approach to bearing surface.

Ildar Nasibullayev, Oleg Darintsev, Elvira Nasibullaeva and Dinar Bogdanov. **Piezoelectric Micropumps for Microrobotics: Operating Modes Simulating and Analysis of the Main Parameters of the Fluid Flow Generation**

Abstract: The operation of a piezoelectric micropump, consisting of a resilient elastic microtube of circular cross-section and a system of ring piezoelectric actuators placed on it, which forms

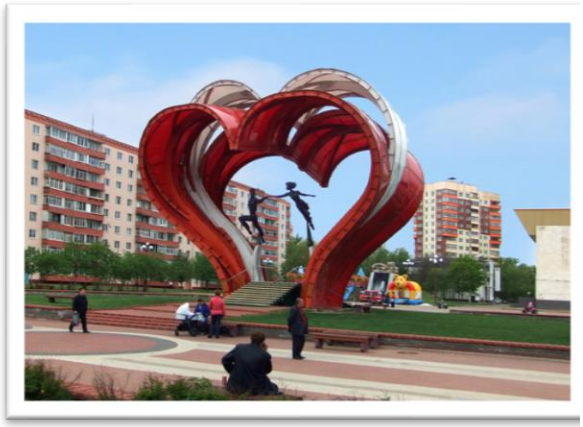
a flow of the working fluid by radial compression, is simulated. The flow created by the oscillations of the piezoelectric actuators according to certain schemes is numerically studied: with a symmetric scheme, the average time flow rate of the liquid is zero; with an asymmetric scheme, it is possible to generate a nonzero time-average flow in the positive direction. It was found that the operation mode of the device according to an asymmetric scheme will allow using it as a piezoelectric micropump having a small size and allowing to pump small volumes of liquid. It is also shown that in an asymmetric mode of operation, with an increase in the frequency of oscillations of the piezoelectric actuators and with an increase in their quantity, the average pumped volume of liquid increases, and with a decrease in the radius of the channel, it decreases. An approximate analytical formula is obtained that relates the main parameters of the operating mode (time to reach the operating mode and average fluid flow rate) with the system parameters (the number and frequency of oscillations of the piezoelectric actuators, the radius of the microchannel), which makes it possible to construct an element of the computational module for evaluating the operating modes of the device in question, as well as manage the device itself in real time.

Dmitriy Ershov and Irina Lukjanenko. **Vibration Amplitude and Frequency Parameters of Technological Equipment Drives**

Abstract: The paper studies the effective non-uniform operation mode of technological equipment by the example of numerically controlled milling machine which is described as a multi-mass technological system. The mathematical models presented can be used in studies of the vibration amplitude and frequency parameters of the torque and the angular velocity of the drive conditioned on the drive dynamics. The dynamic ratios of the technological system appear conditioned on the ratio of electro-magnetic to mechanical time constants of the motor powering the technological equipment drive. The vibration amplitude and frequency parameters of the drive obtained are analyzed and conditioned on the external harmonic disturbances. The resonance-inducing conditions are outlined. These properties require for the drive dynamic parameters to be analyzed in order to correctly evaluate the drive vibration amplitude and frequency parameters.

Ufa sights

Ufa was founded as the oldest Russian fortress on the territory of Bashkortostan.



The main symbol of Ufa (and the whole Republic of Bashkortostan) is a monument to Salavat Yulaev, the national Bashkir hero, sung in Soviet times. It was installed in 1967 on the highest point above the Belaya River - on Cherkalikhin Hill. The author of the sculpture is S.D. Tavasiev. The sculpture weighs 40 tons and was claimed to be the largest at that time in the USSR. Salavat Yulaev is shown on a rising horse rushing forward. Dynamism is enhanced by a high pedestal and a well-chosen installation location. It is especially beautiful here at sunset.

Another attraction of the city of Ufa is the Friendship Monument. It was founded in 1957 and opened in 1965 in honor of the 400th anniversary of the voluntary entry of Bashkiria into Russia. The monument looks like a composition of two female figures who sit half-turned to each other and hold laurel wreaths - a symbol of peace. The figures represent Bashkortostan and Russia. Between them on a bas-relief shows a meeting of the Bashkirs and the Russians, the exchange of letters. At the foot of the monument the words “Glory to the great fraternal friendship of the Russian and Bashkir peoples” are inscribed.

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