WELCOME

from the MMAR 2023 Organizing Committee

I would like to invite you to Międzyzdroje, Poland for the 27th International Conference on Methods and Models in Automation and Robotics. Almost 100 draft papers have been submitted, from which the International Program Committee, chaired by Professor Andrzej Bartoszewicz, has selected 85 papers for presentation. As before also this year Conference is organized under the auspices of the IEEE Robotics & Automation Society and the IEEE Control Systems Society. And as usual it is technically co-sponsored by the Committee on Automatic Control and Robotics of the Polish Academy of Sciences and the Polish Society for Measurement, Automatic Control and Robotics.

The Conference starts on Tuesday afternoon, 22 August 2023. Three distinguished scientists will present their lectures in plenary sessions, all other papers will be presented in two parallel regular sessions, some of them in an on-line form. 8 papers are to be presented in special sessions organized by the Polish Chapter of the IEEE Robotics & Automation Society to present research results of its members. 18 papers will be presented in two poster sessions. Moreover, all the MMAR 2023 papers will be submitted for publishing in the IEEE Xplore Digital Library.

I hope that our conference will give the participants an opportunity to present the progress of their research work and to discuss related problems of current and mutual interest. I also hope that the conference social program – including the conference banquet and the touristic program – will guarantee you unforgettable time in Międzyzdroje.

I wish you a pleasant stay in Międzyzdroje and many fruitful meetings and discussions.

Prof. Zbigniew Emirsajłow

Chairman of the MMAR 2023 Organizing Committee

Faculty of Electrical Engineering

West Pomeranian University of Technology, Szczecin

Contents

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## During the Conference

Amber Baltic Hotel

Promenada Gwiazd 1

PL-72-500 Międzyzdroje, Poland

Phone: (+48 91) 328 1000

## WWW SITE

The Final Program

of the MMAR 2023 Conference

can also be found on the Internet at:

http://www.mmar.edu.pl

## CONFERENCE PROCEEDINGS

The Conference Proceedings will be submitted for inclusion in the IEEE *Xplore* Digital Library at

http://ieeexplore.ieee.org

The Conference Proceedings are also attached to this booklet on USB pendrive.

INTERNATIONAL PROGRAM COMMITTEE

We would like to thank the program committee members for contributing to the success of MMAR 2023 and their efforts in coordinating the review process.

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We would like to thank the following individuals for their efforts in the review process of MMAR 2023.

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## OBJECTIVES

The objective of the Conference is to bring together scientists and engineers to present and discuss recent developments in automation and robotics, to access the current status of research and technology, and to focus on future prospects and possible new directions in this active area of science.

This Conference is the 27th in a series which started in 1994.

## VENUE AND DATES

The Conference will be held at the Amber Baltic Hotel in Międzyzdroje, from Tuesday, 22 August till Friday, 25 August 2023.

The Conference registration desk in Amber Baltic Hotel will be opened on the Tuesday morning, 22 August and during each day of the Conference.

The Conference will start on Tuesday, 22 August at 3:00 p.m.

## PRESENTATION FACILITIES

The conference will be held in a hybrid format. Authors of the accepted papers will present their work online or directly at the venue. Participation in the discussion will also be possible in either one of these attendance methods. Video streams for all ongoing presentations will be accessible through the “Microsoft Teams” application.

Each conference room will be supplied with a projector, laptop, remote control for switching slides, laser pointer, whiteboard (or equivalent surface for writing).

Computers will be provided with: Adobe Reader DC, Microsoft Powerpoint Reader and Word Reader, K-lite codec pack for multimedia support.

Time allotted for presentation of papers is about 20 minutes (inclusive of discussion time).

The language of the Conference will be English.

TIME TABLE

Tuesday, 22nd August, 2023

| | **Room 1**<br>**Marco Polo** | **Room 2**<br>**Vasco da Gama** |
|---|---|---|
| 11.00 | Registration opens<br>(Amber hotel main hall) | |
| 15.00 – 15.30 | Conference Opening | |
| 15.30 – 16.30 | Plenary Lecture (Marco Polo), Chair: Tadeusz Kaczorek<br>**Learning action and interaction**<br>Speaker: **Danica Kragic Jensfelt** | |
| 16.40 – 18.00 | A2L-A<br>**Control & Systems Theory I**<br>Chair: Harald Aschemann<br>6005, 6008, 6009, 6101 | A2L-B<br>**Robotics I**<br>Chair: Przemysław Herman<br>6022, 6042, 6028 |
| 19.00 | Welcome Party<br>(Amber Baltic Hotel, On Deck Restaurant) | |

Wednesday, 23rd August, 2023

| | **Room 1**<br>**Marco Polo** | **Room 2**<br>**Vasco da Gama** |
|---|---|---|
| 9.00 – 10.00 | Plenary Lecture (Marco Polo), Chair: Andrzej Bartoszewicz<br>**The curse of linearity and time-invariance**<br>Speaker: **Alessandro Astolfi** | |
| 10.10 – 11.10 | B2L-A<br>**Modelling & Simulation I**<br>Chair: Paweł Majewski<br>6068, 6036, 6026 | B2L-B<br>**Robotics II**<br>Chair: Dariusz Pazderski<br>6091, 6016, 6019 |
| 10.10 – 13.00 | B3P-C<br>**Poster Session I** (Poster area)<br>Chair: Krzysztof Okarma<br>6003, 6010, 6021, 6035, 6039, 6071, 6078, 6097, 6099 | |
| 11.10 – 11.40 | Coffee break | |
| 11.40 – 13.00 | B4L-A<br>**Control Applications I**<br>Chair: Eero Immonen<br>6087, 6020, 6047, 6082 | B4L-B<br>**Control & Systems Theory II**<br>Chair: Artur Babiarz<br>6088, 6098, 6077, 6050 |
| 13.00 – 15.00 | Lunch | |
| 15.00 – 16.40 | B5L-A<br>**Control Applications II**<br>Chair: Andreas Rauh<br>6014, 6033, 6060, 6062, 6076 | B5L-B<br>**Robotics III**<br>Chair: Bernd Finkemeyer<br>6018, 6023, 6065, 6070, 6072 |
| 19.30 | **Conference Banquet**<br>(Amber Baltic Hotel, Christoper Columbus Hall) | |

Thursday, 24th August, 2023

| | **Room 1**<br>**Marco Polo** | **Room 2**<br>**Vasco da Gama** |
|---|---|---|
| 9.00 – 10.00 | Plenary Lecture (Marco Polo), Chair: Józef Korbicz<br>**Modern IoT onboarding platforms for advanced applications: an introduction to KIS.ME**<br>Speaker: **Marcin Witczak** | |
| 10.10 – 11.10 | C2L-A<br>**Intelligent Systems & Methods I**<br>Chair: Marcin Witczak<br>6054, 6100, 6102 | C2L-B<br>**Signal Processing**<br>Chair: Maciej Rosół<br>6094, 6096, 6085 |
| 10.10 – 13.00 | C3P-C<br>**Poster Session II** (Poster area)<br>Chair: Ewa Pawłuszewicz<br>6004, 6031, 6040, 6045, 6049, 6063, 6073, 6079, 6081 | |
| 11.10 – 11.40 | Coffee break | |
| 11.40 – 13.00 | C4L-A<br>**Control & Systems Theory III**<br>Chair: Krzysztof Oprzędkiewicz<br>6041, 6074, 6037, 6083 | C4L-B<br>**Special Session on Research Results of the PC-IEEE-RAS Members I**<br>Chair: Dominik Belter<br>6095, 6055, 6066, 6064 |
| 13.00 – 15.00 | Lunch (Amber hotel) | |
| 15.00 – 16.40 | C5L-A<br>**Modelling & Simulation II**<br>Chair: Rafał Stanisławski<br>6007, 6017, 6048, 6058 | C5L-B<br>**Robotics IV**<br>Chair: Paweł Skruch<br>6024, 6027, 6044, 6046 |
| 18.00 | Touristic programme<br>(Tourist cruise, Międzyzdroje, end of the pier) | |

Friday, 25th August, 2023

| | **Room 1**<br>**Marco Polo** | **Room 2**<br>**Vasco da Gama** |
|---|---|---|
| 10.00 – 11.00 | D1L-A<br>**Modelling & Simulation III**<br>Chair: Paweł Latosiński<br>6061, 6069, 6080 | D1L-B<br>**Robotics V**<br>Chair: Janusz Szpytko<br>6053, 6056, 6103 |
| 11.00 – 11.30 | Coffee break | |
| 11.30 – 12.50 | D2L-A<br>**Intelligent Systems & Methods II**<br>Chair: Aleksandra Kawala-Sterniuk<br>6043, 6089, 6090, 6092 | D2L-B<br>**Special Session on Research Results of the PC-IEEE-RAS Members II**<br>Chair: Maciej Michałek<br>6030, 6038, 6084, 6059 |
| 13.00 – 13.15 | Conference Program Committee Meeting (Young Author Prize Contest) | |
| 13.15 | The Young Author Award Ceremony and Farewell Lunch | |

TECHNICAL PROGRAM

Tuesday

August 22, 2023

Day: Tuesday, August 22nd, 2023

**Time: 15:00 – 16:30**

**Room: Marco Polo**

Plenary Sesion, P-1

**Day: Tuesday, August 22nd, 2023**

**Time: 15:30 – 16:30**

**Room: Marco Polo**

**Chair: Tadeusz Kaczorek**

**Author: Danica Kragic Jensfelt (Royal Institute of Technology, Sweden)**

**Paper: Learning action and interaction**

**Day:** **Tuesday, August 22nd, 2023**

**Time:** **16:40 - 18:00**

**Room:** **Marco Polo**

**Chair:** **Harald Aschemann**

Paper: **6005** **A2L-A**

## A new approach to the analysis of linear continuous-time systems

**Tadeusz Kaczorek**

*Faculty of Electrical Engineering Bialystok University of Technology*
*Bialystok, Poland*
*email: t.kaczorek@pb.edu.pl*

New approaches to the transformations of the uncontrollable and unobservable pairs of matrices of linear systems to their canonical forms are proposed. It is shown that the uncontrollable pair (A, B) and unobservable pair (A, C) of linear systems can be transform to their controllable ($\bar{A}$, $\bar{B}$) and observable ($\hat{A}, \hat{B}$) canonical forms by suitable choice of nonsingular matrix M satisfying the condition $[A\ B]M = [\hat{A}\ \hat{B}]$.

Paper: **6008** **A2L-A**

## Modeling of Thermal Processes in Microcontroller System by Fractional Order, Discrete, Hybrid Transfer Function Using FOBD Approximation

**Krzysztof Oprzedkiewicz, Maciej Rosol, Wojciech Mitkowski**

*Dept of Aut. Control and Robotics AGH University Krakow, Poland*
*e-mail: kop@agh.edu.pl, mr@agh.edu.pl, wojciech.mitkowski@agh.edu.pl*

The paper is devoted to the problem of modeling of thermal processes in microcontroller evaluation board. The proposed model describes temperature of critical places in the working microcontroller system. The temperature is measured with the use of the industrial thermal camera. The proposed model is the discrete, hybrid transfer function, containing both Integer Order (IO) and Fractional Order (FO) parts. The FO part is described using Fractional Order Backward Difference (FOBD) method. The step responses of the proposed transfer function are calculated numerically using MATLAB. Results of experiments show that the accuracy of the proposed model in the sense of Mean Square Error (MSE) cost function is satisfying. Such a model has not be known yet. It can be applied e.g. to predict of overheating of microcotroller systems.

