ICR 2023

8th International Conference on
Interactive Collaborative Robotics

ICR 2023

Conference Programme and Abstracts

October 25-29, 2023
Baku, Azerbaijan

Springer

ISI

SPC RAS

WENZHOU UNIVERSITY

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- Institute of Control Systems of the Ministry of Science and Education of the Republic of Azerbaijan (Baku, Azerbaijan)
- St. Petersburg Federal Research Center of the Russian Academy of Sciences (SPC RAS, St. Petersburg, Russia)
- Wenzhou University (Wenzhou, China)

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- Andrey Ronzhin, St. Petersburg Federal Research Center of the Russian Academy of Sciences, Russia
- Min Zhao, Wenzhou University, China

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- Roman Meshcheryakov, V.A. Trapeznikov Institute of Control Science of the Russian Academy of Sciences, Russia

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- Alina Mikhailus, Russia
- Khalida Melikova, Azerbaijan
- Anna Motienko, Russia
- Irina Podnozova, Russia
- Shahnaz Shahbazova, Azerbaijan

Conference at a glance

Wednesday, October 25, 2023	
16:00-18:00	**Registration (for on-site participants)**
Thursday, October 26, 2023	
10:00-11:00	**Opening Ceremony:** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Ali Abbasov
11:00-12:00	**Plenary Session 1:** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Andrey Ronzhin
12:00-12:15	**On-line Joint Photography of Conference Participants**
12:15-13:15	**Lunch Break**
13:15-15:00	**Oral Session 1:** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Shahnaz Shahbazova
15:00-15:30	**Coffee Break**
15:30-17:15	**Oral Session 2:** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Anna Klimenko
19:00-21:00	**Dinner**
Friday, October 27, 2023	
10:00-11:00	**Plenary Session 2:** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Roman Meshcheryakov
11:00-11:30	**Coffee Break**
11:30-13:30	**Oral Session 3:** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Konstantin Yakovlev
13:30-15:00	**Lunch Break**
15:00-17:00	**Oral Session 4:** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Anton Saveliev
17:00-17:15	**Closing Ceremony**
19:00-22:00	**Gala Dinner**
Saturday, October 28, 2023	
10:00-12:00	**Round Table: Advancements and Challenges of Science and Education in Azerbaijan and Russia** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09
12:00-17:00	**Social Event**
Sunday, October 29, 2023	
14:00-17:00	**Social Event**

The time of the video conference is specified in the time zone of Baku, Azerbaijan (UTC + 4): https://www.worldtimebuddy.com/utc-to-azerbaijan-baku.

Conference Programme

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	Luis Contreras, Jesus Savage, Stephany Ortuno-Chanelo, Marco Negrete, Arata Sakamaki, and Hiroyuki Okada Fall It Till You Make It: Error Expectation in Complex-plan Execution for Service Robots
	Maksim Mustafin, Elvira Chebotareva, Hongbing Li, and Evgeni Magid Experimental Validation of an Interface for a Human-Robot Interaction Within a Collaborative Task
	Congyu Huang, Ziyang Wang, Haoran Zhu, Jie Li, and Xiaofeng Liu Design and Implementation of a Multimodal Combination Framework for Robotic Grasping
12:00-12:15	**Joint Photography of Conference Participants**
12:15-13:15	**Lunch Break**
13:15-15:00	**Oral Session 1:** https://uso6web.zoom.us/j/83782678933?pwd=SEgEUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Shahnaz Shahbazova
	Guo Wu, Xin Shen, and Vladimir Serebrenny Attention Guided In-Hand Mechanical Tools Recognition in Human-Robot Collaborative Process
	Ali Asgarov and Ali Parsayan 3D-CNNs-based Touchless Human-Machine Interface
	Xin Shen, Guo Wu, and Vadim Lukyanov Moving Person Detection Based on Modified YOLOv5
	Inna Pshenokova, Kantemir Bzhikhatlov, Olga Nagoeva, Idar Mambetov, and Alim Unagasov Autonomous Robot Navigation System as Part of a Human-Machine Team Based on Self-organization of Distributed Neurocognitive Architectures
	Yaroslava Gorbunova and Gleb Kiselev Development of a Mechanism for Recognizing the Emotional State Based on the Unconscious Movements of the Subject
	Andrey Knyazev, Sergey Jatsun, Andrey Fedorov, and Jamil Safarov Development of a Device for Post-Traumatic Ankle Rehabilitation
	Daniyar Wolf, Yaroslav Turovsky, Anastasia Iskhakova, and Roman Meshcheryakov Evaluation of EEG Data for Zonal Affiliation of Brain Waves by Leads in a Robot Control Task

15:00-15:30	**Coffee Break**
15:30-17:15	**Oral Session 2:** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Anna Klimenko
	Eduard Melnik and Irina Safronenkova Ontological Approach to the Organization of Computing in Distributed Monitoring Systems with Mobile Components Based on a Distributed Ledger
	Andrey Gorodetskiy, Konstantin Mironov, and Aleksandr Panov Model-based Policy Optimization with Neural Differential Equations for Robotic Arm Control
	Samir Guliyev Approach to Numerical Solution of Nonlinear Optimal Feedback Control Problems
	Eugene Larkin, Tatiana Akimenko, Alexey Bogomolov, and Vadim Sharov Reliability of Robot's Controller Software
	Viktor Semenov Monitoring the State of Robotic Systems Based on Time Series Analysis
	Anna Klimenko and Arseniy Barinov Resource-Saving Multiobjective Task Distribution in the Fog- and Edge-robotics
	Anna Klimenko Improved Model of Greedy Tasks Assignment in Distributed Robotic Systems
19:00-21:00	**Dinner**
Friday, October 27, 2023	
10:00-11:00	**Plenary Session 2:** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Roman Meshcheryakov
	Nikolay Kuznetsov, Boris Andrievsky, Iuliia Zaitceva, and Elizaveta Akimova Sliding-mode Control of Phase Shift for Two-Rotor Vibration Setup
	Kamil Aida-zade and Vugar Hashimov Optimization of the Placement of Measurement Points and Control of the Power of Moving Sources in Rod Heating
	Daniyar Wolf, Vadim Alexandrov, Dmitrii Shatov, Ilya Rezkov, Peter Trefilov, and Roman Meshcheryakov Development of a Firmware for Multirotor UAV Flight Controller Implemented on MCU MDR 32
11:00-11:30	**Coffee Break**
11:30-13:30	**Oral Session 3:** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Konstantin Yakovlev
	Andrei Konstantinov, Lev Utkin, Vladimir Muliukha, and Vladimir Zaborovsky GBMILs: Gradient Boosting Models for Multiple Instance Learning

