WELCOME

from the MMAR 2022 Organizing Committee

I would like to invite you to Międzyzdroje, Poland for the 26th International Conference on Methods and Models in Automation and Robotics. 94 draft papers have been submitted, from which the International Program Committee, chaired by Professor Andrzej Bartoszewicz, has selected 82 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 of Automation and Robotics of the Polish Academy of Sciences and the Polish Society for Measurement, Automatic Control and Robotics.

The Conference starts on Monday afternoon, 22 August 2022. Every day of the conference begins with a plenary lecture delivered by a distinguished scientist, then all other papers will be presented in two parallel regular sessions, some of them in an on-line form. 9 papers will be presented in a poster session. Moreover, all the MMAR 2022 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 2022 Organizing Committee

Faculty of Electrical Engineering

West Pomeranian University of Technology, Szczecin

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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 2022 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 2022 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 2022.

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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 26th in a series which started in 1994.

VENUE AND DATES

The Conference will be held at the Amber Baltic Hotel in Międzyzdroje, from Monday, 22 August till Thursday, 25 August 2022.

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

The Conference will start on Monday, 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

Monday, 22nd August, 2022

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gama**
11.00	Registration opens (Amber hotel main hall)	
15.00 – 15.30	Conference Opening	
15.30 – 16.30	Plenary Lecture (Marco Polo), Chair: A. Bartoszewicz **Consensus Protocols for Connecting Autonomous Vehicles** Speaker: **Maria Pia Fanti**	
16.30 – 17.00	Coffee break	
17.00 – 18.40	A2L-A **Special Session on the Occasion of the Jubilee of Prof. Stefan Domek** (Special Session) Chair: Józef Korbicz 8002, 8026, 8008, 8003	
19.00	Welcome Party (Amber Baltic Hotel, On Deck Restaurant)	

Tuesday, 23rd August, 2022

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gama**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: T. Kaczorek **Lessons from Adaptive Control: Towards Real-time Machine Learning** Speaker: **Anuradha Annaswamy**	
10.10 – 11.10	B2L-A **Intelligent Systems & Methods I** Chair: Marcin Witczak 8040, 8041, 8091	B2L-B **Control Applications I** Chair: Robert Piotrowski 8081, 8084, 8097
11.10 – 11.40	Coffee break	
11.40 – 13.00	B3L-A **Control Applications II** Chair: Artur Babiarz 8038, 8049, 8054, 8082	B3L-B **Modelling & Simulation I** Chair: Przemysław Ignaciuk 8030, 8035, 8064, 8098
13.00 – 15.00	Lunch	
15.00 – 16.40	B4L-A **Control & System Theory I** Chair: Andrzej Bartoszewicz 8007, 8014, 8025, 8028, 8062	B4L-B **Robotics I** Chair: Jacek Kabziński 8016, 8017, 8023, 8044, 8071
16.40 – 17.10	Coffee break	
17.10 – 18.50	B5L-A **Intelligent Systems & Methods II** Chair: Harald Aschemann 8029, 8034, 8090, 8092	B5L-B **Robotics II** Chair: Grzegorz Bocewicz 8048, 8053, 8056
19.30	**Conference Banquet** (Międzyzdroje International House of Culture)	

Wednesday, 24th August, 2022

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gama**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: H. Aschemann **Distributed Control, Estimation & Optimization in Multi-agent Systems: Algorithms & Applications** Speaker: **Wei Ren**	
10.10 – 11.10	C2L-A **Robotics III** Chair: Wojciech Giernacki 8074, 8066, 8096	C2L-B **Intelligent Systems & Methods III** Chair: Joachim Horn 8072, 8079, 8088
11.10 – 11.40	Coffee break	
11.10 – 13.00	C3P-C **Poster Session** (Poster area) Chair: Krzysztof Okarma 8024, 8031, 8033, 8077, 8078, 8083, 8087, 8089, 8055	
11.40 – 13.00	C4L-A **Robotics IV** Chair: Dariusz Pazderski 8006, 8009, 8020, 8021	C4L-B **Control & System Theory II** Chair: Jerzy Klamka 8045, 8046, 8047, 8067
13.00 – 15.00	Lunch (Amber hotel)	
15.00 – 16.40	C5L-A **Modelling & Simulation II** Chair: Milica Petrovic 8010, 8069, 8015, 8018, 8022	C5L-B **Intelligent Systems & Methods IV** Chair: Per-Olof Gutman 8005, 8050, 8057, 8073, 8075
17.30	Touristic programme (The Village of Slavs and Vikings)	

Thursday, 25th August, 2022

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gama**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: J. Korbicz **Interpretable Fuzzy Rule-Based Systems for Adaptive Control & Data Classification** Speaker: **Jacek Kluska**	
10.10 – 11.10	D2L-A **Modelling & Simulation III** Chair: Krzysztof Oprzędkiewicz 8068, 8085, 8086	D2L-B **Intelligent Systems & Methods V** Chair: Radosław Rudek 8052, 8063, 8065
11.10 – 11.40	Coffee break	
11.40 – 13.00	D3L-A **Robotics V** Chair: Paweł Skruch 8036, 8039, 8042, 8043	D3L-B **Control Applications III** Chair: Paweł Majewski 8019, 8027, 8058, 8080
13.00 – 13.15	Conference Program Committee Meeting (Young Author Prize Contest)	
13.15	The Young Author Award Ceremony and Farewell Lunch	