## Modeling of Thermal Processes in in Microcontroller System by Fractional Order, Discrete, Hybrid Transfer Function Using CFE Approximation

**Krzysztof Oprzedkiewicz, Maciej Rosol, Wojciech Mitkowski**

*Dept of Aut. Control and Robotics AGH University Krakow, Poland*
*e-mail: kop@agh.edu.pl, mr@agh.edu.pl, wojciech.mitkowski@agh.edu.pl*

In the paper the problem of modeling of thermal processes in microcontroller system is addressed. The proposed model describes temperature of critical elements in the working development board of STM32 family. The temperature is measured using the industrial thermal camera. The proposed model is the discrete, hybrid transfer function, containing both Integer Order (IO) and Fractional Order (FO) parts. The FO part is described using Continuous Fraction Expansion (CFE) approximation. The step responses of the proposed transfer function are computed numerically using MATLAB. Results of experiments show that the accuracy of the proposed model in the sense of Mean Square Error (MSE)cost function is satisfying. Such a model has not be presented yet. It can be employed to predict of overheating of microcontroller systems or other integrated circuits.



## A Note on Transfer-Type Function for Nonlinear Fractional Order Difference System

**Ewa Pawluszewicz**

*Faculty of Mechanical Engineering Białystok University of Technology*
*Wiejska 45 C, Białystok 15-351, Poland*

Using the polynomial description related to differentials of inputs and outputs in a h-difference field of meromorphic functions embedded in its quotient field a concept of a transfer function to nonlinear fractional order system with Grünwald-Letnikov h-difference operator is given. To different approaches to defining of this function are discussed. In contrast to the classical case, the transfer function is defined independently of the initial conditions.

**Day:** **Tuesday, August 22nd, 2023**

**Time:** **16:40 - 18:00**

**Room:** **Vasco da Gama**

**Chair:** **Przemysław Herman**

Paper: **6022** **A2L-B**

## Multiple Agent Path Planning for Autonomous Area Monitoring

**David Lindgren**

*The Swedish Defence Research Agency, Linköping, Sweden*
*email: david.lindgren@foi.se*

This paper considers informative path planning for two collaborative autonomous agents tasked with monitoring an area against intruders. The area is decomposed into discrete cells that hold the intruder probability distribution and also form the a priori known map over which the agent moves. A computationally efficient intruder model is proposed and the optimal path is formulated in terms of detection probability. A control strategy based on the suboptimal but computationally feasible receding horizon optimization technique is described. The planning is tested in MATLAB on two experimental maps with 108 and 811 cells, respectively. It is concluded that the agents perform rationally and that two agents may almost half the search time compared to a single agent. Real-time performance on ordinary hardware with dedicated software is deemed feasible.

Paper: **6042** **A2L-B**

## Intuitive Robot Path Planning Through Augmented Reality

**Mohammad-Ehsan Matour, Alexander Winkler**

*Department of Automation Hochschule Mittweida, UAS Mittweida, Germany*
*e-mail: matour@hs-mittweida.de, alexander.winkler@hs-mittweida.de*

In this paper, an approach for intuitive path planning of a collaborative robot based on augmented reality is presented. For this purpose, a user interface is developed that offers practical functions to the operator for full motion control over a robot manipulator. A mixed reality head-mounted display acts as an interface for the operator by displaying virtual content that allows interaction with the robotic system. Besides providing information about the state of the robot, including joint position, velocity, and the force exerted on the robot flange, the gripping force can be adjusted during gripping operations, and motion commands can also be sent to the robot controller. It includes motion commands in joint and Cartesian space, as well as intuitive path planning of the robot based on waypoints created by the operator. A virtual cursor is incorporated into the virtual robot model, with its position and orientation aligned to that of the tool center point of the real robot. The novelty of this

work lies on the one hand, in an extensive interface and, on the other hand, in the robot path planning that takes into account the orientation provided by a virtual pointer.

Paper: **6028** **A2L-B**

## A Geometric Measurement System Using a Robot as Handling System and Reference System

**Kevin Blümel*, Marco Gerlach*, Alexander Winkler **, Christian Thormann***

** Professorship Digital Manufacturing and Quality Monitoring Hochschule Mittweida, University of Applied Sciences Mittweida, Germany*
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*** Professorship Factory Automation Hochschule Mittweida, University of Applied Sciences Mittweida, Germany*
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Collaborating robots are used at production processes to interact with workers and they don't need separation by protective devices. These robots could be used for in-place geometric measurements through some adjustments. This paper deals with the advantages of highly accurate geometric measurements using a cobot, steps of adjustments are described and some first startup measurements are presented.

**A2L-B**

## A New Approach to the Coordination of Autonomous Service Robot Teams

**Andrzej M.J. Skulimowski***

*AGH University of Science and Technology, Department of Decision Sciences and Progress & Business Foundation*
*Kraków, Poland*
*e-mail: ams@agh.edu.pl*

This paper presents a new approach to autonomous robot team coordination based on the multicriteria decision theory. We refer also to multi-level optimization, anticipatory networks, and Stackelberg games with multiple followers. Team coordination is studied in the context of multi-robot task assignment (MRTA) and multiple path planning problems. The key notion in our approach is the virtual formation which may be based on task-precedence relations linking robots considered as a team. In bi-level multicriteria optimization problems that model the MRTA, higher level criteria refer to the overall team performance, while at the lower level each robot optimizes its individual criteria such as energy consumption or damage avoidance. This problem was solved with a heuristic anytime combinatorial nondominated subset selection algorithm combined with the reference-set-based preference modelling. Our approach was applied to design the activity of an anticipatory fruit harvesting robot team which has been developed within a recent research project.

TECHNICAL PROGRAM

Wednesday

August 23, 2023

Day: Wednesday, August 23rd, 2023

**Time: 9:00 – 10:00**

**Room: Marco Polo**

Plenary Sesion, P-2

**Day: Wednesday, August 23rd, 2023**

**Time: 9:00 – 10:00**

**Room: Marco Polo**

**Chair: Andrzej Bartoszewicz**

**Author: Alessandro Astolfi (Imperial College London, UK)**

**Paper: The curse of linearity and time-invariance**

**Day:** **Wednesday, August 23rd, 2023**

**Time:** **10:10 - 11:10**

**Room:** **Marco Polo**

**Chair:** **Paweł Majewski**

Paper: **6068** **B2L-A**

## Online Identification of the Open-Circuit Voltage Characteristic of Lithium-Ion Batteries with a Contractor-Based Procedure

**Marit Lahme, Andreas Rauh**

*Department of Computing Science*
*Distributed Control in Interconnected Systems Carl von Ossietzky Universität Oldenburg*
*Oldenburg, Germany*
*email: Marit.Lahme@uni-oldenburg.de, Andreas.Rauh@uni-oldenburg.de*

An accurate estimation of the dynamic behavior of Lithium-ion batteries is important for a lot of applications, for example, in battery management systems to efficiently and safely charge and discharge the battery cells. The dynamic behavior of Lithium-ion batteries is influenced by aging and temperature effects. In order to precisely estimate the dynamic behavior, these effects have to be considered. This is possible for example with a set-valued online identification approach, combining an interval state estimation with the identification of state-dependent characteristics. A drawback of this approach is, that the estimation uncertainty increases over time, so that the identification accuracy is limited. In this paper, we investigate if a contractor-based procedure can be used to reduce the estimation uncertainty. The contractor-based procedure was successfully integrated into the set-valued identification approach and leads to a significant improvement of the identification result. The extended identification approach is evaluated with a numerical simulation.

Paper: **6036** **B2L-A**

## Generalized Gaussian Distribution with Augmented Pure Quaternion Random Variable

**Robert Krupiński**

*Department of Signal Processing and Multimedia Engineering*
*West Pomeranian University of Technology, Szczecin*
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Quaternion random signals can be analyzed using augmented second-order statistics. If these signals are treated as the augmented quaternion valued random variables, then they can be modeled with the

quaternion generalized Gaussian probability density function. In the case of pure quaternions, this probability density function becomes a limiting case. Therefore, for this case, this article introduces the dedicated generalized Gaussian distribution of an augmented quaternion random variable for pure quaternions.

Paper: **6026** **B2L-A**

## Efficient Combined Physical and Neural Network Modeling and Simulation Using the Functional Mock-Up Interface

**Simon Olma, Seyedehsomayeh Hosseini, Thorben Menne**

*IAV GmbH Berlin, Germany*
*e-mail: {simon.olma, seyedehsomayeh.hosseini, thorben.menne}@ iav.de*

This paper presents efficient methods in the context of modeling, optimization and simulation of Neural Networks (NNs) embedded in Functional Mock-up Units (FMUs). Machine learning models like NNs are widely used in many applications such as control, prediction and decision making. Their integration into simulation environments, that are for example used in the control engineering community, is still a challenging task. With the Functional Mock-up Interface (FMI), a standardized modeling format for dynamic models exists, which can be used to integrate NNs from popular deep learning frameworks into such simulation environments. In this paper, we present a method to integrate NNs into FMUs and show how to combine NN-based and physical simulation models in a single FMU. The proposed methods are validated with several application examples and the results emphasize its effectiveness when used within the model-based design process for a wide range of dynamic models.

**Day:** **Wednesday, August 23rd, 2023**

**Time:** **10:10 - 11:10**

**Room:** **Vasco da Gama**

**Chair:** **Dariusz Pazderski**

Paper: **6091** **B2L-B**

## Leader Following Control of Non-Holonomic Mobile Robots Using EKF-Based Localization

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This paper presents a leader-follower controller combined with localization based on sensor data fusion. The leader robot has a cuboidal shape 3D printed tower on its top. ArUco markers with four different IDs are installed on the leader robot's cuboidal tower. The follower robot has a one-degree of freedom rotating platform with having Intel RealSense Sensor on it. IMU sensors are installed on both the leader and follower robots. The data from wheel encoders and IMU sensors are fused by Extended Kalman Filter (EKF) to get the pose of robots. The proportional-integral-derivative (PID) controller rotates the Intel RealSense sensor on the follower robot to follow the ArUco markers on the leader robot. The follower robot calculates the pose of the leader robot after the detection of ArUco markers. Experiments are performed to validate the algorithm presented in the paper. Robot operating systems (ROS) is installed on both the robot's single-board computers. The Opti-Track system is used to validate and plot the data fusion of robot poses.