	Anatoly Gaiduk, Viacheslav Pshikhopov, Mikhail Medvedev, Vladislav Gissov, Ali Kabalan, and Evgeny Kosenko Design of Hybrid Control System for Nonaffine Plants
	Artem Apurin, Bulat Abbyasov, Edgar A. Martínez-García, and Evgeni Magid Comparison of ROS Local Planners for a Holonomic Robot in Gazebo Simulator
	Artur Podtikhov and Anton Saveliev Ground Mobile Robot Localization Algorithm Based on Semantic Information from the Urban Environment
	Nizar Hamdan, Viacheslav Pshikhopov, Mikhail Medvedev, Dimitry Brosalin, Maria Vasileva, and Boris Gurenko Study of Path Planning Methods in Two-Dimensional Mapped Environments
	Dmitry Dobrynin Movement Along the Trajectory of a Home Quadruped Robot
	Vladislav Savinov and Konstantin Yakovlev DHC-R: Evaluating "Distributed Heuristic Communication" and Improving Robustness for Learnable Decentralized PO-MAPF
13:30-15:00	**Lunch Break**
15:00-17:00	**Oral Session 4:** https://uso6web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09 Chair: Anton Saveliev
	Vladimir Kostyukov, Igor Evdokimov, and Vladislav Gissov Construction of a Three-dimensional UAV Movement Planner when the Latter Moves in Conditions of Difficult Terrain
	Vadim Alexandrov, Ilya Rezkov, Dmitrii Shatov, and Yury Morozov Identification of the Quadcopter Rotational Dynamics for the Tilt Angle
	Dmitry Anikin, Artem Ryabinov, Anton Saveliev, and Alexander Semenov Autonomous Landing Algorithm for UAV on a Mobile Robotic Platform with a Fractal Marker
	Tagir Muslimov Curl-free Vector Field for Collision Avoidance in a Swarm of Autonomous Drones
	Azad Bayramov and Samir Suleymanov Remote Control Robotic System for the Perimeter Security
	Olga Mitrofanova, Ivan Blekanov, Danila Sevostyanov, Jia Zhang, and Evgenii Mitrofanov Development of a Robot for Agricultural Field Scouting
17:00-17:15	**Closing Ceremony**
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Abstracts

Plenary Session 1

Luis Contreras, Jesus Savage, Stephany Ortuno-Chanelo, Marco Negrete, Arata Sakamaki, and Hiroyuki Okada

Lecture Title: Fail It till You Make It: Error Expectation in Complex-Plan Execution for Service Robots

Abstract: Domestic service robots (DSR) are devices aimed to carry out daily household chores. Recently, the range and difficulty of the activities they can perform are reaching amazing performances, frequently resulting in complex plans with several steps requiring many skills where errors are more likely to occur. In this paper, we introduce the concept of error expectation in complex plans for domestic service robots and propose a classification of DSR's tasks based on the abilities required for their execution. We also propose a recovery system where a type of feedback is chosen based on error expectation and DSR task type. We test our proposal in the context of an object manipulation task and discuss how error expectation contributes to a good feedback choice. An action involving several robot skills, namely navigation, human and object recognition, natural language processing, etc., was illustrated by the "take" action. The video showing the complete execution of a complex command by a robot using error recovery is presented.

Maksim Mustafin, Elvira Chebotareva, Hongbing Li, and Evgeni Magid

Lecture Title: Experimental Validation of an Interface for a Human-Robot Interaction within a Collaborative Task

Abstract: This paper presents a prototype of a non-contact UR robot based Virtual Control (UR-VC) system for collaborative robots of the UR family, which is based on computer vision techniques and a virtual interaction interface. A control method involved specific hand movements within a field of view of a web camera, which was connected to a laptop with the running UR-VC system. We present the UR-VC system and the results of an experimental validation. To inquire if the UR-VC system is comfortable and user-friendly for an interaction with collaborative robots and to study opportunities for a further development and expansion directions of the system, we designed a test case that simulates a joint product assembly in a collaborative workspace. The constructed collaborative workspace included the UR3e robot, the laptop with the running UR-VC system and assembly parts for a collaborative task. 24 participants were involved in the experiments. First, the participants learned how to control the robot using the UR-VC system. After the training, all participants successfully controlled the robot using the proposed interface for performing the collaborative task. Participants' experience of operating the robot was analyzed via surveys, their unconstrained comments and video recordings of the experiments.

Congyu Huang, Ziyang Wang, Haoran Zhu, Jie Li, and Xiaofeng Liu

Lecture Title: Design and Implementation of a Multimodal Combination Framework for Robotic Grasping

Abstract: Robotic grasping plays a crucial role in manipulation tasks. However, due to the complexity of human-robot interaction, service robots still face significant challenges in handling task-oriented operations in real-world environments. To address this issue and better meet practical interaction needs, we propose a multimodal combination framework for robotic grasping. It leverages language texts to facilitate communication and detects and grasps target objects based on point clouds and feedback. The framework comprises several multimodal components, including ChatGPT, stereo cameras, and wearable devices, to complete instruction processing, grasp detection, and motion execution. To enable effective interaction, ChatGPT facilitates basic communication and responds to instructions between humans and robots. Additionally, the robot can detect the 6-DoF grasp of objects based on point clouds obtained by stereo cameras. These grasps are combined with the feedback provided by ChatGPT to further meet the requirement from human. Finally, we utilize wearable devices to teach robots generalized motor skills. This enables the robot to learn corresponding movements and perform them effectively in various scenarios, further improving its manipulation abilities. The experimental results from simulated conversations and real-scene tasks highlight that our proposed framework provides logical communication, stable grasping, and effective motion.

