7th International Conference on

**Interactive Collaborative Robotics**

# ICR 2022

# Conference Programme and Abstracts

**December 16-18, 2022**

**Fuzhou, China**

Springer

SPC RAS

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- Tsinghua University
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- Fuzhou University
- Gaitech Intelligence
- Shanghai Jiao Tong University Press
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## Conference at a glance

| Friday, December 16, 2022 | |
|---|---|
| 11:00-13:00 | **Registration (for on site participants)** |
| **Saturday, December 17, 2022** | |
| 09:00-09:15 | **Opening Ceremony:** https://us06web.zoom.us/j/82923942530?pwd=RDlSdk8vc3doendlcU8rWXFISEU0UT09 |
| 09:15-11:15 | **Session 1:** https://us06web.zoom.us/j/82923942530?pwd=RDlSdk8vc3doendlcU8rWXFISEU0UT09 |
| 11:15-11:30 | **On-line Joint Photography of Conference Participants** |
| 11:30-13:30 | **Session 2:** https://us06web.zoom.us/j/82923942530?pwd=RDlSdk8vc3doendlcU8rWXFISEU0UT09 |
| 13:30-14:30 | **Lunch break** |
| 14:30-16:30 | **Session 3:** https://us06web.zoom.us/j/82923942530?pwd=RDlSdk8vc3doendlcU8rWXFISEU0UT09 |
| 16:30-17:00 | **Closing Ceremony:** https://us06web.zoom.us/j/82923942530?pwd=RDlSdk8vc3doendlcU8rWXFISEU0UT09 |
| **Sunday, December 18, 2022** | |
| 10:00-14:00 | **Social event** |

The time of the video conference is specified in the time zone of St. Petersburg/Moscow (UTC + 3): https://www.worldtimebuddy.com/utc-to-russia-moscow.

## Conference Programme

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| 09:15-11:15 | **Session 1 (6 full presentations, 20 min):**<br>https://us06web.zoom.us/j/82923942530?pwd=RDlSdk8vc3doendlcU8rWXFISEU0UT09<br>**Chair: Xin Li** |
| | *Yunhan Li, Jingjing Lou, Xiyuan Wan, Qingdong Luo, and Pengfei Zheng*. Gesture Control System for Desktop Robotic Arm |
| | *Guo Wu, Leonard Pak, Madin Shereuzhev, and Vladimir Serebrenny.* Supervisory System for a Collaborative Robotic Cell Based on RGBD Camera |
| | *Yizhou Chen, Jie Li, Rongrong Ni, and Xiaofeng Liu.* Design and Implementation of an Interactive Docent Robot for Exhibitions |
| | *Guoyu Zuo, Zonghan Gu, Gao Huang, and Daoxiong Gong*. Attention Guided 6D Object Pose Estimation with Multi-constraints Voting Network |
| | *Xiaolong Hao, Qiang Cheng, Chengru Jia, He Huang, Shuai Zhao, and Yi Wang.* Design of Intra-oral Radiograph Assisted Robot Based on Face Recognition |
| | *Yue Zhang, Yehui Wang, Xin Li, and Viswanath Goud Bellam.* Moving + : Semantic Scene Classification on YOLOv5 |
| 11:15-11:30 | **On-line Joint Photography of Conference Participants** |
| 11:30-13:30 | **Session 2 (13 short presentations, 10 min)**<br>https://us06web.zoom.us/j/82923942530?pwd=RDlSdk8vc3doendlcU8rWXFISEU0UT09<br>**Chair: Evgeni Magid** |
| | *Liaisan Safarova, Bulat Abbyasov, Tatyana Tsoy, Hongbing Li, and Evgeni Magid*. Comparison of Monocular ROS-Based Visual SLAM Methods |
| | *Igor Shardyko, Victor Titov, and Vladislav Kopylov.* Impedance Control of an Elastic Actuator with Strongly Coupled Structure |
| | *Daniil Pushkarev, Konstantin Mironov, Ilya Basharov, Margarita Kichik, Sergey Linok, Dmitry Yudin, Muhammad Alhaddad, and Aleksandr Panov.* Door Opening Strategy for Mobile Manipulator with Constrained Configuration |
| | *Shixuan Wang, Fengge Wu, Yijun Lin, and Junsuo Zhao.* Domain Randomization with Adaptive Weight Distillation |
| | *Georgy Karabanov, Alexander Selyukov, and Oleg Krakhmalev.* Numerical Solution of the Inverse Kinematics Problem on the Example of a 6-DOF Robot |
| | *Artem Sukhanov, Ivan Ermolov, Maxim Knyazkov, Eugeny Semenov, and Filipp Belchenko.* Experimental Study of the Sensitivity Adjustment Algorithm for Exoskeleton Arm |
| | *Ilya Mitin, Roman Korotaev, Nikolay Tschur, Innokentiy Kastalskiy, Susanna Gordleeva, and Victor Kazantsev.* Modeling Biomorphic Robotic Fish Swimming: Simulations and Experiments |