Paper: **6016** **B2L-B**

## Building Safer Robots: From Simulation to Hardware Deployment

**Mirgita Frasheri*, Gill Lumer-Klabbers*, Jakob Levisen Kvistgaard*, Jacob Odgaard Hausted*, Casper Thule**, Lukas Esterle*, Peter Gorm Larsen***

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Robots represent a pervasive technology foreseen to have an integral role in our societies, across different domains, from elderly care to agricultural solutions. Therefore, it is crucial that their

behaviour is thoroughly tested, to provide guarantees as to their intended safe operation around humans, other robots, equipment, and environment. Such testing should be performed throughout the different development stages, and is associated with several challenges that relate to cost, time, and resource management. In this paper, we address these issues by proposing a Digital Twin (DT) enabled approach that can be used in various development stages of robots, from pure simulation, to gradual introduction of hardware, to a complete robot with its DT. Additionally, it is possible to apply fault-injection at the interface level of the components on the DT side, while maintaining a best effort real-time communication between the former and the coupled hardware. We showcase the utility of the proposed approach through three proof of concept scenarios for a safety monitoring component of the system, with simulated faults at the component level, and on the data coming to the digital twin.

Paper: **6019** **B2L-B**

## MyoBit: A Public Dataset Based on an Armband with 16 sEMG Channels for Gesture Recognition Under Non-Ideal Conditions

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The robustness of surface electromyography (sEMG)-based gesture recognition in practical applications has received much attention due to the influence of external non-ideal factors. Unlike most existing sEMG-based gesture recognition datasets that use sparse or high-density resolution instruments for data acquisition under ideal conditions, this paper proposes a sEMG armband (Bitwave) with semi-dense resolution that records 7 gestures from 24 subjects (12 male, 12 female) under 9 non-ideal conditions as a public dataset (MyoBit). The results demonstrate that Bitwave has a high signal-to-noise ratio and repeatability, the MyoBit is able to achieve a high accuracy of gesture recognition by classical classifiers. Furthermore, two methods for dataset augmentation (increasing resolution, expanding rotation data) have been proposed for researchers.

**Day:** **Wednesday, August 23rd, 2023**

**Time:** **10:10 - 13:00**

**Room:** **Poster Area**

**Chair:** **Krzysztof Okarma**

Paper: **6003** **B3P-C**

## Controlling Intelligent Agents: Virtual to Real Task Environment Transformations

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In robotics, fixed-base arms face challenges in manipulating and grasping objects. Mapping the task environment to the robot's coordinates is crucial for automation. We develop an anchor point detection algorithm for robot arm calibration. We use computer vision to perceive the task environment and propose 2D linear transformation and rotation to map it to the physical world. Our experiment shows that 2D transformations with a rotation matrix improve pick-and-place automation as compared to translation-only approach.

Paper: **6010** **B3P-C**

## An Autonomous Navigation Approach Based on Bird's-Eye View Semantic Maps

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With the continuous expansion of the use of mobile robots, providing them with autonomous navigation capabilities for different environments has become a very active research topic. In most cases, navigation systems are built around sensors like LiDAR which are expensive, not only due to the sensor cost but also to the computational power required for the processing of Point-Clouds. To provide an alternative to such systems, we propose a navigation approach that only requires a front-facing RGB Camera. In this system, every image is processed online using a semantic segmentation

model to build a Bird's-Eye view semantic map, from which a local path and the corresponding motion commands can be calculated. Our method is evaluated first in simulation and later on, in a real mobile robot. The results show that our system enables the robot's successful navigation and collision avoidance through simulated and real indoor and outdoor environments.

Paper: **6021** **B3P-C**

## Agriculture Rotary Tedder Fault Diagnosis Based on Evolutionary Convolutional Neural Network with Genetic Algorithm Optimization

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Since the mechanization of agriculture, agriculture itself inherited the same problems, as an industry has: the necessity of machines maintenance and machines failures which causes downtime and may make unanticipated costs. To counteract such problems, we propose a method of monitoring agricultural rotary machinery, which should allow to predict when the machine would break down, and to plan repair time in advance, to eliminate downtime to minimum. Our approach utilizes machines' vibration signal, which after being turned into a spectrogram, is fed as input data to the convolutional neural network (CNN). The convolutional part of a neural network is the feature extractor, and the dense part is the feature selector and classifier. Since machines are usually not created equal, CNNs architecture is permanently defined, but rather is adjusted to the machine's and system's needs by using the genetic algorithm (GA), which adds an additional layer of flexibility. Experimental results showed, that our approach was able to reach 99.7% of classification accuracy.

Paper: **6035** **B3P-C**

## Comparison of Decision Support Models -- a Recruitment Case Study as a Multiclass Classification Problem with Limited Data

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We present a comparative case study of machine learning models, evaluating their efficiency in a practical task of multiclass classification of samples being submissions to a recruitment survey and assigning them scores denoting the match level for a given candidate to a given workgroup (committee) in the AGH Students' Council. This research is based on the Council's recruitment applications that carried candidates' responses to a set of 10 hypothetical Council member activity scenarios, where they were to choose one of four given solutions to the problems.

## Deterministic Framework Based Structured Learning for Quadrotors

**Rupam Singh*, Jan Steinbrener**, Stephan Weiss****

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The design of a continuous learning controller for quadrotors often entails some specific implementations that require significant system knowledge and are prone to experience catastrophic forgetting. To address these challenges, a deterministic approach is trained with a quadrotor on relatively small amounts of automatically generated data. The twin delayed deep deterministic policy gradient (TD3) algorithm is utilized to develop the policy for learning the maneuver of a quadrotor and control it alongside the low-level controller. This algorithm is capable of effectively handling large state spaces and continuous actions and incorporates clipped double Q-learning, target policy smoothing, and delayed policy updates for efficient training. The performance of the proposed control approach is assessed through numerical simulations carried out on a quadrotor under normal and wind operating conditions. The results identified that learning with TD3 reduced the overestimation bias, improved the convergence accuracy, and achieved efficient maneuver with less tracking error by using the dense reward structure.



## Interpretable Deep Learning Approach for Classification of Breast Cancer - A Comparative Analysis of Multiple Instance Learning Models

**Jakub Buler*, Rafał Buler*, Maciej Bobowicz**, Maria Ferlin*, Marlena Rygusik**, Arkadiusz Kwasigroch*, Michał Grochowski***

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Synthesis a Deep Learning-based system for automated breast cancer diagnosis is not easy due to the lack of annotated data, especially at pixel level, the large size of the images and class imbalance, a wide diversity of cancerous lesions, a variety of breasts, both in size and density, make the training of the neural models challenging. Moreover, clinicians are often concerned about using black-box models because of the lack of transparency in their inference. To address these issues, we propose Multiple Instance Learning system, supported by attention mechanisms. We researched AMIL, GAMIL, DSMIL and CLAM models trained in a weakly-supervised manner and compared them with a common model in image classification tasks, ResNet18. Described approach is multimodal and combines two mammographic projections in the training process. Developed neural system achieved high classification efficiency. Exploiting the generated attentional maps allowed the localisation of

cancerous lesions, thus increasing the interpretability of the algorithm. Thanks to this mechanism, we were also able to detect artifacts in the database, difficult to spot but drastically skewing the algorithm's performance.

Paper: **6078** **B3P-C**

## Comparison of Artificial Neural Network Adaptive Control Techniques for a Nonlinear System with Delay

**Bartłomiej Guś, Jakub Możaryn**

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This research paper compares two neural-network-based adaptive controllers, namely the Hybrid Deep Learning Neural Network Controller (HDLNNC) and the Adaptive Model Predictive Control with Nonlinear Prediction and Linearization along the Predicted Trajectory (AMPC-NPLPT), for controlling a nonlinear object with delay. Specifically, the study investigates the effect of delay on the accuracy of the two controllers. The experimental results demonstrate that the AMPC-NPLPT approach outperforms HDLNNC regarding control accuracy for the given nonlinear object control problem.

Paper: **6097** **B3P-C**

## Detection-Segmentation Convolutional Neural Network for Autonomous Vehicle Perception

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Object detection and segmentation are two core modules of an autonomous vehicle perception system. Currently, the most algorithms are based on deep neural networks, which guarantee high efficiency but are computationally complex. This issue can be addressed by using an appropriate: architecture, representation (reduced numerical precision, quantization, pruning), and computing platform. In this paper, we focus on the first factor - the use of so-called detection-segmentation networks. We considered the task of segmenting the drivable area and road markings in combination with the detection of selected objects (pedestrians, traffic lights, and obstacles). We compared the performance of three different architectures: MultiTask V3, HybridNets, and YOLOP. We conducted the experiments on a custom dataset consisting of approximately 500 images of the drivable area and lane markings, and 250 images of detected objects. MultiTask V3 proved to be the best architecture, achieving 99% mAP_50 for detection, 97% MIoU for drivable area segmentation, and 91% MIoU for lane segmentation, as well as 124 fps on the RTX 3060 GPU. This makes it a good solution for embedded perception systems.

# Using AI for Healthcare Management – Vinci Medicine Solution

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Vinci Medicine is a comprehensive healthcare system that combines mobile technology and machine learning to provide efficient medical advice and services. The system consists of a mobile application, an administrative panel, a machine learning module, and a database. The mobile application allows users to input their symptoms, which are analyzed by the machine learning module to provide accurate medical advice. The administrative panel enables staff members to manage appointments and doctor schedules, improving the efficiency of the healthcare facility. The machine learning module provides preliminary diagnoses and suggests tests and examinations, enhancing the accuracy and efficiency of medical services. The system's database stores user data and medical information, providing a secure and accessible repository for medical records. With user experience in mind, the system offers an intuitive and easy-to-use interface. The system offers convenient access to medical advice and services from mobile devices, improving accessibility to healthcare.

**Day:** **Wednesday, August 23rd, 2023**

**Time:** **11:40 - 13:00**

**Room:** **Marco Polo**

**Chair:** **Eero Immonen**

Paper: **6087** **B4L-A**

## Learning-Based Predictive Control Using a Hybrid Model with Adaptive Domain of Validity

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The model quality is a key factor for any model predictive control (MPC) scheme to achieve the desired performance of the system while satisfying the constraints. In order to handle the plant-model mismatch, we augment a mechanistic model with a data-based model trained offline using historical data which compensates the mismatch between the mechanistic model and the plant dynamics. If the prediction accuracy of the nominal model deteriorates due to new modes of operation, the nominal model is augmented with an additive model learned online using a limited amount of data to capture the residual of the offline trained model. As using data-based models can be unreliable outside their training regions, we estimate their domain of validity via a one-class support vector machine (SVM) trained on low-dimensional projections of the training data. The predicted validity of each data-based model is used to weigh its contribution to the overall model. During online application, the performance of the models is monitored and their domains of validity are adapted. We show the advantages of the proposed learning-based MPC (LBMPC) approach via a continuous stirred tank reactor (CSTR) example.

## Observability of an Industrial Heating Process with Diffusion and Transportation

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Analysing observability is an important step in the process of designing a state feedback controller. While for linear systems observability has been widely studied and easy-to-check necessary and sufficient conditions are available, for nonlinear systems, such a general recipe doesn't exist and different kinds of systems require different techniques. In this paper we analyse observability for an industrial heating process, where a stripe-shaped plastic workpiece is moving through a heating zone where it is heated up to a specific temperature by applying hot air to its surface through a nozzle. A modeling approach for this process is briefly presented, yielding a nonlinear ODE-model. Sensitivity-based observability analysis is used to identify unobservable states and make suggestions for additional sensor locations. In practice however, it is not possible to place additional sensors, so the available measurements are used to implement a simple open-loop state estimator with offset compensation and numerical and experimental results are presented.