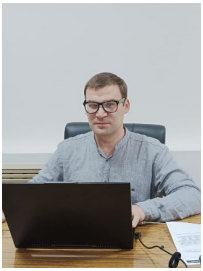
Oral Session 1

Guo Wu, Xin Shen, and Vladimir Serebrenny

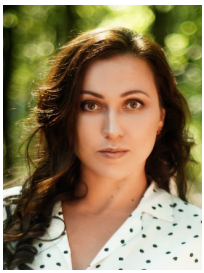
Lecture Title: Attention Guided In-Hand Mechanical Tools Recognition in Human-Robot Collaborative Process

Abstract: The task of recognition of human behavior in a collaborative robotic system is crucial for the organization of seamless and productive collaboration. We design a vision system for the industrial scenario for riveting a metal plate and concentrate on the task of recognizing in-hand mechanical tools. However, there is a severe occlusion problem during hand-object interaction process. Incorporating attention modules into the backbone part are often utilized to handle occlusion and enhance the ability of extract features with contextual information. In view of that, three modified occlusion-aware models based on YOLOv5 for in-hand mechanical tools recognition are proposed: by adding SimAM into each of bottleneck network in the backbone part, inserting a Criss-Cross attention layer between the last C3 block and the SPPF block of the back-bone network, and replacing the last C3 block of the backbone network with Criss-Cross attention layer. We create a

	dataset specifically for our task of in-hand mechanical tools recognition and validate four modified models after training separately, which proves the effectiveness of SimAM module and ineffectiveness of Criss-Cross attention module. The real-time detection is still imperfect under the occlusion of various directions of the hands.
	**Ali Asgarov and Ali Parsayan** **Lecture Title:** 3D-CNNs-based Touchless Human-Machine Interface **Abstract:** Interacting with machines via hand gestures is a common way for people to communicate with robots. Human utilize gestures in a regular talk to convey meaning and emotions to one another. Gesture-based interactions are utilized in a wide range of applied to a wide range of fields, as telephones, TVs, monitors, video games, and other electronic devices. By technological improvements, gesture recognition is now a more realistic and appealing approach in the context of human interaction. In this research, the relevant experiments are con-ducted using numerous types of convolutional neural networks, including the proposed customized model, to see which ones performs the best. Because of the introduction of such Microsoft Kinect sensor, increased depth and vision sensing has been widely important for several purposes. Given its ability to measure ranges to objects at a fast frame rate, these types of sensors are widely being employed for 3D acquisitions, as well as for other purposes in robotics and machine learning. This research made use of the Kinect sensor and the use of an RGB-D camera and a 3D convolution neural network, which offer a novel approach for fingertips identification and hand gesture classification in real time that is both accurate and fast (3DCNN).
	**Xin Shen, Guo Wu, and Vadim Lukyanov** **Lecture Title:** Moving Person Detection Based on Modified YOLOv5 **Abstract:** Visual Dynamic SLAM (Simultaneous Localization and Mapping) is a fundamental technology for intelligent mobile systems, enabling applications in robotics, augmented reality, and self-driving cars. This paper presents a novel approach to improve the performance of Visual Dynamic SLAM by integrating the YOLOv5 object detection framework with attention mechanisms (CBAM) and a BiFPN (Bidirectional Feature Pyramid Network) structure. The dynamic feature points, which are located in the bounding box of the dynamic object, are removed in the tracking thread, and only the static feature points are used to estimate the position of the camera. The primary focus is on improving the detection performance of dynamic objects, particularly persons, and addressing challenges such as occlusion and small object detection. Overall, the integration of YOLOv5 with attention mechanisms and a BiFPN structure presents a significant

	advancement in visual dynamic SLAM. The proposed approach enhances the detection of persons, addresses challenges related to small objects and occlusion, and improves the overall performance of the system in dynamic environments. These findings demonstrate the effectiveness of the proposed methodology and its potential for real-world applications in various domains, including robotics, augmented reality, and self-driving cars.
	**Inna Pshenokova, Kantemir Bzhikhatlov, Olga Nagoeva, Idar Mambetov, and Alim Unagasov** **Lecture Title:** Autonomous Robot Navigation System as Part of a Human-Machine Team Based on Self-organization of Distributed Neurocognitive Architectures **Abstract:** The relevance of this study is due to the solution of the problem of developing the basic principles and algorithms for providing adaptive settings for autonomous robots intelligent control systems as part of a human-machine team based on the general method of machine learning. To do this, the paper proposes to use a formalism based on multi-agent neurocognitive architectures. Implementation of the possibility of adaptation is considered on the example of performing the task of orientation and navigation of an autonomous robot in an unfamiliar environment. An autonomous robot navigation system based on self-organization of distributed neurocognitive architectures has been developed. A multi-agent neurocognitive architecture is presented, which forms an active map containing all the locative information necessary to ensure the orientation and navigation of an autonomous robot between loci. The use of a multi-agent architecture to provide the representation of locative information in the task of implementing an interface in human-machine team will make it possible to build an ontology responsible for representing the location of objects in the external environment, as well as provide interaction with the user in natural language, taking into account its semantics.
	**Yaroslava Gorbunova and Gleb Kiselev** **Lecture Title:** Development of a Mechanism for Recognizing the Emotional State Based on the Unconscious Movements of the Subject **Abstract:** The task of assessing emotional state is not easy for a human and especially challenged for an automated system. It requires not only detection but also complex analysis of various factors. The effectiveness of existing algorithms based on such modalities as text, audio, video, physiological characteristics, etc., depends on the subject's race, language, and other affiliations, which makes it difficult to study in case of lack or complete absence of such data. The paper deals with the creation of a mechanism capable of detecting the emotional state of a person based on his interaction with a computer via a mouse. To solve the problem, we collected a dataset using a web application developed in the Python