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| | *Dmitriy Levonevskiy, Anna Motienko, and Mikhail Vinogradov.* Complex User Identification and Behavior Anomaly Detection in Corporate Smart Spaces |
| | *Anna Klimenko.* Model and Method of Resource-saving Task Distribution for the Fog Robotics |
| | *Mikhail Khachumov and Vyacheslav Khachumov.* Intelligent-Geometric Control Architecture for Extinguishing Fires by a Group of UAVs |
| | *Roman Iakovlev.* Approach to Automated Collection of Stones from Agricultural Lands by Means of a Heterogeneous Group of Robotic Systems |
| | *Valeriia Lebedeva, Roman Iakovlev, Vitaliy Bryksin, and Vadim Agafonov.* Method for Planning a Coverage Trajectory for a Group of UAVs Marking out Zones for Installing Seismic Modules |
| | *Marina Orda-Zhigulina, Eduard Melnik, and Sergey Kapustyan.* Simulation Program Model of Mobile Robots Groups for Multi-Robotic Complex |
| 13:30-14:30 | **Lunch break** |
| 14:30-16:30 | **Session 3 (6 full presentations, 20 min)**<br>https://us06web.zoom.us/j/82923942530?pwd=RDlSdk8vc3doendlcU8rWXFISEU0UT09<br>**Chair: Ilshat Mamaev** |
| | *Artem Apurin, Liaisan Safarova, Alexandra Dobrokvashina, Bulat Abbyasov, Tatyana Tsoy, Edgar A. Martínez-García, and Evgeni Magid*. LIRS-ArtBul: Design, Modelling and Construction of an Omnidirectional Chassis for a Modular Multipurpose Robotic Platform |
| | *Kirill Muravyev and Konstantin Yakovlev.* Evaluation of RGB-D SLAM in Large Indoor Environments |
| | *Andrey Gorodetsky, Konstantin Mironov, Daniil Pushkarev, and Aleksandr Panov.* Goal and Force Switching Policy for DMP-Based Manipulation |
| | *Dmitry Dobrynin.* Gait Synthesis of a Home Quadruped Robot |
| | *Polina Kozyr, Yuliya Vasunina, and Anton Saveliev.* Algorithm for Replacing the Battery of a Robotic Tool Using Servicing Mobile Robots on Inhomogeneous Surfaces |
| | *Olga Gerget, Andrey Kravchenko, Roman Meshcheryakov, Tatiana Lysunets, Rinat Galin, Daniiar Volf, and Mark Mamchenko.* Software Library for KUKA iiwa Robot to Improve the Efficiency of Human-Robot Interaction in Robotic Medical Applications |
| 16:30-17:00 | **Closing Ceremony:**<br>https://us06web.zoom.us/j/82923942530?pwd=RDlSdk8vc3doendlcU8rWXFISEU0UT09<br>**Chair: Roman Meshcheryakov** |
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# Abstracts

## Session 1

**Yunhan Li, Jingjing Lou, Xiyuan Wan, Qingdong Luo, and Pengfei Zheng**

**Lecture Title:** Gesture Control System for Desktop Robotic Arm

**Abstract:** As an important human-machine interation method, gesture control attracts lots of researchers' concentration in resent years. Different from other literatures on on industrial manipulator, This paper presents the possibility of using Leap motion gesture sensor to control a desktop robotic arm's movement by means of gestures. It describes the system framwork and control algorithm of robot control. A Leap motion senser, a desktop robotic arm and one computer are used to construct the system. In the control flow of the system. coordinate transformation between the palm position detected by Leap motion gesture sensor and the tool center point (TCP) of the desktop robotic arm is calculated using the method of spatial mapping. The mapping data can be used to control the desktop robotic arm. In order to filter the noise and smooth the gesture signal acquired by the sensor, mean filter and Kalman filter are applied. The program for the system is developed in Python language with Leap motion Python SDK and xArm Python SDK. The experiments show that the system can operate stably, and can control the movement of the desktop robotic arm accurately in real time by human palm' gesture.