## Constraints-Aware Trajectory Tracking Control of Spacecraft Attitude Using LPV and MPC

**Alen Turnwald, Niklas Baldauf**

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This paper presents an approach for trajectory tracking of quaternions representing spacecrafts attitude. A nonlinear controller is applied to a time-varying error system to track realizable trajectories of quaternions. The resulting closed loop is linearized leading to a linear parameter varying system (LPV), which is then used to analyze the closed loop and parameterize the nonlinear controller. Additionally, an outerloop controller is applied to achieve objectives beyond closedloop stability. Results demonstrate the effectiveness of the overall controller with two different linear controllers, LQR and MPC, for improving attitude control performance and input constraint satisfaction, respectively.

# Comparative Research of Nonlinear Decoupled Tracking Controller Design for an Open-Frame AUV

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This study presents the design and implementation of two different nonlinear controllers for trajectory tracking control of an open-frame observer type Autonomous Underwater Vehicle (AUV). The AUV's dynamics are modeled using the Newton-Euler formalism, and the state-space representation is obtained. The controller comparison consists of two nonlinear controllers for horizontal motion control in planar coordinates(x,y): Backstepping Control (BS) and Sliding Mode Control (SMC), and a Linear Quadratic Regulator (LQR) for controlling the depth and rotational dynamics. Both controller structures are designed to ensure stability using the Lyapunov stability criteria for trajectory tracking while LQR guarantees stability by placing eigenvalues on the left half plane for depth and rotational dynamics. The system states are decoupled to facilitate control design, and Simulink models are developed to validate the controllers' performance in the presence of sinusoidal disturbance. The results show that both BS and SMC provide robust and accurate tracking performance under sinusoidal disturbances, while LQR exhibits good performance in the remaining coordinates.

**Day:** **Wednesday, August 23rd, 2023**

**Time:** **11:40 - 13:00**

**Room:** **Vasco da Gama**

**Chair:** **Artur Babiarz**

Paper: **6088** **B4L-B**

## Time-Varying Model Predictive Control Based on Dynamics Decomposition and Exponential Data Weighting Approach

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This paper deals with the nonlinear control of under-actuated systems and describes a Time Varying Model Predictive Control (TV-MPC) approach for a class of nonlinear systems in the context of nonlinear control synthesis. The approach comprises the formulation of the TV-MPC which is based on the model structure derived using a novel dynamics decomposition approach. Furthermore, deploying this model structure, the future control trajectory for the response prediction is modelled using a set of orthonormal basis functions- the Laguerre functions. The mathematical details of the proposed TV-MPC algorithm is supported by a simulation example and the results are discussed for two different cases; firstly, using the exponential data weighting technique and then without using the exponential data weighting in the cost function for the time-varying reference tracking problem. The time-varying reference trajectory thus considered is a cubic polynomial type trajectory reference. The results shows that with the addition of prescribed degree of stability through exponential data weighting, an asymptotically stable behaviour of the nonlinear system is guaranteed.

## Set-Valued State Estimation for Uncertain Dynamic Systems with Imprecisely Known Measurement Time Instants

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Set-membership state estimation approaches have been developed in recent years to implement observers that allow for bounding the domains of possible system states in a guaranteed manner. For that purpose, it is necessary to describe the system dynamics either by continuous-time or discrete-time state equations in which uncertainty of parameters and initial conditions as well as the influence of noise are represented by bounded domains. The same holds for the system's output equation, where measurement noise is again assumed to be bounded with measurement time instants that are typically assumed to be perfectly known. This latter assumption is removed in this paper to make the bounded-error state estimation approach applicable to a wide range of systems where measurement time instants are only imprecisely known. This is typically the case for distributed control systems in which sensor and actuator signals are transmitted via a communication network. As such, the wide classes of robotic multi-agent systems as well as distributed energy systems belong to this kind of models.



## Stability Analysis and Stabilization of Discretized Uncertain Spatially Interconnected Systems

**Bartłomiej Sulikowski*, Krzysztof Gałkowski**, Łukasz Hładowski*, Anton Kummert***, Joerg Velten*****

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In this paper spatially interconnected (ladder) systems have been discussed. First, the multidimensional, in that case, 2D - continuous in time and discrete in the spatial variable, has been introduced. Next, the temporal dynamics has been discretized, which has allowed to create the general, discrete model for the system dynamics. It has been assumed that system elements are the subject of uncertainty of the norm bounded form. Finally, robust stability testing and robust stabilizing controller conditions have been proposed and its effectiveness is illustrated by an simulation example.

# Optimal Sliding-Mode Control Using Sensitivity-Based Parameter Optimisation

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This paper introduces a novel technique for optimising tracking controllers for nonlinear systems that is based on iterative feedback tuning (IFT). The IFT algorithm is expanded to apply to both linear and nonlinear systems in state-space form with nonlinear state-feedback control, resulting in the iterative state-feedback tuning method (ISFT). The primary contribution of this approach is the development of first- and second-order sensitivity equations for quadratic cost functions, which are commonly used in control optimisation problems. This proposed method utilises a gradient-based iterative algorithm for adjusting the corresponding controller parameters. The paper concludes by presenting a comparative simulation study for three alternative sliding-mode control approaches for a nonlinear system, which illustrate the effectiveness and the benefits of this new design technique.

**Day:** **Wednesday, August 23rd, 2023**

**Time:** **15:00 - 16:40**

**Room:** **Marco Polo**

**Chair:** **Andreas Rauh**

Paper: **6014** **B5L-A**

## Comparison of Parallel, Cascade and Hybrid Control Structures for Two Rotor Aerodynamical System Using FOPID Controllers

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In the Two Rotor Aerodynamical System the aim of the control is to achieve the azimuth and pitch angles reference values. However, TRAS is a non-linear system in which cross-coupling occurs - each of the two rotors affects both angular values. Therefore, to prepare two control values one should use both angular values for each of them. The obvious solution is a system that uses four controllers. In the article it was decided to use only FOPID and to check the behavior of the system in three different arrangements: parallel, cascade and hybrid. The tests were carried out in the Matlab / Simulink environment. For optimization purposes the Grey Wolf Optimizer algorithm was used, which helped to find coefficients.

Paper: **6033** **B5L-A**

## Decentralized Control of a Water Distribution Network Using Repeated Games

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In this paper, our aim is to design a decentralized control scheme for pumping stations in a water distribution network that supplies drinking water. The considered water distribution network consists of pumping stations, piping networks, and consumers. The pumping stations supply water to consumers and their objective is to ensure the supply of water to the consumers in an optimal way

such that the consumer demand is satisfied with minimum energy consumption by the pumping station itself. This gives rise to a non-zero-sum game as the pumping stations have a common objective of satisfying consumer demand and a selfish objective of minimizing their own energy consumption. A real-life water distribution network with two pumping stations was emulated in a lab and the proposed control scheme was tested on this setup. The consumer demand follows a periodic trend that mimics real-life consumption and has some stochastic noise added to it so as to emulate uncertainty in consumer demand. The proposed control scheme was able to track the reference signal while each pumping station was minimizing its own energy consumption.

Paper: **6060** **B5L-A**

## Development of Simplified Lumbar Spine Mechanism Implemented with Tendon-Driven Motion

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The spine refers to a bony structure with complex characteristics, which provides the foundation for the composition of the spinal cord, in addition to promoting the stability and posture of the human body. The lumbar region of the spine has important characteristics for the investigation of pathological dysfunctions, where the largest abnormalities present in the spine are caused, thus, many researches are carried out in order to explore the understanding of this structure. This paper presents the development and implementation of a controlled and simplified lumbar spine mechanism. The construction occurred through the use of the 3D program Slicer, using tomographic images and STL files, applied to SolidWorks for 3D printing with Ultimaker Cura software. The control action is based on a motion trajectory system realized with conventional, PID-type control. The physical implementation of the motion drive was performed and results show the correct execution of the planned movements, following the references specified for the movement of the structure.

## Nonlinear Control of a Vapor Compression Cycle by Input-Output Linearisation

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This paper proposes an input-output linearisation for the trajectory tracking control of a vapor compression cycle. For this purpose, a physical model-order reduction of an existing high-order system model is performed. Then, the design of a nonlinear feedback control structure exploiting an input-output linearisation is described, which involves the inversion of the system dynamics and the use of a reduced-order condenser submodel for the online reconstruction of unmeasurable states. An analysis of the stability of the internal dynamics is conducted. Here, a region of instability is identified that is dependent on the values of the external dynamics. The boundary of this region is calculated numerically and used for trajectory planning. Both the feedforward controller and the feedback controller are tested w.r.t. trajectory tracking on a high-order simulation model. The simulations show that the achieved performance of the feedforward controller validates the model-order reduction, whereas the feedback controller provides an accurate tracking even in the presence of unknown disturbances.



## Input-Output Linearization of a Thermoelectric Cooler for an Ice Clamping System Using a Dual Extended Kalman Filter

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This paper deals with an input-output linearization for a nonlinear ice clamping system based on Peltier cells used in an innovative manufacturing system. For this model-based design, a third-order state-space model based on physical principles is derived. Unknown states as well as disturbances are estimated by a dual extended Kalman filter. Based on the estimated states and disturbances, an inputoutput linearization of the nonlinear system can be performed, with an asymptotically stable internal dynamics. Accordingly, an accurate tracking control is designed to track a desired cold-side temperature even in the presence of disturbances. Meaningful simulation results are shown that point out the effectiveness of the proposed control approach.

**Day:** **Wednesday, August 23rd, 2023**

**Time:** **15:00 - 16:40**

**Room:** **Vasco da Gama**

**Chair:** **Bernd Finkemeyer**

Paper: **6018** **B5L-B**

## Increasing Robot Precision by Stroke Division

**Jan Baumgärtner*, Alexander Puchta*, Bernd Bertschinger**, Gajanan Kanagalingam***, Oliver Sawodny***, Stephan Reichelt***, Jürgen Fleischer***

** wbk Institute of Production Science, KIT, Germany*
*** Institute of Technical Optics, University of Stuttgart, Germany*
**** Institute for System Dynamics, University of Stuttgart, Germany*

Robots are increasingly performing complex tasks in industrial settings, such as welding, painting, and cutting, but their lower stiffness and repeatability, especially in the cheaper end of the market, limit performance. While previous research aimed to improve robot repeatability by optimizing the pose of the workpiece, these approaches were not feasible for large and complex paths. This paper proposes a novel approach of incorporating a second robot to adjust the workpiece's position during the manufacturing process, thereby forming a single high- precision robotic system. This paper aims to investigate the feasibility of this approach. For this purpose, it presents a path planner to leverage the resulting additional degrees of freedom to achieve greater repeatability. The effectiveness of this planner is then compared to previous approaches.