	programming language. The application is focused on collecting data about the subject's cursor movement such as distance travelled, maximum deviation from the line that connects the start and end points of the movement, the time the subject interacted with the computer mouse during the session and the maximum speed of the cursor movement. Trained classifiers for emotion analysis based on human control of the computer mouse on the created dataset and analyzed the results.
	**Andrey Knyazev, Sergey Jatsun, Andrey Fedorov, and Jamil Safarov** **Lecture Title:** Development of a Device for Post-Traumatic Ankle Rehabilitation **Abstract:** This article discusses a device for active-passive mechanotherapy of the ankle joint. The device is based on a controllable mobile platform equipped with force-moment sensors, on which the patient's foot is mounted by means of cuffs, and the platform rotation angles are controlled by linear motion sensors. The platform of the device is designed in such a way that the rotation axis of the platform always coincides with the centre of the ankle joint. For this purpose, a parallel kinematics mechanism is used, which is based on three linear electric drives. The control system of the device provides both active and passive movement of the platform. For realization of the control algorithm of the mobile platform movement, a mathematical model is developed, which allows establishing connections between angular motions of the mobile platform and linear drives of the parallel mechanism. Models of reaction forces of the platform support on the patient's foot during operation of the device are also described. A functional control diagram of the device is presented, and the modes of operation of the device are described.
	**Daniyar Wolf, Yaroslav Turovsky, Anastasia Iskhakova, and Roman Meshcheryakov** **Lecture Title:** Evaluation of EEG data for Zonal Affiliation of Brain Waves by Leads in a Robot Control Task **Abstract:** The task of creating a neural interface for controlling a robotic system by means of an oculographic interface and bioelectric signals, is considered. The article highlights the results of scientific experimental research aimed at the evaluation of the representativeness of bioelectrical signals obtained by electroencephalography (EEG). The basic hypothesis is formulated and tested with the help of artificial neural network technology. The authors consider an experiment on the formation of steady-state visually evoked potentials in a group of people with the subsequent creation of an applied database. They describe an original approach for extracting representative features from the EEG signal. With the help of deep machine learning technology the representativeness of the data under study is evaluated. The main conclusions are

	formulated and the hypothesis that each brain lead reproduces unique waves which are characteristic of each brain zone is confirmed. The proposed model of a symmetric multilayer multi-adaptive direct propagation neuron can find its application in solving problems related to the processing of EEG signals. Based on the results of this study, the authors suggest that data on the bioelectrical activity of the brain can be uniquely identified, and thus used as control signals for various robotic devices.
Oral Session 2	
	**Eduard Melnik and Irina Safronenkova** **Lecture Title:** Ontological Approach to the Organization of Computing in Distributed Monitoring Systems with Mobile Components Based on a Distributed Ledger **Abstract:** The implementation of mobile components into monitoring systems has significantly expanded their scope of application. A distributed ledger (DL) allows to synchronize copies of data received from geographically distributed sources. This makes it possible for mobile components to work with the "nearest" copy of the ledger in terms of data access, which reduces the time and energy costs associated with data access. This paper considers issues related to the efficiency of distributed monitoring systems with mobile components based on the concept of fog computing and DL technologies. The problem of organizing the computational process in terms of placement and workload reallocation is highlighted. It is proposed to use the ontological approach in order to reduce the search space of candidate nodes for the placement of computational load. The use of other known methods of placing the computational load is limited by the characteristics of the environment and the system. The core of ontological approach is the ontological model built with the subject domain in mind. Experimental studies have shown that the application of the ontological approach can reduce the search space by 80%. The obtained data are consistent with the results of the experiment conducted for another subject area.
	**Andrey Gorodetskiy, Konstantin Mironov, and Aleksandr Panov** **Lecture Title:** Model-based Policy Optimization with Neural Differential Equations for Robotic Arm Control **Abstract:** Applying learning-based control methods to real robots presents hard challenges, including the low sample efficiency of model-free reinforcement learning algorithms. The widely adopted approach to tackling this problem uses an environment dynamics model. We propose to use the Neural Ordinary Differential Equations to approximate transition dynamics as this allows for finer control of a trajectory generation process. NODE offers a continuous-time formulation that captures the temporal dependencies. We evaluate our approach on various tasks from

	simulation environment including learning 6-DoF robotic arm to open the door, which represents particular challenges for policy search. The NODE model is trained to predict movement of the arm and the door, and is used to generate trajectories for the model-based policy optimization. Our method shows better sample efficiency on this task comparing to the model-free and model-based baseline. It also shows comparable results on several other tasks. The application of NODE to model-based reinforcement learning enables more precise modeling of robotic system dynamics and enhances the sample efficiency of learning-based control methods. The empirical evaluation on various tasks demonstrates the efficacy of our approach, offering promising prospects for improving the performance and efficiency of real-world robotic systems.
	**Samir Guliyev** **Lecture Title:** Approach to Numerical Solution of Nonlinear Optimal Feedback Control Problems **Abstract:** In the paper, we consider optimal feedback control problems for dynamic, in the general case, nonlinear systems with lumped parameters based on continuous and discrete feedback on the object's state. To calculate the values of the feedback control's parameters, we propose to use the measured values of observable components of the phase vector or the object's output at the current and some previous (past) moments of time in order to compensate for the inability to measure all the components of the object's phase state. As a result of this kind of formation of the dependence of the parameters of the synthesized control on a part of the object's state, the process under consideration will be described by ordinary differential equations with time-constant delay arguments in the phase state. The feedback control problem is solved numerically by reducing it to a finite-dimensional optimization problem. To this end, we derive formulas for the gradient of the objective functional of the reduced problem with respect to the optimizable parameters are zonal values of the feedback parameters. These formulas make it possible to formulate necessary first-order optimality conditions, as well as to use them for numerical solution to model problems using first-order optimization methods.
	**Eugene Larkin, Tatiana Akimenko, Alexey Bogomolov and Vadim Sharov** **Lecture Title:** Reliability of Robot's Controller Software **Abstract:** The reliability of robots' digital control systems, based on Von Neumann type computer platform is investigated. An approach is proposed for assessing the reliability of a robot control program, based on the analysis of software as a model of a computational process unfolding in real physical time. It is shown that in systems of suchlike class the importance of software in ensuring the reliability of robot operation as a whole increases