**Guo Wu, Leonard Pak, Madin Shereuzhev, and Vladimir Serebrenny**

**Lecture Title:** Supervisory System for a Collaborative Robotic Cell Based on RGBD Camera

**Abstract:** The task of supervision in a collaborative robotic system is an important issue. Supervisory system is primarily necessary for the organization of safe human-robot interaction. In this paper, another approach to the application of the similar systems is considered. Two RGBD cameras are proposed for modeling the human state and conditions and further organization of the dialogue between robots and humans. This dialog is necessary to arrange the dynamic allocation of tasks, validity of which depends on analysis of human behavior and intention. In view of that, four algorithms based on neural networks are proposed: for face recognition, body recognition, gestures recognition and tools recognition. The Python library "face_recognition" provided by Adam Geitgey is applied to face recognition. The OpenPose library is applicable to body and hand key points detection. Finally, the YOLOv5 model of convolutional neural network is used to train our own dataset and recognize mechanical tools. The concept of this paper is presented as finite state machine based on ROS2 package. Experimental results demonstrate the effectiveness of proposed supervisory system.

**Yizhou Chen, Jie Li, Rongrong Ni, and Xiaofeng Liu**

**Lecture Title:** Design and Implementation of an Interactive Docent Robot for Exhibitions

**Abstract:** Interactive docent robot is a novel and interesting service in modern exhibition hall research. It is still challenging to develop a service robot used in exhibition halls that can be used as a guide and interact naturally with visitors. In this paper, we first analyze the basic functions that a service robot should have, and then develop a service robot for exhibitions from the functional design. The service robot completes the functions of multi-point navigation, autonomous obstacle avoidance and explanation in local embedded device through path planning algorithm. To achieve the anthropomorphic interaction effect, an anthropomorphic robotic head for interaction is designed to realize the facial action change in the process of explanation and interaction. In addition, the functions of human-robot dialogue and facial recognition based on convolutional neural network are realized on the cloud platform. The experimental results in navigation accuracy evaluation and human-robot interaction show that the service robot designed in this paper can maintain stable motion, accurate navigation and natural interaction.

**Guoyu Zuo, Zonghan Gu, Gao Huang, and Daoxiong Gong**

**Lecture Title:** Attention Guided 6D Object Pose Estimation with Multi-constraints Voting Network

**Abstract:** For visual-based robotic manipulation, it has always been a challenging task to perform real-time and accurate pose estimation of target objects under cluttered background, illumination variations, occlusion and weak texture, especially under severe occlusion conditions. In recent years, the RGB-based methods based on vector field prediction are proved to be robustness on 6D object pose estimation under occlusion. At the same time, network with attention mechanism has achieved outstanding performance in 2D object detection. In this paper, we propose an attention-driven 6D pose estimation method with multi-constraints loss and pixel-wise voting. We calculate the distance weighted unit vector length and included angle length based on prediction results to regularize unit vectors prediction. Moreover, we introduce Dense Atrous Spatial Pyramid Pooling (DenseASPP) and Channel-wise Cross Attention (CCA) mechanisms into the network structure to improve the accuracy of output prediction. Experiments on LINEMOD and Occlusion LINEMOD datasets manifest that our method outperforms state-of-the-art two-stage sparse 2D keypoints prediction methods without pose refinement.

**Xiaolong Hao, Qiang Cheng, Chengru Jia, He Huang, Shuai Zhao, and Yi Wang**

**Lecture Title:** Design of Intra-oral Radiograph Assisted Robot Based on Face Recognition

**Abstract:** To ensure the high quality and stability of oral diagnosis and treatment images. It is required that the position of the X-ray ball tube is accurate during the shooting process. The artificial difference should be eliminated. In order to avoid cross infection between doctors and patients, an overall solution of intra-oral radiograph assisted robot (IRAR) was proposed, including face recognition, camera calibration, end effector spatial positioning and robot-oral interaction. The working environment and mechanism kinematics of IRAR were analyzed. Based on the establishment of binocular vision calibration system, a face recognition algorithm aided image method was proposed. The interaction model between virtual image and robot pose was analyzed. By analyzing the function of the robot end effector, the related parameter requirements of the end effector were established. Finally, the imaging work area planning scheme of the imaging robot was obtained. Through the interaction between the robot and the oral cavity, the non-contact dental medical images were photographed and disinfected. The repeated positioning accuracy of IRAR system shall not be greater than 1mm. The average error is 0.5 mm. The experiment proved that IRAR can finish the shooting task smoothly and accurately.