Paper: **6023** **B5L-B**

## Controlling a Teleoperated Robotic Eye Surgical System Under a Communication Channel's Unknown Time Delay

**Ali Soltani Sharif Abadi*, Andrew Ordys*, Barbara Pierscionek****

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One of the most critical challenges in Robotic Eye Surgery (RES) is the applied force of the surgical instrument of the robot as it penetrates the human eye. Safe surgery requires accurate control of this

force. In a teleoperated eye surgical system, there is likely to be a time delay that can affect the system control. This paper focuses on designing a predefined-time Sliding Mode Control (SMC) method to control a teleoperated robotic eye surgical system under an unknown time delay of the communication channel. The Lyapunov theory is used to prove the system stability. For the master and slave parts, manipulator robots are considered for designing and testing the controller. MATLAB software is used to simulate the controller. The simulation results show the robustness of the controller against the time delay of the communication channel.

Paper: **6065** **B5L-B**

## Towards Surgical Skill Modeling in Cardiac Ablation Using Deep Learning

**Seyedfarzad Famouri, Pedram Fekri, Majid Roshanfar, Javad Dargahi**

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The rising interest in surgical robots and simulations has led to a greater demand for more objective methods of skill evaluation. Traditionally, the performance of novices is evaluated using surgeons' skills through a specific and streamlined ablation task. To this end, an experimental setup was proposed to provide a simulated ablation procedure through a mechanical system. It is equipped with the synthetic heartbeat mechanism of the heart with the capability of measuring the contact forces between a catheter's tip and a force sensor. Using a commercially available catheter for ablation, the task was to maintain the force within a safe range while the tip of the catheter is touching the surface of the sensor. Accomplishing multiple experiments by novices and experts, a deep recurrent neural network was considered to extract the model of skills by solving a binary classification problem. The results of the trained model showed that the proposed pipeline was able to properly distinguish the novices' from experts' maneuvers with 95% accuracy.

Paper: **6070** **B5L-B**

## Artificial Potential Field APF-Based Obstacle Avoidance Technique for Robot Arm Teleoperation

**Mustafa Elahres, Manel Abbes, Aïcha Fonte, Gérard Poisson**

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The use of robotic arms through teleoperation has become increasingly significant in various fields such as medicine, industry, agriculture, and space exploration. However, controlling robot arms through teleoperation can be challenging, particularly in complex and constrained environments where obstacles must be avoided. This is due to the multi-DOF and polyarticulated structure of the robot, making it difficult for human operators to manually perform the obstacle avoidance subtask. In this study, we propose a technique to integrate an artificial potential field (APF) motion planner into a teleoperation control scheme for a polyarticulated robot in a constrained environment. This technique was successfully tested with a UR3e robot in a laboratory, where the aim was to manipulate

an ultrasound probe on a patient in a constrained environment. The results showed success in combining obstacle avoidance with teleoperation. The next step is to test this technique in a clinical environment.

Paper: **6072** **B5L-B**

## Depalletisation Humanoid Torso: Real-Time Cardboard Package Detection Based on Deep Learning and Pose Estimation Algorithm

**Santheep Yesudasu*, Wafae Sebbata**, Jean-François Brethé*, Patrick Bonnin*****

** Normandy University Le Havre, France*
*** ECE, Engineering School Paris, France*
**** University of Versailles Mantes-la-Ville, France*

This paper presents a system for efficiently depalletising textureless and versatile cardboard boxes, even when they are tightly packed together, by utilizing deep learning and point clouds. The system uses an industrial humanoid torso equipped with a 6 DoF dual-arm and a single RGB-D camera that provides a 360° view of the pallet, allowing for fast, accurate, and adaptable object handling without the need for additional sensors or setup. Operating in a warehouse environment, the robot is responsible for loading/unloading pallets of cardboard packages and placing them onto conveyor belts for further processing. The system uses ROS interface for communication, control, and MoveIt for dual-arm path planning and achieves impressive F1 scores of 0.81 and 0.90 for single-face and multi-face boxes, respectively, as demonstrated through real-time testing. These results provide valuable insights into the system's capabilities and potential future improvements.

TECHNICAL PROGRAM

Thursday

August 24, 2023

Day: Thursday, August 24th, 2023

**Time: 9:00 – 10:00**

**Room: Marco Polo**

Plenary Sesion, P-3

**Day: Thursday, August 24th, 2023**

**Time: 9:00 – 10:00**

**Room: Marco Polo**

**Chair: Józef Korbicz**

**Author: Marcin Witczak (University of Zielona Góra, Poland)**

**Paper: Modern IoT onboarding platforms for advanced applications: an introduction to KIS.ME**

**Day:** **Thursday, August 24th, 2023**

**Time:** **10:10 - 11:10**

**Room:** **Marco Polo**

**Chair:** **Marcin Witczak**

Paper: **6054** **C2L-A**

## A Clustering-Based Data Reduction for the Large Automotive Datasets

**Patryk Siwek*, Paweł Skruch**, Marek Długosz****

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Large datasets used in automotive consist of a set of recorded sequences that represent possible road scenarios. Such scenarios are mainly utilized as test scenarios to verify developed driver assistance systems. Another application of the dataset is the training and verification of machine learning-based algorithms. As the number of possible road scenarios is, in fact, infinite, the process of selecting representative and meaningful sequences is a difficult and challenging task. This article presents an approach based on various clustering techniques for data reduction for large datasets that are used in the automotive industry to evaluate environmental perception algorithms. The approach is supported by the results obtained on representative datasets.

Paper: **6100** **C2L-A**

## Chebyshev Polynomials for Efficient Gaussian Process Computation

**Adrian Dudek , Jerzy Baranowski**

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Gaussian processes (GP) are becoming more and more popular way to solve statistics and machine learning problems. One of the reasons is the increase in computational power that can handle the inherent computational problem for GP models. Still, in the case of big data, the computational burden can be impractical. For this reason, various approximation methods are developed. In our work, we would like to present an alternative to the internal approximation by using the properties of Chebyshev polynomials. The idea is to calculate the GP model only at Chebyshev nodes and use the property of transforming function values in them to Chebyshev coefficients giving a solution to the original

problem. In our research, we propose our version of the algorithm and test it on cases of various functions.

Paper: **6102** **C2L-A**

## Occupational Diseases Forecasting for Polish Coal Mining Based on Prophet Algorithm

**Nataliia Kashpruk*, Marta Kraszewska*, Jerzy Baranowski*, Mariusz Kapusta****

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In paper, forecasting models using Prophet algorithm for occupational diseases incidence rate for Polish coal mining are presented. Prior to this, data is analyzed and approach for building forecasting models in Prophet is described in details. Forecasting models for occupational diseases incidence rate are revealed, respectively for all sectors in Poland, mining industry and finally for coal mining including only pneumoconiosis. Improved forecast accuracy with presented models might provide coal mine enterprises more precise data, supporting safety management in those organizations.

**Day:** **Thursday, August 24th, 2023**

**Time:** **10:10 - 11:10**

**Room:** **Vasco da Gama**

**Chair:** **Maciej Rosół**

Paper: **6094** **C2L-B**

## Pilot Study on Using Hybrid–Cascade Filtering on Brain Signals for the Control Purposes

**Mariusz Pelc*, Dariusz Mikołajewski**, Edward Jacek Gorzelańczyk**, Anna Wieczorek*, Henryk Racheniuk***, Adam Sudoł****, Kayhan Latifzadeh*****, Luis A. Leiva*****, Aleksandra Kawala-Sterniuk***

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We present an initial study conducted on fNIRS signals using Hybrid-Cascade filters for the purpose of their quality improvement. Whilst many studies focus on filtering brain signals, so that their frequency domain properties would allow e.g. widely understood diagnostics, here we focus on the study of time-domain signal characteristics, which is relevant for potential control purposes. Taking into account various kinds of artifacts, we propose a novel cascade 1D Kalman filter to handle fNIRS signals.

## Custom-Made Near Infrared Spectroscope as a Tool for Obtaining Information Regarding the Brain Condition

**Anna Wieczorek*, Edward Jacek Gorzelańczyk**, Mariusz Pelc*, Saravanakumar Duraisamy***, Luis A. Leiva***, Aleksandra Kawala-Sterniuk***

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We can obtain valuable information about the human brain using functional Near Infrared Spectroscopy (fNIRS). This paper describes the theoretical basis associated with this neuroimaging method through a custom-made prototype of a single-channel fNIRS device. The optodes were soldered to a milled Printed Circuit Board (PCB) and enclosed in a 3D printed housing. Using this fNIRS device, we performed a preliminary study to measure emotional responses from participants. Our results suggest that fNIRS allows for accurate measurement of emotions evoked by positive and negative images.



## Spatialization of Sound Recordings Using Intensity Impulse Responses

**Witold Mickiewicz , Kaja Kosmenda**

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The article focuses on a new technique for creating a realistic listening experience from audio recordings. The main objective of the research is to propose a way to segment the pressure impulse response using room intensity impulse responses (RIIR), on which simulation of room acoustic properties is based. This is intended to allow the spatialization of recordings. This approach to audio spatialization can increase the realism of audio recordings in many applications, whether virtual reality, gaming, or audio production for movies or video conferences. The paper describes a method for extracting the room's intensity impulse responses, a segmentation algorithm, and the results of the effectiveness of this technique and its ability to spatialize audio recordings. The research in the article aims to help highlight the potential of using intensity responses to spatialize recordings and the impact the proposed technique can have on the audio industry.

**Day:** **Thursday, August 24th, 2023**

**Time:** **10:10 - 13:00**

**Room:** **Poster Area**

**Chair:** **Ewa Pawłuszewicz**

Paper: **6004** **C3P-C**

## Intelligent Scheduling in MES Systems for Industry 4.0 - a Systematic Review of the Scientific Literature

**Zohreh Shakeri*, Nourhan Halawi-Ghoson*, Nisar Hakam*, Esma Talhi**, Anthony Quenehen***, Khaled Benfriha***

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One of the most important goals of factories and manufacturers is the development of new solutions to increase dynamism to better adapt to changing marketplaces. This is because there have been significant technological advancements in the manufacturing industry in recent years, and production planning is essential to ensure the completion of all production. Production Scheduling Due to the possibility of unpredictable events in the production system, problems related to scheduling problems are NP-hard and complex.This article aims to provide a systematic literature review on intelligent scheduling based on MES and in the framework of Industry 4.0. In a non-ideal situation, in complex, dynamic production systems, unpredictable disturbances can happen, including machine breakdowns, changes in the priority of orders, absence of personnel, etc. Production management has gained new opportunities in recent decades due to the growth of technologies such as artificial intelligence. This study discovers an outstanding research topic with a high potential for further investigation through a comprehensive literature analysis of the pertinent domains.

## Fractional Order Model Reference Adaptive Control with Chattering Elimination Algorithm for Wind Turbine Speed Control

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This paper presents a new fractional-order model reference adaptive control (FO-MRAC) design with a chattering elimination algorithm for controlling a simplified wind turbine model. The FO-MRAC algorithm continuously updates the controller parameters that allow the wind turbine output to track a reference model. The chattering attenuation algorithm is applied to improve the performance of the FO-MRAC controller by reducing the chattering phenomenon that can occur when using adaptive controllers. The results show that the FO-MRAC with chattering attenuation algorithm can effectively control the wind turbine model, reducing tracking errors and improving control performance. This paper demonstrates the potential of advanced control techniques for wind turbine control and provides insight into using FO-MRAC and chattering elimination algorithms for this application.