	significantly. It is determined that software failure potential is being laid to the control program at its designing stage due to neglect of such digital controllers properties, as time delays when data processing. The model of control program failures emerging, caused by time factor, is worked out. For delays between transactions estimation the semi-Markov model of poling procedure is used, that permit to estimate probabilities of exceeding data skew, pure lag, and sampling period the threshold, beyond which the control system failure takes place. Using a stochastic matrix, describing poling procedure, probability of failure, caused by transactions order disturbances is estimated. Probabilities and sampling period obtained are used for simulation of failure flow generator, describing reliability of control program.
	**Viktor Semenov** **Lecture Title:** Monitoring the State of Robotic Systems Based on Time Series Analysis **Abstract:** In view of the close integration of robotic systems into industrial and technological systems, critical infrastructure objects, as well as a significant number of possible entry points, the task of monitoring operational safety for robotic systems is more complex than ensuring information security in classical information systems. The paper presents a method for monitoring the state of robotic systems based on time series analysis. The developed method differs from the existing ones by the combined approach of using an ensemble of parallel classifiers and Fishburn weight coefficients in the security event management system. The time series is composed of a set of informative features, characterizing the functioning of a robotic system. Values for previous discrete time points are ranked using significance weights. The method was approved on a data set of a real industrial system. Due to parallel computing, it was possible to significantly increase the speed of determining the state of robotic systems. The identification precision due to the combined approach increased by 1.45 % compared to the best results presented in scientific papers, the recall increased by 4.45 % and amounted to 99.85 % for both indicators. The results of the study can be applied in monitoring the safety of robotic systems.
	**Anna Klimenko and Arseniy Barinov** **Lecture Title:** Resource-Saving Multiobjective Task Distribution in the Fog- and Edge-Robotics **Abstract:** In the current paper the question of the resource-saving tasks distribution in the robotic groups is under consideration. As a wide range of computational tasks in robotics are performed in a distributed manner, tasks can be assigned to the devices with a relatively low computational capacity. At the same time, data preprocessing, machine learning, SLAM problems are computationally complex, and so the participants of the

	computational process can be overloaded, while the latter causes the deterioration of average residual life of the computational nodes within the robots. In this paper the problem of resource-saving tasks distribution is formulated as structural-parametric multiobjective one, with paying attention to the workload of those robots in the group, which have to transmit sensor data. The general solution technique is proposed based on global problem decomposition, local time constraints estimations and simulated annealing technique. The a priory time estimations are used according to the tasks graph analysis, as well as time constraints are divided into shares considering the number of transit nodes. Also, some selected experimental results are presented, as well as comparison with the previously conducted results are made.
	**Anna Klimenko** **Lecture Title:** Improved Model of Greedy Tasks Assignment in Distributed Robotic Systems **Abstract:** The problem of computations efficiency estimation is a topical one nowadays because of cost and various constraints, including energy consumption, resource spending, data transmission constraints, etc. Taking into account the tight connection between distributed robotic systems and IoT concepts, including fog and edge, the problem of computational resource spending is considered as one of the efficiency criteria. In the current paper the improved model for computational tasks distribution efficiency estimation is presented and discussed. As the failure rate of the node depends on the workload, we consider the strategy, when each node can choose its regime - to transmit or to process data. The decision depends on the estimation inequality, which includes such parameters as computational complexities of data processing, data transmission and time share of the data transmission in the overall time constraint for the tasks performing. The model developed allows to implement the greedy strategy of tasks distribution, in which every robotic device chooses the best individual state and differs from the previously presented model by more precise estimations of the data transmission. Also, some selected experimental results are presented, pros and cons of such greedy approach are discussed.
Plenary Session 2	
	**Nikolay Kuznetsov, Boris Andrievsky, Iuliia Zaitceva, and Elizaveta Akimova** **Lecture Title:** Sliding-mode Control of Phase Shift for Two-Rotor Vibration Setup **Abstract:** This paper successfully developed and studied a phase shift control system for a two-rotor vibration mechatronic setup, aiming to maintain the desired revolving speed of the rotors. The sliding mode motion was achieved by utilizing a relay controller in the phase loop, while PI controllers were employed in the velocity control loops. Through numerical study and simulations using the