**Yue Zhang, Yehui Wang, Xin Li, and Viswanath Goud Bellam**

**Lecture Title:** Moving + : Semantic Scene Classification on YOLOv5

**Abstract:** For intelligent moving agents, robots especially, it is important to be aware of the surroundings to help analyze the situation and what might happen in the future. Scene classification is a hotspot with the development of moving agent. Different from the approach directly solving the problem caused by moving platform, our approach does the classification on object detection results from YOLOv5, which is with meaningful and semantic information. Since YOLOv5 works on frames in video, with state of art detect speed and accuracy in area of object detection, it can perfectly avoid performance degradation caused by the moving platform. By further integrating with TF-IDF,five ways to train the model are obtained, the semantic representation sequence is feed into LSTM to handle the temporal relations among frames. Our dataset was consisted with three parts: moving+ dataset: taken from a mobile robot platform, extension dataset: downloaded from internet by keywords retrieval and mixed dataset: mix both of them. Experiment results on three datasets prove the effectiveness of our approach particularly in the moving+ dataset and mixed dataset, our approach shows a high recognize accuracy up to 93% and 92%.

## Session 2

**Liaisan Safarova, Bulat Abbyasov, Tatyana Tsoy, Hongbing Li, and Evgeni Magid**
**Lecture Title:** Comparison of Monocular ROS-Based Visual SLAM Methods
**Abstract:** Simultaneous Localization and Mapping (SLAM) is a robot navigation approach used to estimate a movement of a sensor in an unknown environment. SLAM application examples include urban search and rescue operations in high-risk environments, visual surveillance and service robotics. Compared to laser-range finders, visual sensors are more light weight, have less power consumption and provide more vast amount of environmental information. Visual SLAM methods are based on visual information only and employ monocular, stereo or RGD-D cameras as input sensors. Monocular SLAM methods are often preferred for a robotic platform when cost, energy and system weight requirements are limited. Calculation of errors and testing on ready-made datasets allow to check applicability of an algorithm in real-world scenarios with less efforts than experiments with a real robot. Verification of a sensor position and robot trajectory estimation accuracy is achieved by measuring Absolute Trajectory Error (ATE), Relative Pose Error (RPE) and Root Mean Square Error (RMSE). This article presents analysis and comparison of the most widely used Visual SLAM monocular algorithms built for Robot Operating System (ROS): ORB-SLAM2, ORB-SLAM3, DSO and LDSO. The KITTI and Euroc MAV datasets were selected to evaluate the algorithms' performance.

**Igor Shardyko, Victor Titov, and Vladislav Kopylov**
**Lecture Title:** Impedance Control of an Elastic Actuator with Strongly Coupled Structure
**Abstract:** Compliance has become a widespread topic in industrial robotics in the last decades, both in hardware and in software. In terms of software, virtual compliance is applied widely, mostly the various implementations of impedance control algorithms. Concerning mechanics, series elastic actuators have gained a lot of attention, which are superior to the traditional rigid robotic joints in terms of shock robustness, interaction safety, torque control etc. In this article, one relatively rare case of such system is considered, i.e. a differential-drive robotic joint. This type of joint makes it possible to move the motors out of the joint unit and transmit motion regardless of the configuration of the joint axes. However, this layout leads to strong coupling between input and output joint angles. Introduction of elasticity further complicates the matter, as in general there is coupling in elastic torques as well. Hence, the control system should provide as much decoupling as possible to get satisfactory performance. A mathematical model of this joint has been designed as well as a control system based on elastic structure preserving impedance control. The latter has been verified by simulation in Simulink.

**Daniil Pushkarev, Konstantin Mironov, Ilya Basharov, Margarita Kichik, Sergey Linok, Dmitry Yudin, Muhammad Alhaddad, and Aleksandr Panov**
**Lecture Title:** Door Opening Strategy for Mobile Manipulator with Constrained Configuration
**Abstract:** We address the task of robotic door opening in office environments. This task is important for providing indoor mobility for collaborative mobile manipulators. In our work, we mainly focus on the use of high-level control opportunities and identification of the door parameters from visual and lidar data. We develop a solution, which includes handle recognition, handle twisting, and opening. The position of the handle is identified from stereo images by a neural-network-based method. We divide the opening procedure into two stages: first, handle twisting and slightly opening, and second, wide opening. The first stage is implemented via high-level task-space control of the robotic arm, while the platform is static. The position of the door axis is identified during the slight opening by fitting lidar data to the kinematic model. At the second stage, both the platform and the arm are active. The trajectory of the platform is defined by the model predictive planner in such a way that it avoids pushing the arm into a singular configuration, while the manipulator is operated via high-level impedance control. In our experiments, a mobile manipulator composed from the wheeled platform and the robotic arm was able to open office doors using the proposed approach.