## Energy Savings Possibilities Gained from Neural Network Application in Compressed Air Supervisory Control Systems

**Kamil Kasprzyk, Adam Gałuszka**

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The aim of this paper is to check whenever usage of sequence based neural networks for predicting compressed air demand can be useful in screw compressor room supervisory control systems. Industrial enterprises frequently employ compressed air systems to generate the compressed air needed for daily operations. Data was gathered from three different compressor rooms with different air demand characteristics and configuration over the period of one month. Then data was prepared, analyzed, trained and tested followed by simulation tests which determined usefulness of trained networks. Since nowadays high energy prices force energy saving build of the screw compressor itself the purpose of this text was to check if there is any room for optimization in less modern and also modern applications.

## Fault Detection and Diagnostics of Complex Dynamic Systems Using Gaussian Process Models - Nuclear Power Plant Case Study

**Bartosz Puchalski**

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The article examines the use of Gaussian Process Models to simulate the dynamic processes of a Pressurized Water nuclear Reactor for fault detection and diagnostics. The paper illustrates the potential of Gaussian Process Models as a tool for monitoring and predicting various fault conditions in pressurized water nuclear reactor power plants, including reactor coolant flow and temperature variations, deviations from nominal working point or faulty power measurements. The article discusses the characteristics and benefits of Gaussian process models and how they can be utilized to improve: the reliability and accuracy of nuclear power plant anomaly detection, fault diagnosis and decision making process in states of emergency. Overall, this paper highlights the capabilities of Gaussian process models to enhance the safety and efficiency of nuclear power plants. The results of this study are expected to provide valuable insights for engineers and researchers in the fields of control engineering and nuclear power.



## New Trends in Industry 4.0 – Voice Control

**Jakub Szaj, Janusz Pochmara**

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This paper presents the possibilities of controlling a robotic arm using voice commands with the use of an external API responsible for speech-to-text translation. The article describes the creative process of designing the robot model and user interface included in the simulator used to control the robot. The software was developed in the Unreal Engine 4.27.2 environment using the built-in visual programming language - blueprint, as well as C++ and Python. The three-dimensional model was created entirely in Blender 3D software. The simulator's task is to faithfully reproduce manipulation of simple objects in real-time, as well as record and load the manipulator's trajectory along with all objects on the scene.

## PID Controller Tuning for Capsubot with Standard and Fractional-Order PSO Algorithm

**Artur Babiarz**

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The presented paper contains comparison two algorithms for searching optimal value of PID controllers: particle swarm optimization (PSO) and fractional-order particle swarm optimization (F-PSO) for the control system of capsubot robot. A cost function which is used with PSO and F-PSO is presented. At the end, the obtained simulation results are shown and discussed.



## Improved Model of the PWM Driven 3/2 Solenoid Valve Pneumatic System for Soft Pneumatic Actuators

**Krisjanis Visnevskis*, Shakiru Olajide Kassim*, Maria Elena Giannaccini*, Vahid Vaziri**, Sumeet S. Aphale***

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Soft pneumatic actuators (SPAs) are the building blocks of soft robots that are characterized by their inherent compliance, high degree of dexterity, and safety in human-robot interaction. The non-linear dynamics of the pneumatic system and elastomeric material deformation in SPAs presents a challenge in developing control systems for these actuators. Therefore simulations are often used to aid in the design and validation of new control schemes for SPAs. Pressure control is an important aspect of achieving precise motion control of the SPA. This paper presents an improved simulation model for a SPA pneumatic system that utilizes a 3/2 solenoid valve. The model was implemented using the SimScape Fluids toolbox in MATLAB. The proposed simulation model builds on existing models by accounting for the 3/2 solenoid valve dynamics. The open-loop response of the improved model was compared with the previous model and experimental data. The results showed that the improved model was more representative of the real-world performance of the system under open-loop control.

## Implementation and analysis of Ryze Tello drone vision-based positioning using AprilTags

**Mariusz Pawlicki, Kacper Hulek, Adrian Ostrowski, Jakub Możaryn**

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The paper describes the method of the Ryze Tello drone to move autonomously using a basic vision system. The drone's position is determined by identifying AprilTags' position relative to the drone's built-in camera. The accuracy of the drone's position readings and distance calculations was tested under controlled conditions, and errors were analysed. The study showed a decrease in absolute error with decreasing drone distance from the marker, a little change in the relative error for large distances, and a sharp decrease in the relative error for small distances. The method is satisfactory for determining the drone's position relative to a marker.



## Prospective Estimation of BESS Nominal Values for Frequency Control with High PV and Wind Integration

**Lázaro Guerra-Hernández*, Antonio A. Martínez-García**, Miriam Vilaragut-Llanes**, Yorlandys Salgado-Duarte***, Janusz Szpytko*****

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Energy storage systems (BESS) have been proposed to mitigate photovoltaics (PV) and wind generation variability, reducing the need to operate traditional spinning reserves and offering auxiliary grid services. BESS selection necessary to mitigate PV and wind generation variability is directly related to the worst daily short-time PV and wind generation variability. This paper proposes a practical estimation of BESS nominal parameters required to mitigate prospective power generation variability associated with high PV and wind generation penetration in Electrical Power Systems (EPS) under actual conditions, which includes significant loads impact through scenario analysis.

**Day:** **Thursday, August 24th, 2023**

**Time:** **11:40 - 13:00**

**Room:** **Marco Polo**

**Chair:** **Krzysztof Oprzędkiewicz**

Paper: **6041** **C4L-A**

## Topological Derivative Method for Control of Wave Equation on Networks

**Martin Gugat*, Meizhi Qian**, Jan Sokolowski*****

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The dynamical, boundary optimal control problems on networks are considered. The domain of definition for the distributed parameter system is given by a graph G. The optimal cost function for control problem is further optimized with respect to the shape and topology $\Omega$ of the graph. The small cycle is introduced and the topological derivative of the cost with respect to the size of the cycle is determined. In this way, the singular perturbations of the graph can be analyzed in order to change the topology $\Omega$. The topological derivative method in shape and topology optimization is a new tool which can be used to minimize the shape functionals under the PDEs constraints. The topological derivative is used as well for solution of optimum design problems for graphs. As an example, optimal control problems are considered on a cross with a small cycle. The state equation is the wave equation on the graph. The boundary control problem by Neumann conditions at a boundary vertex is solved for a tracking cost function. The shape functional is given by the optimal value of the control cost. Numerical results for a model problem are presented.

## Stable Sliding Mode Control of Dynamical Systems Subject to Unknown Disturbance

**Paweł Latosiński**

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Sliding mode control strategies are best known for ensuring a high degree of system robustness with respect to disturbance with negligible computational overhead. However, such strategies typically require information about lower and upper bounds of disturbance to ensure a stable motion of the system. Such bounds cannot be feasibly obtained in many practical applications. Motivated by this problem, we propose a new approach to sliding mode control of perturbed systems, which involves on-line estimation of unknown disturbance. Indeed, evolution of the disturbance is modeled as a random value with parameters determined from a number of past samples. Then, an appropriate disturbance estimator is defined in order to minimize the future effect of this disturbance on sliding motion of the system. It is demonstrated that the proposed approach guarantees a stable and robust response of the system even when no prior information about disturbance is available.



## Containment Problem for a Multi-Agent System with Heterogeneous Delays

**Branislav Rehák**

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The consensus problem for a multi-agent system with linear agents is considered. The agents may exhibit a time delay, this delay is not required to be equal for each agent. It is shown that different values of the delay may prevent the follower agents to settle in the precise convex hull of the leader agents, however, they converge to a larger set that can be determined using the robust control methods. The results are illustrated by examples.

# Nonlinear Luenberger Observer for Velocity Estimation in Active Magnetic Levitation System

**Rafał Bieszczad, Adam Piłat**

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The article presents the problem of designing a non-linear observer for an active magnetic suspension system. The nonlinear Luenberger observer (also known as Kazantzis–Kravaris–Luenberger observer) design process is presented. Particular attention was paid to the critical non-linearity of the system - the electromagnetic force, which is modeled using the function describing the change in inductance as a function of the distance of the levitating object from the electromagnet surface. Theoretical analysis were confirmed by the results of experimental studies in which the task of moving the sphere between the given positions using current control was carried out. The control tasks were carried out in the real-time regime on an embedded platform. The analysis of measurement signals and estimated speeds is a discussion about its operation and the possibility of future applications in control applications.

**Day:** **Thursday, August 24th, 2023**

**Time:** **11:40 - 13:00**

**Room:** **Vasco da Gama**

**Chair:** **Dominik Belter**

Paper: **6095** **C4L-B**

## Comparative Study of Subset Selection Methods for Rapid Prototyping of 3D Object Detection Algorithms

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Object detection in 3D is a crucial aspect in the context of autonomous vehicles and drones. However, prototyping detection algorithms is time-consuming and costly in terms of energy and environmental impact. To reduce the time and costs associated with designing algorithms i.e. training and evaluating different deep neural network architectures, one can check the effectiveness of different models by training on a subset of the original training set. In this paper, we present a comparison of three algorithms for selecting such a subset - random sampling, random per class sampling, and MONSPeC (Maximum Object Number Sampling per Class). We provide empirical evidence for the superior effectiveness of random per class sampling and MONSPeC over basic random sampling. By replacing random sampling with one of the more efficient algorithms, the results obtained on the subset are more likely to transfer to the results on the entire dataset.

Paper: **6055** **C4L-B**

## Position Tracking Control of a Robotic Joint Using Error-Based ADRC with Full and Reduced Order ESO

**Patryk Bartkowiak, Dariusz Pazderski**

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The error-based active disturbance rejection control (EADRC) structure is investigated for precise tracking control of a mechanical system with one degree of freedom. We formally take into account the uncertainty of the input gain, which affects the performance of the controller, and consider stability of the closed-loop system for the full-order and reduced-order extended-state observers (ESOs). Apart from theoretical analysis, we present experimental results, which confirm that the application of the

reduction-order observer can improve control performance. We also investigate whether the explicit formulation of the feedforward in EADRC makes it possible to improve the tracking precision under real conditions.

Paper: **6066** **C4L-B**

## VFO Control Design for a Mobile Robot in the Presence of Time and Input Constraints

**Rafał M. Sobański*,**, Maciej M. Michałek*, Michael Defoort****

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This paper presents a solution to the set-point control problem for nonholonomic mobile robots in the presence of time and control input constraints. We consider the kinematics of a unicycle mobile robot, in which the constraints on the control inputs are longitudinal and angular velocity limitations, while the time constraints impose an upper bound on a settling time for stabilization errors. We show a solution based on the Vector-Field-Orientation (VFO) methodology, which is characterized by non-oscillatory transient states and well-predictable time evolution of these states. Formally derived upper bounds of settling time for configuration errors are verified by results of numerical simulations and experimental results obtained in a fast prototyping system.