	parameters of the Mechatronic Vibration Setup SV-2M, the effectiveness of the proposed velocity and phase shift control laws was demonstrated. The possibility of sliding mode occurrence in the phase shift loop was examined through analytical and numerical analysis, confirming its presence. The relationship between the relative degree of the transfer function of the plant and the possibility of the occurrence of a sliding mode is analyzed based on the locus of a perturbed relay system approach. Simulation results indicated that sliding mode motion appeared after a finite transient time and showcased the dynamical properties of the closed-loop system. In conclusion, the findings of this study validate the efficacy of the phase shift control system in achieving the desired rotor speed and demonstrate the feasibility of implementing sliding mode motion in the mechatronic setup.
	**Kamil Aida-zade and Vugar Hashimov** **Lecture Title:** Optimization of the Placement of Measurement Points and Control of the Power of Moving Sources in Rod Heating **Abstract:** The problem of synthesis of power control of point-wise heat sources of heating of a rod moving along the rod by given trajectories and optimization of the placements of temperature measurement points is considered. To form the current power values of each of the heat sources, it is proposed to use the formula of their linear dependence on the temperature of the rod at the measured points. In general, the original optimal control problem is reduced to finding a finite-dimensional vector of feedback parameters and coordinates of measurement points that optimize the given objective functional. Regarding the feedback parameters and the coordinates of the measurement points, the necessary conditions for the optimality of the functional of the problem are formulated, containing formulas for the components of the gradient of the objective functional. The obtained formulas make it possible to use effective numerical first-order optimization methods for solving the problem. The results of numerical experiments obtained on initial test data are presented, and the analysis of the results is carried out. In particular, the influence of the temperature measurement errors at the measurement points on the quality of process control, namely on the value of the objective functional is analyzed.
	**Daniyar Wolf, Vadim Alexandrov, Dmitrii Shatov, Ilya Rezkov, Peter Trefilov, and Roman Meshcheryakov** **Lecture Title:** Development of a Firmware for Multirotor UAV Flight Controller Implemented on MCU MDR 32 **Abstract:** The paper is devoted to study unmanned aerial vehicle (UAV) flight operational features and UAV's automatic control system operating in manual mode (it processes pilot's control commands). The analysis of operation in special cases and conditions is carried out for the aircraft equipped with a radio-operating human-controlled system and automatic flight control

	system. The main goal of the research is to develop fully functional flight controller the flight controller based on the domestic made microcontroller unit (MCU) MDR 32. The main novelty is that board LDM-BB-K1986BE92QI with the MDR32F9Q2I microcontroller core is used as a hardware base for the flight controller. The development of hardware and software are described separately including some features that was used to overcome several limitations of the selected MCU. The base flight controller firmware modules, functions and algorithms are described. A sample quadrotor based on the S550 frame was assembled using the developed flight controller to carry out testing flights. Two test experiments are presented: the first one is a checking of the flight controller base functionality (parameters configuration and calibration) and the second one is a test flight performed by a pilot.
Oral Session 3	
	**Andrei Konstantinov, Lev Utkin, Vladimir Muliukha, and Vladimir Zaborovsky** **Lecture Title:** GBMILs: Gradient Boosting Models for Multiple Instance Learning **Abstract:** An approach based on using the gradient boosting machine for solving the Multiple Instance Learning (MIL) problem under condition of small tabular data is proposed. The MIL deals with labeled objects called bags which consist of several parts of the objects called instances with unknown labels and each bag label depends on the instance labels. Three modifications of the approach are developed and studied. They are determined by different aggregation functions which combine the intermediate predictions of the instance classes in each bag and allow gradient-based optimization through them. The modifications are based on the following aggregation functions: the Hard Max Aggregation, the Simple Attention Aggregation, and the Ensemble of gradient boosting machines in fusion with the Attention Neural Networks. The former two modifications can use an arbitrary decision tree gradient boosting model, which allows iterative training on loss gradients. The later modification simultaneously optimizes an ensemble of parallel gradient boosting models and the parameters of neural network. Numerical experiments with tabular datasets illustrate the proposed modifications of the approach and their superiority comparing to available MIL approaches accompanied by accuracy improvement up to 8%.

Anatoly Gaiduk, Viacheslav Pshikhopov, Mikhail Medvedev, Vladislav Gissov, Ali Kabalan, and Evgeny Kosenko

Lecture Title: Design of Hybrid Control System for Nonaffine Plants

Abstract: The purpose of this article is to develop a design method that ensures the stability of the zero-equilibrium position of a closed nonaffine control system in a certain area. The objects described by a nonlinear system of differential equations with one control and one output are considered. A constraint is introduced, which consists in the differentiability of the right-hand sides of differential equations with respect to all state variables. The task of designing control in the form of a function of the setting action, state variables and control values at previous points in time is set. This problem is solved using a quasilinear model of the control object. In the quasilinear model, matrices and vectors are functions of the variables of the state of the control object. The control is found using an algebraic polynomial matrix method. This article presents the expressions for calculating the control in accordance with the polynomial-matrix method. Based on the given coefficients of the desired polynomial, as a result of solving an algebraic system of equations, coefficients are found that are a function of control and state variables. The fulfillment of the controllability condition guarantees the existence of a solution of the specified algebraic system.

Artem Apurin, Bulat Abbyasov, Edgar A. Martínez-García, and Evgeni Magid

Lecture Title: Comparison of ROS Local Planners for a Holonomic Robot in Gazebo Simulator

Abstract: A safe robot navigation in a dynamic environment is an essential part of an autonomous exploration path planning. A path planning part of a navigation involves global and local planners. While a global planner finds an optimal path with a prior knowledge of an environment and static obstacles, a local planner recalculates the path to avoid dynamic obstacles. The main goal of a local planning is adjusting an initial plan produced by a global planner in an online fashion. It is a crucial step to ensure a robot operation in dynamic environments because in real world scenarios an environment usually contains people and thus, a dynamic obstacles avoidance must respond quickly and recalculate an actual route. Holonomic robotic platforms are robotic vehicles that use omni-wheels to move in any direction, at any angle, without an additional rotation. These robotic platforms are ideal for working zones with a limited space access. This paper provides a comparison of ROS local planners that support omni-wheel mobile robots: Trajectory Rollout, DWA, EBand, and TEB. The algorithms were compared using a path length, a travelling time and a number of obstacle collisions. Gazebo simulator was used for modeling virtual scenes with dynamic obstacles.