**Shixuan Wang, Fengge Wu, Yijun Lin, and Junsuo Zhao**

**Lecture Title:** Domain Randomization with Adaptive Weight Distillation

**Abstract:** Domain Randomization (DR) is one of the increasingly popular techniques for domain generalization, which learns a policy from simulation by randomizing domain parameters. However, integrating information from randomized domains into one policy may lead to high variance and an unstable training process. Thus we draw on policy distillation, distilling multiple policies into a single policy to effectively reduce the high variance of the model. The following question is whether the importance of multiple tasks may affect the performance of the distilled policy. To address this issue, we propose an adaptive-weight distillation strategy depending on teacher policy performance called Domain Randomization with Adaptive Weight Distillation (DRAWD) to control the student policy to learn toward better-performing teacher policy. This way, DRAWD addresses the problem of the under-generalization of a single policy and the potential imperfect teacher of a multiple-policy ensemble. We compare DRAWD with two baselines on two Mujoco continuous control tasks. Our results show that the target domain performance of policies trained with DRAWD is better than the other two baselines on the metric of variance and average rewards of the task.

**Georgy Karabanov, Alexander Selyukov, and Oleg Krakhmalev**

**Lecture Title:** Numerical Solution of the Inverse Kinematics Problem on the Example of a 6-DOF Robot

**Abstract:** A geometric model has been created for the selected 3D model 6-DOF the robot. It is a mathematical model using matrices of transformation of homogeneous coordinates. For matrices of transformation of homogeneous coordinates using special differentiation matrices partial derivatives has been obtained and Jacobi matrix corresponding to selected geometric model has been formed. Rotation matrix reflecting working member orientation in space using aircraft angles has been obtained. These angles are a variation of Euler angles. The Gauss method has been chosen as the numerical method for solving the systems of linear equations. Based on the Gauss method, an algorithm for solving the inverse kinematics problem and software implementing it has been developed. When developing the software, object-oriented programming tools were used. The software has been verified using a 3D model of the real industrial robot. The software has been tested on an Intel Core i5-2430M microprocessor running the Windows 10 operating system. Results of studies has been presented by values of given and actual coordinates corresponding to trajectory of 6-DOF robot movement, orientation of its working member and operating time of the algorithm for different number of iteration steps.

**Artem Sukhanov, Ivan Ermolov, Maxim Knyazkov, Eugeny Semenov, and Filipp Belchenko**

**Lecture Title:** Experimental Study of the Sensitivity Adjustment Algorithm for Exoskeleton Arm

**Abstract:** Manipulating objects during the working day affects a person's fatigue, his muscle tone changes. Therefore, when applying biofeedback algorithms based on an electromyogram technique, it is important to take into account the dynamics of such changes and research the possibility of adapting the control system to the psychophysical state of the operator. This technique is being developed as part of the study of the remote control possibility of a robotic platform designed for cleaning ship hulls. The use of this control technique may also be relevant in human-machine systems designed to manipulate heavy objects, for example, during loading and unloading operations at docks or assembly operations. The study considers the possibility of using the operator's electromyogram as a source signal for exoskeleton motor control. This paper shows the features of the variation in the electromyogram envelope during the implementation of rapid movements and the effect of muscle deactivation on the attenuation of the amplitude of the electromyogram envelope on the example of the biceps brachii muscle of the operator. The results of the application of the method of adjusting the sensitivity of the active exoskeleton control system to the operator's actions, previously developed within the project, are shown.

**Ilya Mitin, Roman Korotaev, Nikolay Tschur, Innokentiy Kastalskiy, Susanna Gordleeva, and Victor Kazantsev**

**Lecture Title:** Modeling Biomorphic Robotic Fish Swimming: Simulations and Experiments

**Abstract:** We present fish robot implementing thunniform type of movement in aquatic medium. Shape of the robotic fish body was copied from tuna fish using 3D model constructed from a photograph. The robot is equipped with flexible tail whose oscillations provide translational motion in a water pool. We design a control system imitating simple CPG (central pattern generator), propulsion system implementing a simple form of muscle contraction activity and build experimental setup to monitor functional characteristics of the robot movement. We analyze how these characteristics including motion speed and energy consumption depend on the parameters of the oscillating tail, e.g. shape of the tail, frequency and amplitude of the oscillations. We also develop a simulation model of the fish swimming. The model includes exact copy of the geometry robotic fish body comprising rigid compartments and oscillating tail. Virtual robot movement in the water medium is modeled by numerical solutions of hydrodynamic and robot body biomechanics equations. In numerical experiments we calculated kinematic parameters of fish movement and visualized hydrodynamic flows at different stages of movement.