Paper: **6064** **C4L-B**

## Altruistic Coordination Strategy for On-Ramp Merging on Highway of a Formation of Cooperative Automated Vehicles

**Lyes Saidi, Lounis Adouane, Reine Talj**

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It is getting increasingly recognized that, to get full advantage from Automated Vehicles (AVs), a number of situations involving multiple AVs will compulsory require the coordination of their relative activities and movements. Under the Multi-Vehicle Systems (MVS) paradigm, instead of considering individually each AV, it is proposed to create with several AVs a group that evolves under a certain coordination strategy. In this paper, it is proposed to utilize Cooperative Automated Vehicles (CAVs) synchronization ability to tackle one challenging scenario: on-ramp merging on highway. The main contribution of this paper is an overall collaborative approach, called Altruistic Formation Reconfiguration Strategy (AFRS), based on a multi-criteria optimization, to guarantee the safety and the energetic efficiency of CAVs, performing on-ramp merging on highway. Under the AFRS, it is proposed the extension of the Constrained Optimal Reconfiguration Matrix (CORM) [1] in order to overcome the CORM limitations, while guarantying both the CAV's non-collision requirement and the smooth collaborative navigation of the fleet. Several simulations are performed.

**Day:** **Thursday, August 24th, 2023**

**Time:** **15:00 - 16:40**

**Room:** **Marco Polo**

**Chair:** **Rafał Stanisławski**

Paper: **6007** **C5L-A**

## Application of Control Scheme for Trajectory Tracking of Hovercraft and Indoor Airship

**Przemyslaw Herman**

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This paper is concerned with the application of a velocity transformation-based control scheme developed for underpowered marine vehicles to other vehicles with a similar mathematical model to the underwater vehicle. The problem of applicability of known control algorithms to systems that differ from the original is important in that its solution makes it possible to adapt a known control strategy for a similar class of vehicles. It is then not necessary to construct a new algorithm, but it is enough to transform one that is known. The effectiveness of the proposed approach was verified using simulations for a 3 DOF hovercraft model and an 3 DOF indoor airship.

Paper: **6017** **C5L-A**

## A Computational Model for Underground Heating Control of Outdoor Sports Fields in Winter Conditions

**Eero Immonen*, Tommi Paanu**, Fatemeh Ardaneh*, Ashvinkumar Chaudhari***

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We introduce a computational model for energy efficient underground heating control of outdoor sports fields in winter conditions. The proposed model is a nonlinear lumped-parameter representation of heat transfer within the soil layers, coupled to heat and mass transfer above the ground. The model addresses the sports field underground structure (with transient heating control), and time-dependent ambient conditions (air temperature, wind, precipitation, clouds and sky radiation). As an application, we demonstrate that, upon parameter identification, the model can predict the snow depth profile trend

seen in South-Western Finland in 2021. Moreover, we illustrate the use of the proposed model for comparing the effects of different heating set point control power settings on removing the ground snow cover.

Paper: **6048** **C5L-A**

## Factors Influencing Fractional-Order Dynamics in Large, Scale-Free Robotics Swarms

**Bill Goodwine**

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Prior work by the author has identified fractional-order dynamics in large, scale-free networks and noted that fractional-order models often better match the dynamic response of the network when the stiffness relationship (a spring constant) in the relationship between nodes in the network is larger. This work extends those results by systematically determining what parameters in the network are statistically significantly correlated with fractional-order models better matching the large-scale dynamics than integer-order models. Specifically we find a correlation between the degree of connectivity of the network, the spring constant, the distance in the network between the two nodes, and the size of the network to be statistically significantly correlated to whether fractional models are better. Interestingly, in contrast to the stiffness, the damping is statistically uncorrelated with fractional-dynamics.

Paper: **6058** **C5L-A**

## Modeling a Dynamic Object with Distributed Parameters

**Igor Korobiichuk*, Viktorij Mel'nick**, Vera Kosova**, Zhanna Ostapenko**, Viktoriia Pavlenko***, Józef Wrona***

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This article is developed and improved a mathematical model that describes the influence of errors in determining the structure of the approximating function on the results of automatic control object identification. A dynamic string with a load fixed at both ends is considered, an approximation is made and its modeling is carried out. Methods for determining the parameters of the selected approximating structure from the system's response to a known input signal have been analyzed. An

unconventional method for determining the transfer function using the method of least squares has been proposed. The universality of the mathematical description expands the possibilities of taking into account many factors that affect its properties and also establishes the validity degree of assumptions and simplifications in the process of analyzing the dynamics as a whole.

**Day:** **Thursday, August 24th, 2023**

**Time:** **15:00 - 16:40**

**Room:** **Vasco da Gama**

**Chair:** **Paweł Skruch**

Paper: **6024** **C5L-B**

## A Robotized Environmental Sensor Array for Gravitational Wave Observatory Sites

**Giulio Ballardin*, Luca Francescon*, Federico Paoletti**, Emmanouil Sotiropoulos***, Dimitrios Spyropoulos***, Maria Concetta Tringali*, Francesca Badaracco****, Matteo Di Giovanni*****, Irene Fiori*, Jan Harms*****, Paolo Bastia******

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A movable array of environmental sensors is intended for the feed-forward cancellation of the Newtonian noise generated by atmospheric density fluctuations and seismic displacements at the Virgo gravitational wave detector site, with the prospect of being used at the sites of future 3rd generation detectors. Each robot unit is equipped with a seismic sensor - optionally also a microphone and a magnetometer - for low-noise and low-frequency observations. The robots need to move autonomously in the experimental areas indoors, avoiding obstacles to reach the assigned positions where they start the data acquisition process. Then, the data will be transferred wirelessly to the control software that elaborates them and imparts to all robots the command to move to new optimal positions. Essential requirements of the system are accuracy in positioning and timing. The project is described highlighting the technical choices and their implementation.

## Fine-Tuning Method of the GA-Based Collision Avoidance System for AUVs

**Rafał Kot, Piotr Szymak**

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This article presents a fine-tuning methodology for an anti-collision system based on local path planning using Genetic Algorithms. The anti-collision system has been implemented using the mathematical model of Autonomous Underwater Vehicle (AUV). Based on a map of the underwater environment with a high degree of complexity, depending on the input parameters of the simulation, the average number of collisions and the average deviation from the set trajectory were tested. The fine-tuning aimed to minimise the above-mentioned parameters and determine the set of input parameters that would provide the best results. Fine-tuning was performed based on an exhaustive search method within specified limits. Compared to the average deviation value and the number of collisions calculated based on 45000 trials for each of the three selected sets, better results were obtained, which proves the purposefulness of this type of fine-tuning. Additionally, based on simulations results, when fine-tuning the collision avoidance system, it is more effective to adjust the parameters related to the vehicle's maneuvres first than the parameters related to the path planning method.



## Gesture Control of a Lightweight Industrial Robot Supported by Augmented Reality

**Christian Thormann, Mohammad Ehsan Matour, Alexander Winkler**

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This paper presents an approach to intuitive robot control by gestures made by a human operator supported by augmented reality. Unlike to the concepts of different robot manufactures to guide the robot using the manual control pendant, gesture control would be a universal method to drive the manipulator arm. For this purpose, we develop a set of gestures to move the robot in Cartesian space and to operate the gripper. In order to that, it is possible to program handling tasks, which are very relevant concerning robotic tasks. Augmented reality is then used for verification and modification of the robot program. In contrast to several approaches which use expensive hardware, for example head mounted displays, our concept needs only a monitor or a video projector. We compare the performance of gesture based robot control with conventional methods.

# SRPB: A Benchmark for the Quantitative Evaluation of a Social Robot Navigation

**Jarosław Karwowski, Wojciech Szynkiewicz**

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In recent years, social robots have gained popularity and many human-aware navigation approaches have emerged. In this work, we present a comprehensive benchmark for the quantitative evaluation of different robot navigation algorithms. It is intended to assist the system designer in the selection of the best method for the application. We tested traditional and human-aware trajectory planners with a TIAGo robot in simulated and real-world environments (Fig. 1). We assessed robot behaviour using state-of-the-art task performance scores and novel social metrics regarding robot motion naturalness and the perceived safety of humans surrounding the robot. Our social metrics take human tracking reliability into account. An open- source implementation of our benchmark, compatible with the Robot Operating System, is provided.

Friday

August 25, 2023

**Day:** **Friday, August 25th, 2023**

**Time:** **10:00 - 11:00**

**Room:** **Marco Polo**

**Chair:** **Paweł Latosiński**

Paper: **6061** **D1L-A**

## Nonlinear, Adaptive Model-Following Control Using Numerical Inverse of a Fuzzy Model

**Jacek Kabziński, Marcin Jastrzębski**

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A novel, adaptive, nonlinear model-following control using an on-line, numerical inversion of a fuzzy model is proposed. We consider a nonlinear plant (slave system) with unknown parameters and implicit, nonlinear dependance of control and state variables. The plant is supposed to follow a nonlinear master system. The appropriate function of control and state of the plant is represented by a fuzzy model, not necessarily being a one-to-one map. The model is numerically inverted on-line to get the desired control value. Consequent functions of the model are changed by robust adaptive laws, to cope with any modelling inaccuracies, while the other adaptive parameters are changed to follow the unknown parameters of the plant. This approach achieves a short execution time and can be applied in standard DSP-based controllers.

Paper: **6069** **D1L-A**

## A Physical Realization of the Minimum Variance Control-Like Algorithm Based on the Real-Life Servomechanism System: A Pilot Case Study

**Paweł Majewski, Marek Krok, Tomasz Feliks, Wojciech P. Hunek**

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A new form of the minimum variance control algorithm devoted to the physical systems is presented in the paper. A special attention is paid to its practical implementation guaranteeing a maintenance of the technological limitations in the actual process. In such a way, the robust control procedure allows us to obtain the maximum-speed and maximum-accuracy behaviors of a closed-loop system blurred by disturbances. It has turned out that the new approach could compete with the LQ algorithm subjected to the predefined weighting matrices. A real-life servomechanism example confirms a

correctness of the new method ultimately addressing a set of the open problems worth future research efforts.

Paper: **6080** **D1L-A**

## Linear-Quadratic-Gaussian Control of Fractional-Order Systems Based on Delta vs. Nabla Fractional-Order Difference

**Marek Rydel, Rafał Stanisławski, Grzegorz Bialic**

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The paper presents two ways of modeling fractional-order systems using delta and nabla definitions of Grunwald-Letnikov fractional-order difference. Finite-length approximation of fractional-order system are then applied for designing a linear-quadratic-estimator of fractional-order system. Predicted state-space vector are used by linear-quadratic-regulator. That approach enables simple determination of standard integer-order LQG controller for control of fractional-order system. The simulation experiments confirm that presented methodology is efficient and enables obtaining a good controller performance.

**Day:** **Friday, August 25th, 2023**

**Time:** **10:00 - 11:00**

**Room:** **Vasco da Gama**

**Chair:** **Janusz Szpytko**

Paper: **6053** **D1L-B**

## Iterative Learning-Based Model Predictive Control for Mobile Robots in Space Applications

**Niklas Baldauf, Alen Turnwald**

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This paper presents an iterative learning-based model predictive controller (MPC) for trajectory tracking control of an autonomous planetary rover on unknown terrain. In order to achieve accurate trajectory tracking under model uncertainties, a nonlinear controller and an MPC are utilized, combined with a learning-based uncertainties approximation. The model uncertainties and disturbances are learned using a deep neural network (DNN) as well as a parametric model and results are compared. For test and validation purposes, a gazebo simulation is used, which is itself already validated using data from a prototype rover. With that, the trajectory tracking performance of the proposed learning-based MPC is validated and compared to other well-performing controllers. The results show that the algorithm is able to learn model uncertainties and to compensate them during runtime while being practicable for the implementation and in the training phase.