Artur Podtikhov and Anton Saveliev

Lecture Title: Ground Mobile Robot Localization Algorithm Based on Semantic Information from the Urban Environment

Abstract: This paper presents the SLAM algorithm, which use the semantic information extracted from the urban environment to increase the accuracy of ego-vehicle localization in ORB-SLAM2 system. For this purpose, a semantic segmentation module is added to the standard algorithm to assign an object on each frame to one of a given set of classes. The CARLA Simulator was used as a simulation environment, which generates a photorealistic urban environment with the ability to run an arbitrary number of active elements in it, which usually make localization difficult, causing interference with the system. Based on the environment, a training dataset for semantic segmentation was collected. The training dataset consists of 3,696 pairs of city images and corresponding segmentation masks in which each pixel corresponds to one of 23 semantic labels. Using this dataset, the DeepLabV3+ segmentation model was trained with mean per-class IoU metric equals to 81.48%. By using semantic information to filter potentially dynamic objects and matching key points, we were able to increase the localization accuracy relative to the base algorithm by an average of 23% and build a semantic map of the environment.

Nizar Hamdan, Viacheslav Pshikhopov, Michael Medvedev, Dimitry Brosalin, Maria Vasileva, and Boris Gurenko

Lecture Title: Study of Path Planning Methods in Two-Dimensional Mapped Environments

Abstract: The article studies the problem of path planning in two-dimensional environments. The review and analysis of known planning algorithms are carried out. This article is devoted to the development of a modified rapidly growing random trees algorithm (RRT) and the study of its effectiveness in comparison with known methods. The presented modified RRT algorithm checks the path to some area near the specified node while planning the path to a new potential node of the tree, which reduces the constructed nodes of the tree. The developed algorithm is compared with the original RRT algorithm. The comparison criteria are the path calculation time, the amount of memory required, the path length, and the percentage of situations in which the trajectory to the target point was successfully found. Next, the developed algorithm is compared with the planning algorithms of other classes. The study uses representative samples of numerical experiments and various environments that differ in the density of obstacles and the presence of mazes. A study of planning algorithms using the results of experiments on a ground-based wheeled robot has also been conducted.

Dmitry Dobrynin

Lecture Title: Movement Along the Trajectory of a Home Quadruped Robot

Abstract: Home walking robots imitating pets have a high appeal due to increased maneuverability in a cramped home environment. Planning the movements of a home robot is an important component of the control system of a quadruped walking robot. The article deals with the problem of following the trajectory of a walking robot, which relates to motion planning. The article presents a model of a robot and a mathematical model of its legs. Two methods of approximation of the trajectory of motion are proposed in the article are piecewise linear approximation and approximation by arcs of a circle. The use of piecewise linear approximation makes it possible to solve the problem using simple robot movements. The use of approximation by arcs of a circle allows you to build a universal gait for a walking robot. The simulation of robot movements using two types of approximations is carried out. The article presents experimental modeling data. It is shown that the average speed of a walking robot with piecewise linear approximation is significantly lower than the speed of the robot moving in a straight line. The article presents the conclusions drawn from the results of experiments.

Vladislav Savinov and Konstantin Yakovlev

Lecture Title: DHC-R: Evaluating "Distributed Heuristic Communication" and Improving Robustness for Learnable Decentralized PO-MAPF

Abstract: Multi-agent pathfinding (MAPF) is a problem of coordinating the movements of multiple agents operating a shared environment that has numerous industrial and research applications. In many practical cases the agents (robots) have limited visibility of the environment and must rely on local observations to make decisions. This scenario, known as partially observable MAPF (PO-MAPF), can be solved through decentralized approaches. In recent years, several learnable algorithms have been proposed for solving PO-MAPF. However, their performance is oftentimes not validated out-of-distribution (OOD), and the code is often not properly open-sourced. In this study, we conduct a comprehensive empirical evaluation of one of the state-of-the-art decentralized PO-MAPF algorithms, Distributed Heuristic Communication (DHC) [2], which incorporates communication between agents. Our experiments reveal that the performance of DHC deteriorates when agents encounter complete packet loss during communication. To address this issue, we propose a novel algorithm called DHC-R that employs a similar architecture to the original DHC but introduces randomness into the graph neural network-based communication block, preventing the passage of some data packets during training. Empirical evaluation confirms

	that DHC-R outperforms DHC in scenarios with packet loss. Open-sourced model weights and the codebase are provided: https://github.com/acforvs/dhc-robust-mapf.
Oral Session 4	
	**Vladimir Kostyukov, Igor Evdokimov, and Vladislav Gissov** **Lecture Title:** Construction of a Three-dimensional UAV Movement Planner when the Latter Moves in Conditions of Difficult Terrain **Abstract:** The known methods of planning the routes of movement of robotic platforms based on cellular decomposition of the area of movement in a three-dimensional formulation are severely limited in speed. Therefore, the construction of high-speed planning algorithms in a three-dimensional mapped environment is an urgent task. This article proposes a method for planning the movement of robotic platforms in this environment, combining the use of the well-known Dijkstra algorithm for constructing a two-dimensional projection curve with subsequent projection reconstruction and multi-stage correction of the target spatial piecewise polyline curve. The restoration of the original spatial curve by its two-dimensional projection onto the horizontal plane is performed on the basis of a given discrete elevation map of the motion area, and the specified adjustment is made taking into account the requirements, firstly, the minimality of the total length of the final piecewise polyline, and, secondly, taking into account the specified known kinematic limitations of the apparatus. The algorithm for the synthesis of a spatial curve is detailed for the common case when obstacles are represented in the form of rectangular cylinders with polygonal generators. The effectiveness of the developed global scheduler algorithm is confirmed by the results of numerical modeling.
	**Vadim Alexandrov, Ilya Rezkov, Dmitrii Shatov, and Yury Morozov** **Lecture Title:** Identification of the Quadcopter Rotational Dynamics for the Tilt Angle **Abstract:** The pitch and roll angles of the quadcopter attitude are controlled by torque arising from the difference in thrust of different rotors. Rotational dynamics of the quadcopter as a rigid body is considered. The pitch and roll angles that form the quadcopter tilt angle have similar dynamics for the case of symmetric quadcopter frame, so the pitch angle is studied separately in the paper. The finite frequency identification approach is used to find the transfer function from the experimental flight data. The approach needs data, when sine wave test signals are fed to the system input. In the case of the unstable loop of the quadcopter tilt angle, the closed loop identification procedure is used where the test signal is added to the setpoint of the operating