**Dmitriy Levonevskiy, Anna Motienko, and Mikhail Vinogradov**

**Lecture Title:** Complex User Identification and Behavior Anomaly Detection in Corporate Smart Spaces

**Abstract:** This research deals with the task of detecting security anomalies and incidents in corporate smart spaces equipped with physical access control systems that support simultaneous implementation of various user identification and/or authentication methods and are often integrated with corporate cyber-physical and robotic systems. This approach allows gathering auxiliary data related to user behavior and thus detecting a wider range of security-related situation, such as entry and exit mismatches, usage of another person's passes, and even faults and failures of the access control system itself, as well as achieving the higher reliability of user identification. For this purpose, an architectural solution for a system that uses RFID identification and face recognition was built. A corresponding data model was proposed. Using this data model and its implementation (for example, using relational databases and object-relationship mappings), the gathered data can be processed in order to detect potentially anomalous situations and security incidents. Then, the description and classification of such situations was given, and the delays of operation were measured during the experiment. The measurement shows that the delays allow experiencing the process of interaction as being one continuous flow. The tasks of future research were also specified.

**Anna Klimenko**

**Lecture Title:** Model and Method of Resource-saving Task Distribution for the Fog Robotics

**Abstract:** In the current paper the question of the resource-saving tasks distribution is under consideration. Fog robotics, integrating fog computing and robotics, transfers the issues of the fog computing to the new subject area, as well as modern robots re-quire more and more computing power. Tasks offloading to the fog spotlights the problem of assigning the task to those fog nodes, which failure rate decrease is acceptable. However, the models and methods of such task relocation problem are not presented in the literature, as well as the questions of devices reliability in the fog are not considered. In this paper a new model of task distribution is pro-posed, which allows to estimate the expediency of the task assigning to the node from the resource-saving point of view. Every node chooses: to process the data or to transmit them to the next node, which is situated farer from the data source. With the transfer of the data processing to the node of the low computational re-sources, its reliability can be improved by means of workload distribution through the extra-time, which appears due to the data transfer time reduction. Some selected simulation results are presented and discussed as well.

**Mikhail Khachumov and Vyacheslav Khachumov**

**Lecture Title:** Intelligent-Geometric Control Architecture for Extinguishing Fires by a Group of UAVs

**Abstract:** The article is devoted to solving cutting-edge scientific problem of creating models and methods for increasing the autonomy of unmanned aerial vehicles (UAVs) during fire-fighting operations in an uncertain environment. We show the necessity of using vehicles, both capable to monitor the fire hazard situation and to participate directly in fire extinguishing. A novel three-level hierarchical control architecture for UAVs is proposed, aimed at joint application of precise geometric and adaptive intelligent control methods providing operational reliability and ability to effectively plan motion and behavior in complex external conditions. A model problem of extinguishing a fire by a group of intelligent UAVs capable of exchanging information, choosing leaders, and autonomous planning of actions under wind disturbances in the presence of no-fly zones is considered and solved. To conduct experiments and test an intelligent-geometric approach, we use mathematical models of vehicle's dynamics and onboard rotary camera stabilization in the form of transfer functions integrated into a single control system. In accordance with the proposed architecture, the solution to the problem of controlling a UAV group involved in putting out a large-scale fire under uncertainty was simulated in the MATLAB Simulink system.

**Roman Iakovlev**

**Lecture Title:** Approach to Automated Collection of Stones from Agricultural Lands by Means of a Heterogeneous Group of Robotic Systems

**Abstract:** Within the development of robotic agricultural systems aimed at automating production processes, the actual task is to develop an approach to the detection and collection of extraneous objects, which is characterized by a high level of autonomy, a wide working area and the ability to perform tasks in a continuous mode. In this work, an approach to automated collection of stones from the territory of agricultural lands, based on the use of a group of heterogeneous robotic systems (RS), was proposed. Testing of the proposed approach was performed in the virtual environment Gazebo on the example of a simulated area of terrain with irregular topography. The final evaluation of the effectiveness of the proposed solution, averaged over all selected land sectors, was 77.2%. According to the results of the experiment, the proposed solution allows not only successfully perform tasks of stone collection on large agricultural objects in a continuous mode, but also carry out autonomous identification of potential areas where performing the appropriate operations is essential. Such potential areas are identified based on the analysis of the values of NDVI index in the observed area.

**Valeriia Lebedeva, Roman Iakovlev, Vitaliy Bryksin, and Vadim Agafonov**

**Lecture Title:** Method for Planning a Coverage Trajectory for a Group of UAVs Marking out Zones for Installing Seismic Modules

**Abstract:** Today, the task of planning the trajectory of covering the area with a group of unmanned aerial vehicles (UAVs) remains relevant. This paper presents a method for planning the coverage trajectory when a group of UAVs performs aerial monitoring of the terrain in order to mark out the zones for installing seismic modules. The developed method allows solving the problem of constructing high-precision three-dimensional maps of vast territories by a group of UAVs due to the effective distribution of group agents over various parts of the global trajectory of terrain coverage. The proposed solution not only takes into account the current parameters of the UAV, the distance to the segments of the covering trajectories, but also ensures the minimization of the total time of the aerial monitoring mission. According to the results of experiments, using the proposed method, the average error in reconstructing maps of simulated areas using the ADNN metric was 13.01 cm. In the future, the proposed solution can be modified by introducing new algorithms for the decomposition of the global coverage trajectory, as well as methods for smoothing the covering trajectories.