Paper: **6056** **D1L-B**

## Task-Oriented Programming System for Cobot-Assisted Assembly Workstations

**Bernd Finkemeyer*, Peer Lüthje*, Martin Scheuer*, Wiebke Waller**, Cindy Eggers**, Jan Kasten****

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Robots have become indispensable in many areas. In production technology in particular, they are a valuable component. However, they reach their limits when used in small businesses. Their use is often uneconomical, especially for assembly tasks in small batches. The engineering effort is then too high in relation to the benefit. This paper presents the concept of a task-oriented robot programming

system. It allows the easy creation and maintenance of robot applications for the implementation of assembly tasks. The possibilities of human-robot collaboration are an integral part of the system and extend the application portfolio. The paper explains the resulting work steps for the creation and operation of the robot application. Finally, the validation of the presented programming approach is discussed.

Paper: **6103** **D1L-B**

## Disparity Error in Advanced Vision Sensors

**Jurek Z. Sasiadek*,**, Mark J. Walker***

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*** Space Research Centre Polish Academy of Sciences, Warsaw, Poland*

This paper reports research in which feature-based disparity error is reported against corresponding features identified in a subset of images in the Karlsruhe Institute of Technology and Toyota Technological Institute or KITTI 2012 benchmark. The dataset provides real-world imagery. The theory behind finding corners or features, matching them across image pairs, and then calculating the resultant disparity is explained. These disparity results are compared against disparity data provided by the KITTI 2012 dataset, to produce disparity errors. The disparity errors are graphed. Concluding remarks are discussed.

**Day:** **Friday, August 25th, 2023**

**Time:** **11:30 - 12:50**

**Room:** **Marco Polo**

**Chair:** **Aleksandra Kawala-Sterniuk**

Paper: **6043** **D2L-A**

## Scheduling Charging Jobs in the System of an Autonomous Charging Station Under Power and Energy Constraints

**Rafał Różycki*, Grzegorz Waligóra*, Przemysław Grobelny****

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In the paper a problem related to the field of edge computing is considered. We discuss a situation where an autonomous energy charging station is used to perform the process of charging a fleet of electric vehicles. The station consists of two modules: a computing and an executive one. The computing module is equipped with a variable speed processor, and is responsible to find a schedule of the charging jobs. We discuss the model of the system and the resulting scheduling problem, as well and we propose a few basic approaches for solving it. Some conclusions and directions for future research are given.

Paper: **6089** **D2L-A**

## Evaluation of the Effectiveness of Physical Protection Systems with Consideration of its Cyber-Resilience

**Jan Kapusta*,**, Waldemar Bauer**, Jerzy Baranowski****

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The importance of security in the modern, dynamically changing world seems to be understood across the globe. Different types of organizations, both from the public and the private sector, are creating strategies and investing large amounts of funds to implement Physical Protection Systems (PPS) in order to protect their assets. It appears relatively obvious that assessment of the effectiveness of PPS is important and required. Moreover, the result of the assessment should be reliable and cover as much

as possible current threats, including those that are coming from cyberspace. In this paper, we propose a new approach to evaluating PPS. Our proposition as a starting point is using well-known EASI methodology but reinforced with methods aiming to cover the cybersecurity of PPS considering all potential adversary paths.

Paper: **6090** **D2L-A**

## Spatial Modelling of Virus Transfer and Exposure Using Bayesian Inference with Integrated Nested Laplace Approximation

**Andrzej Neścior, Adrian Dudek , Waldemar Bauer, Jerzy Baranowski**

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Airborne transmission is a key element in the spread of viral contagion. To prevent this, health organization publish guidelines for every major disease outbreak. However, they are often based on researches carried out without access to modern solutions. In this paper, we propose usage of Bayesian inference as an additional, to computationally-intensive methods such as CFD or FEM, way to analyse short - range virus exposure. We build a spatial model, using INLA package, which allows us to optimize the complicated computational process and deal with conundrums of virus exposure modeling.

Paper: **6092** **D2L-A**

## Optimization and Planning of Equipment Allocation on Multiple Projects - Solution Proposal in ERP System

**Mateusz Fijas*,**, Katarzyna Grobler-Dębska*, Edyta Kucharska*, Waldemar Bauer***

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Organizations in the design and construction industry performing project work use in-house and rented equipment to carry out the work. Management of such resources requires a great deal of managerial and process knowledge due to the sharing of resources across multiple projects. So it is a complex decision-making system, requiring quick and accurate decisions processes. Enterprise Resource Planning (ERP) systems support such processes, however at the basic level and unsatisfied for system users. Businesses using to support their processes require from the system a quick and concise presentation of information to support the user's action, clearly indicating the need for graphical presentation of data. In addition, there is a lack of tools to optimize the allocation of resources to projects. The business problem is Vehicle Routing Problem with Service Time in the Hard Time Windows constrains (VRPHTW). The paper presents mathematical formulation of the business problem, numerical experiments of optimization of resource allocations and a solution in the IFS Applications ERP system which allow graphical and numerical representation of machine load on multiple projects.

**Day:** **Friday, August 25th, 2023**

**Time:** **11:30 - 12:50**

**Room:** **Vasco da Gama**

**Chair:** **Maciej Michałek**

Paper: **6030** **D2L-B**

## Comparison of Machine Learning Techniques for Self-Collisions Checking of Manipulating Robots

**Adam Krawczyk, Jakub Marciniak, Dominik Belter**

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In this paper, we deal with the problem of self-collision detection for a mobile-manipulating robot. Typically, this problem is solved by the method that precisely checks the collision between triangles in the 3D meshes. Typically, the iterative methods for collision checking use techniques like Bounding Volume Hierarchy that reduce the computation time. However, collision checking is still time-consuming during motion planning when this procedure is executed multiple times. To deal with this problem, we propose to define collision detection as a binary classification problem. Then, we show how to collect samples to train the machine learning model for classification. We systematically compare a set of techniques and evaluate them in the task of motion planning for a robotic arm taking into account the accuracy and computation time. The obtained collision classifier is implemented and verified in the Robot Operating System.

Paper: **6038** **D2L-B**

## Arithmetic Billiard Paths Revisited: Escaping from a Rectangular Room

**Somnath Kundu*, Yeganeh Bahoo[1]*, Onur Çağırıcı*, Steven M. LaValle****

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In this work, we consider a problem where a robot can move in a straight line inside a 2D rectangular room with integer lengths until it hits any part of the wall of the room. If the robot hits any part of a wall other than the corners or any point of an opening, then the robot bounces off the wall and follows

a new direction in another straight line following the laws of symmetric reflection. The robot needs to escape through an opening on the wall that has a minimum length of one unit. The robot can only escape through the opening if it reaches any point of the opening with a non-zero angle. We present an efficient algorithm for which the robot is guaranteed to find the opening if there is any or declare that there is none. We prove that the algorithm works if and only if the sides of the rectangle are co-prime. As a by-product of our main result, we also provide some interesting results related to the coverage of the interior of the rectangle when the robot follows similar algorithms to escape from the rectangular room.

Paper: **6084** **D2L-B**

## Distributed Control for Teams of Non-Holonomic Mobile Robots Executing Competitive Tasks

**Wojciech Kowalczyk, Arpit Joon**

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Multi-robot systems have been widely used in a variety of applications to perform tasks cooperatively. A greater challenge is to design control when two teams of robots have to compete with each other when performing tasks. This paper presents a control algorithm for teams of differentially-driven mobile robots that perform such a task. The goal of each team is to follow an individual reference trajectory keeping the desired shape of the formation. In the transition state, the robots of one group must penetrate the other team to reach desired poses. Artificial potential functions are used to avoid collisions. They are shaped to reduce the risk of deadlocks between groups of robots. Numerical simulations illustrate the effectiveness of the proposed algorithm.

Paper: **6059** **D2L-B**

## Roll-Motion Stabilizer Design for a Sounding Rocket Using the ADRC Methodology

**Natalia Wiśniewska, Andrzej Rafalski, Maciej Marcin Michałek**

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A high roll rate can decrease the chance of the research-oriented rocket mission success. There is scant information about the effective roll-motion stabilizer solutions for sounding rockets. Thus, a roll-motion stabilizer for a sounding rocket using the active disturbance rejection control (ADRC) methodology is proposed. The presented roll-motion stabilizer is designed for a subsonic sounding rocket. The effectiveness of the designed control system was verified by simulations and experiments in the wind tunnel. The results of the verification show that the designed control system enables robust roll-motion stabilization despite large uncertainty of a rocket model. Practical guidelines for designing of roll-motion stabilizer application are provided.

Index of Authors

## SESSIONS

WHAT TO SEE AT MIĘDZYZDROJE?

Międzyzdroje is a popular charming seaside holiday resort located on the Wolin Island in the north-western corner of Poland (ca. 100 km north of Szczecin, ca. 250 km northeast of Berlin and ca. 600 km north-west of Warsaw) between the Wolin National Park Forest and sandy beach with a steep cliff shoreline. The beauty of Międzyzdroje lies in its fine architecture and natural environment. Together with the adjoining Wolin National Park, which houses one of the very few bison reserves in the world, and offers a series of awe-inspiring hiking trails, it is a place of unique scenic, cultural and tourist value.

Places particularly worth visiting:

**Kawcza Góra**, a hill in the eastern part of the town. A nice walking path leads to the top, where two rocks commemorate two congresses of foresters; stairs go down to the sea.

**The Międzyzdroje cliff**, the highest sea shore in Poland, rising up to 95 meters above sea level, is damaged by marine erosion - up to one meter of land is cut by waves every year.

**The Parish Church of St. Peter the Apostle**, built in 1862, was designed by the famous architect Stüler and co-designed by King of Prussia Frederic William IV, who covered most of the construction costs. The International Choir Song Festival and concerts of organ music are held in the church.

**The Stella Matutina (Morning Star)** Chapel built in 1902, houses a hospice run by the Borromean Nuns.

**The fishing harbour** in the eastern part of the town.

**The bison reserve**, established in 1976, it is also inhabited by other animal species, e.g. the wild boar and the roe-deer.

**The marked path in the National Park** : the red trail along the sea coast, the green trail to Lake Czajcze near Warnowo, and the blue trail to Zielonka hill at Lubin pass by many vantage points and nature reserves.

**Zielonka hill** at Lubin, the most beautiful panoramic view of the Old Swina river marshes and the Szczecin Lagoon.

**Lake Czajcze** near Warnowo, a picturesque postglacial water reservoir shaped like a horseshoe. The peninsula in the middle was a site of a 14th-c.

settlement.

**Lake Turkusowe** at Wapnica hides a flooded chalk mine. Its turquoise water and picturesque steep shores are an attraction of this landscape reserve.

**Wolin**, the legendary 9th/11th-c. port town of Vineta. It has an archaeological museum and other ancient sites, including the 9th-c. burial ground with barrows.