	controller. As a result, a more complex model is identified than is commonly used. Moreover, the nonlinear model of the quadcopter pitch angle is considered, taking into account the translation velocity. Parameters of this model are estimated from the same experimental data using the nonlinear grey-box model parameters identification procedure. The transfer function founded from this model confirms the structure of the transfer function obtained via the finite frequency identification procedure.
	**Dmitry Anikin, Artem Ryabinov, Anton Saveliev, and Alexander Semenov** **Lecture Title:** Autonomous Landing Algorithm for UAV on a Mobile Robotic Platform with a Fractal Marker **Abstract:** This article describes experiments related to the simulation of automatic landing of UAV on a mobile robotic platform using computer vision and a control system based on PID and polynomial regulators within the Gazebo environment. Algorithm has been developed to generate control inputs for maintaining the velocities of the UAV based on the data from the computer vision system and feedback from onboard sensor devices. A series of experiments were conducted at altitudes ranging from 5 to 20 meters, which allowed for identifying limitations that affect the successful landing of the UAV. Measurements were taken of the landing time and landing error, calculated as the distance between the platform center and the UAV's center of mass upon completion of the landing. The average landing time and error ranged from 19.64 seconds and 0.16 meters at an initial altitude of 5 meters to 121.01 seconds and 0.27 meters at an initial altitude of 20 meters. Analysis of the obtained results revealed that both the average error and landing time increase with the initial altitude, which is associated with the accuracy of marker recognition at altitudes above 15 meters. The obtained results can be valuable for further improvement of systems for automatic landing of UAVs on mobile platforms.
	**Tagir Muslimov** **Lecture Title:** Curl-free Vector Field for Collision Avoidance in a Swarm of Autonomous Drones **Abstract:** To perform complex tasks, drones must have the ability to move autonomously. Ensuring collision avoidance is very important for the safe movement of autonomous drones indoors. FIRAS function-based potential field method is the standard for collision avoidance as implemented in isolated drones. However, its use in an autonomous swarm can be problematic. Its complex interconnected structure causes one of the known issues when there are multiple simultaneously active control objectives. They are intra-swarm collision avoidance and reaching the target relative distance (normally referred to as formation control). This paper shows that with collision avoidance active, the standard potential

	field method will cause a local minima-like effect in an autonomous swarm. To prevent it, this paper proposes a modified curl-free vector field-based algorithm. This modification enables extended lateral circular motion to prevent swarm members from getting stuck in a local minimum. Stability theory methods are invoked to show that the formation remains stable when running the proposed algorithm. Comparative numerical experiments were run on a drone swarm model in MATLAB/Simulink to illustrate the functioning of this algorithm. To prove the proposed method effective, the paper presents simulation results for standard vs modified potential field.
	**Azad Bayramov and Samir Suleymanov** **Lecture Title:** Remote Control Robotic System for the Perimeter Security **Abstract:** The results of the development, preparation and preliminary laboratory and field tests of the robotic security system along the perimeter of any object remotely controlled by radio waves have been presented in paper. Radio signals are coded using a cryptographic method. The robotic system consists of a remote control and controlled units (blocks) that can perform various functions to protect the perimeter of the selected zone. The principle of operation and the structure of the robotic security system are presented. To ensure safety, the blocks are controlled by coded signals. The working principle, management, operation rules, management and telemetry of the security system were explained. Cryptographic coding based on the Neyman algorithm was used to encrypt the telemetry of the security system. The robotic security system can be used for the protection of territory, borders or objects, including for military purposes. Such control can be carried out around the clock, in any weather, at any area and distance. The working principle and management of the protection system are given in the paper.
	**Olga Mitrofanova, Ivan Blekanov, Danila Sevostyanov, Jia Zhang, and Evgenii Mitrofanov** **Lecture Title:** Development of a Robot for Agricultural Field Scouting **Abstract:** Since agricultural environments are mostly in unstructured feature information, in order to facilitate agricultural robots to better adapt to environmental change problems in agricultural environments, this paper proposes a robot system architecture for agricultural fields scouting. The article proposes: 1) the analysis of some existing field agricultural robots; 2) a novel approach that first constructs a map using the Rtabmap SLAM technique and second employs a particle filter-based Monte Carlo method to estimate the robot's position post-hoc with a loopback detection process; 3) the pipeline of robot works (which is developing), including its architecture, taking into account selected

	hardware and software components. Firstly, the hardware architecture of the robot and its required sensors are considered, then the AMCL route planning algorithm is applied. The depth camera+lidar+RTK approach is used for the robot's map construction, the simulation model of robot route planning by ROS, the robot design by SolidWorks, and finally the required sensors and hardware structure parts are analyzed and summarized. Based on the considered project, it is planned to create a field agricultural scouting robot, which will become part of the implementation of a digital twin in crop production.

Venue and Format of the Conference

8th International Conference on Interactive Collaborative Robotics (ICR 2023) will be held in a hybrid format: face-to-face participation taking place on the basis of the Institute of Control Systems of the Ministry of Science and Education of the Republic of Azerbaijan (Azerbaijan, Baku city, 68 Bakhtiyar Vahabzadeh Street, AZ1141, Assembly Hall, first floor. The Institute is located opposite the Baku State University, at the new exit from the metro ELMLƏR AKADEMİYASI) and an online video conference. The conference programme with link on video conference is available on the website too: https://icr.cyber.az/

The official language of the conference is English.

One link for video conference for Opening ceremony, Sessions, Closing ceremony is: https://us06web.zoom.us/j/83782678933?pwd=SE9EUlhxdnpsbWVENEJ2aEhrWXJDdz09.

NB: Please, be so kind to write all your questions to speakers in chat.

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