**Marina Orda-Zhigulina, Eduard Melnik, and Sergey Kapustyan**

**Lecture Title:** Simulation Program Model of Mobile Robots Groups for Multi-Robotic Complex

**Abstract:** This paper describes a model of a multi-robotic complex which is based on a previously developed method of robustly stable motion control of a group of mobile robots (MR) with a leader in solving monitoring problems by multi-robotic systems (MRS) in the presence of an indefinite, limited time delay in the communication channels of the MR-leader with group of MRs arising from the exchange of information through a distributed data registry. MR complex is a group of robots of various types and numbers. Any robot could carry various types of smart sensors. The effectiveness of the proposed model is achieved by a control system, the multidimensional digital control device with sufficiently high order. Algorithms for calculating the values of control actions are obtained using decomposing control and the method of analytical synthesis of systems with control by output and actions. It was achieved the property of robustness to deviations of uncertain delays in the communication channels of each MR by using the property of the previously proposed polynomial control equations. There were testing the performance and effectiveness of the proposed approach by the help of the simulation software model for the functioning of MR groups as MatLab numerical experiments.

## Session 3

**Artem Apurin, Liaisan Safarova, Alexandra Dobrokvashina, Bulat Abbyasov, Tatyana Tsoy, Edgar A. Martínez-García, and Evgeni Magid**

**Lecture Title:** LIRS-ArtBul: Design, Modelling and Construction of an Omnidirectional Chassis for a Modular Multipurpose Robotic Platform

**Abstract:** Service robotics is a promising area of commercializing robotic solutions of various kinds, from education and medical services to entertainment and advertisement. It might be useful to construct a series of different specialized service robots that have a modular construction and share the same chassis. Such approach allows to reuse encapsulated locomotion libraries instead of their development from scratch for each model of a robot and easily add or replace particular robot modules depending on a target task or an operational environment. This paper provides a tutorial on developing an omnidirectional mecanum wheeled chassis for a modular multipurpose robotic platform. We describe a chassis design, modelling in Blender, selection of components, assembly process and basic locomotion software development. We used Gazebo simulator for robot behaviour emulation due to its support of the Robot Operating System (ROS). For control Raspberry PI 4 and Arduino Mega2560 modules were employed. The chassis model behavior was validated in virtual environments of Gazebo and, after assembling, in real world locomotion scenarios. The chassis will be further employed in development of several new in-house mobile platforms, which could serve for particular purposes within the service robotics field.

**Kirill Muravyev and Konstantin Yakovlev**

**Lecture Title:** Evaluation of RGB-D SLAM in Large Indoor Environments

**Abstract:** Simultaneous localization and mapping (SLAM) is one of the key components of a control system that aims to ensure autonomous navigation of a mobile robot in unknown environments. In a variety of practical cases a robot might need to travel long distances in order to accomplish its mission. This requires long-term work of SLAM methods and building large maps. Consequently the computational burden (including high memory consumption for map storage) becomes a bottleneck. Indeed, state-of-the-art SLAM algorithms include specific techniques and optimizations to tackle this challenge, still their performance in long-term scenarios needs proper assessment. To this end, we perform an empirical evaluation of two widespread state-of-the-art RGB-D SLAM methods, suitable for long-term navigation, i.e. RTAB-Map and Voxgraph. We evaluate them in a large simulated indoor environment, consisting of corridors and halls, while varying the odometer noise for a more realistic setup. We provide both qualitative and quantitative analysis of both methods uncovering their strengths and weaknesses. We find that both methods build a

high-quality map with low odometry noise but tend to fail with high odometry noise. Voxgraph has lower relative trajectory estimation error and memory consumption than RTAB-Map, while its absolute error is higher.

**Andrey Gorodetsky, Konstantin Mironov, Daniil Pushkarev, and Aleksandr Panov**

**Lecture Title:** Goal and Force Switching Policy for DMP-Based Manipulation

**Abstract:** Effective solving of manipulation tasks is significant for collaborative robots to act within human-oriented environments. It may be executed using classical or learning-based control methods. Classical methods are accurate; however, they require complicated tuning of the regulators. Learning-based control provide obtaining the parameters of the process model while training, but this model is rough. We apply a combined approach to solving manipulation tasks, where the robot moves to the target vicinity under learning-based control and then operates the target under simplified classical control. On the first stage, control system generates reference trajectory for execution using dynamic movement primitives (DMP). The parameters of the DMP are determined by output of a neural network and trained via policy optimization. On the second stage the forcing term of the DMP is set to zero, while goal is defined by the simplified predictive control model. We evaluate our approach on the tasks of reaching target point by end effector and pushing elevator button with UR5 collaborative manipulator. Evaluation is made in Isaac and URSim simulation taking in mind dynamics and functionality of the robot. The approach is successfully reproduced on a real robot.

**Dmitry Dobrynin**

**Lecture Title:** Gait Synthesis of a Home Quadruped Robot

**Abstract:** Quadruped robots have high adaptability and high dynamics, which provides excellent maneuverability and adaptability to the environment. Robots have learned to walk on difficult terrain, overcome various obstacles in the form of stairs and bumps. There were walking robots capable of running like animals. Home walking robots have a high appeal because they mimic the behavior of pets. Gait planning is an important component of a walking robot's control system. This article suggests a rules-based approach to gait synthesis. The article presents a robot model and its mathematical model. The robot gait control system is considered. The synthesis of the gait of a home robot is made using elementary foot movements. The calculation of elementary movements is carried out using a kinematic model of the leg. The issues of stability of the robot when walking are considered The article provides examples of various gaits of a home robot - wave gaits, irregular gait and rotation of the robot body in place. The proposed gait construction principle allows you to change the robot's gaits as needed, as well as to build complex models of robot movement. A simulation of the robot's movement using synthesized gaits was carried out.

**Polina Kozyr, Yuliya Vasunina, and Anton Saveliev**

**Lecture Title:** Algorithm for Replacing the Battery of a Robotic Tool Using Servicing Mobile Robots on Inhomogeneous Surfaces

**Abstract:** The paper proposes an algorithm for replacing the battery of a robotic tool (RT) by a group of servicing mobile robots (SMR), which includes: positioning the SMR under the battery compartment of the RT; removal of the discharged and installation of a charged battery. For the positioning of the SMR, data from the LiDAR are used, on the basis of which the RT wheels are clustered and the set of necessary offsets for positioning is determined. Then positioning is carried out according to ArUco markers, images of which the system receives using cameras. After that, according to the data from the MEMS sensor, the platform is leveled in a horizontal plane, when positioning on an inhomogeneous surface. The proposed algorithm was implemented using ROS (Robotic Operating System) and tested in the Gazebo simulator. As a result of the experiments, mobile robots successfully removed and installed a battery, the average battery replacement time based on the developed algorithm on a homogeneous surface was 4 minutes 8 seconds, on a non-uniform surface 6 minutes 4 seconds. The advantage of the developed solution is the completely autonomous replacement of the battery, which reduces the idle time of the RT.

**Olga Gerget, Andrey Kravchenko, Roman Meshcheryakov, Tatiana Lysunets, Rinat Galin, Daniiar Volf, and Mark Mamchenko**

**Lecture Title:** Software Library for KUKA iiwa Robot to Improve the Efficiency of Human-Robot Interaction in Robotic Medical Applications

**Abstract:** The article presents a client-server library for the interaction with the KUKA LBR iiwa collaborative robot via a remote personal computer (PC) in a medical-oriented collaborative robotic system (CRS). An intuitive high-level library implemented in the MathWorks MATLAB software framework includes a server for the KUKA iiwa controller, and a client-based application. The library has more than 30 functions for such operations as calculating forward and inverse kinematics, robot control in Cartesian space, path planning, graphical output, and feedback. The developed software runs on a remote computer connected to the controller of the robot via the TCP/IP protocol. The paper presents the requirements to the software related to the systems and strategies used to control the CRS, and the safety of collaborative human-robot interaction (HRI). The article also presents the description of the technical implementation of the library, its architecture, the scheme of "robot – remote PC" communication, software methods used for interaction with the robot, as well as data flow diagrams (DFDs) for the executable code. As an example of controlling the robot using the developed library, we show the results of a practical experiment: the calculation of the robot's inverse kinematics and the path coordinates on a given trajectory.

## Format of the Conference

Due to measures for prevention of the spread of coronavirus infection on the territory of the China, the 7th International Conference on Interactive Collaborative Robotics (ICR 2022) will be held in a hybrid format: face-to-face participation taking place on the basis of Fuzhou University (Fuzhou, China) and an online video conference. The conference programme with link on video conference is available on the website too: http://icr.nw.ru/2022/documents/ICR-2022_Programme+Abstracts.pdf.

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/82923942530?pwd=RDlSdk8vc3doendlcU8rWXFISEU0UT09.

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

# Contacts

## E-mail

conf@spcras.ru

icr2022@gaitech.net

## Web site

http://icr.nw.ru

https://icr2022.gaitech.net/