TECHNICAL PROGRAM

Monday

August 22, 2022

Day: Monday, August 22nd, 2022

Time: 15:00 – 16:30

Room: Marco Polo

Plenary Sesion, P-1

Day: Monday, August 22nd, 2022

Time: 15:30 – 16:30

Room: Marco Polo

Chair: A. Bartoszewicz

Author: Maria Pia Fanti (University Polytechnic of Bari, Italy)

Paper: Consensus Protocols for Connecting Autonomous Vehicles

Day: **Monday, August 22nd, 2022**

Time: **17:00 - 18:40**

Room: **Marco Polo**

Chair: **Józef Korbicz**

Paper: **8002** **A2L-A**

Standard and Fractional Descriptor Linear Systems with State and its Derivatives Feedbacks

Tadeusz Kaczorek

Faculty of Electrical Engineering Bialystok University of Technology
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The standard and fractional descriptor linear continuous-time systems with state and its derivative feedbacks are considered. Sufficient conditions for the existence of state and its derivative feedbacks are established for which the closed loop system is positive and asymptotically stable for standard and fractional linear systems. Procedures for computation of the feedback matrices are given and illustrated by simple examples.

Paper: **8026** **A2L-A**

Model-Based Trajectory Tracking in Sliding Mode Control of Continuous-Time Systems

Pawel Latosiński , Andrzej Bartoszewicz

Institute of Automatic Control, Ł´od´z University of Technology
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Sliding mode controllers are well known for their ability to reject the effect of uncertainties on the motion of the system. However, they are typically unable to impose any constraints on individual state variables, which may limit their applicability. In this work we propose a strategy, which allows one to impose strict constraints on state variables in sliding mode control while still maintaining its disturbance rejection property. In the proposed method, we introduce a particular reference model of the plant. This model is then used to design favorable, bounded target trajectories for the original system. These trajectories are obtained from a polynomial function, which is selected after taking the known initial conditions of the system into account. Finally, a sliding mode control strategy is used

to drive the state of the original plant alongside that of the reference model. We have proven that, with the application of the proposed strategy, each state variable of the plant exactly follows the respective variable of the model, regardless of disturbance. As a result, state variables of the actual plant are bounded in exactly the same way as those of the reference model.

Paper: **8008** **A2L-A**

Constrained Controllability of Second Order Systems

Klamka Jerzy

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In the paper constrained controllability of linear, second order infinite-dimensional, continuous-time control systems is considered. Using methods and results taken directly from functional analysis necessary and sufficient conditions for approximate controllability are formulated and proved. Moreover, illustrative example is also discussed.

Paper: **8003** **A2L-A**

Modeling of Temperature of 2D Surface Using Fractional Order Transfer Functions

Krzysztof Oprzędkiewicz , Maciej Rosół , Wojciech Mitkowski

dept of Automatic Control and Robotics,AGH University,
Kraków, Poland
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The paper proposes fractional order (FO) transfer function models to describe a dynamics of temperature of a flat surface. Parameters of transfer functions were identified via minimization of the MSE cost function, describing difference between step response of a model and real experimental system. The step responses of models are described by analytical formulae. Experiments were done with the use of thermal camera. Results confirm good accuracy of both proposed transfer function models in the sense of MSE cost function.

TECHNICAL PROGRAM

Tuesday

August 23, 2022

Day: Tuesday, August 23rd, 2022

Time: 9:00 – 10:00

Room: Marco Polo

Plenary Sesion, P-2

Day: Tuesday, August 23rd, 2022

Time: 9:00 – 10:00

Room: Marco Polo

Chair: T. Kaczorek

Author: Anuradha Annaswamy (Massachusetts Institute of Technology, MA, USA)

Paper: Lessons from Adaptive Control: Towards Real-time Machine Learning

Day: **Tuesday, August 23rd, 2022**

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

Room: **Marco Polo**

Chair: **Marcin Witczak**

Paper: **8040** **B2L-A**

Mapping an Unknown Environment with Explored Area-Detection

Anna Barbara Ádám , Emese Gincsainé Szádeczky-Kardoss

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Budapest University of Technology and Economics
Budapest, Hungary
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Mapping and exploring an unknown area is required in many fields of life. There exist rescue robots, which are able to explore dangerous, hard to reach areas. Other robots are used for exploring areas in order to find minerals or oils. This paper presents a method, which uses a lidar sensor for detecting the environment. The presented exploration method is applicable in corridor environments. The exploration path is planned by using an n-direction scanning detection algorithm. During the exploration, those areas are detected, which do not have to be visited again. In each step of the exploration, the currently seen area is approximated with a polygon, whose area is classified into two groups: those points, which do not have to be visited again, and those points, which should be visited again during the exploration. The exploration of example maps is presented.

Loop-Closure Detection with 3D LiDAR Data for Extreme Viewpoint Changes

Dimitrios Alexiou*, Kosmas Tsiakas *,, Ioannis Kostavelis*, Dimitrios Giakoumis*, Antonios Gasteratos **, Dimitrios Tzovaras***

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The paper at hand presents a 3D point cloud-based method for loop closure detection that is tolerant to extreme viewpoint changes. Our method utilizes local 3D geometrical descriptors to tackle scenarios where the robot passes from the same place, yet with completely opposite direction, and is capable of understanding the similarity of the revisited area, in complete absence of common visual data in respective RGB images. To achieve this, rotation invariant Fast Point Feature Histograms (FPFHs) calculated over the Unsupervised Stable Interest Point Detection (USIP) keypoints formulate a descriptor matrix, upon which the similarity score for previously re-visited scenes is calculated. Probabilistic voting is applied to extract the top loop closure candidates and a geometric validation step is used for the final matching decision. Our method has been extensively verified on the state-of-art MulRan dataset as well as in a custom-built dataset acquired from an autonomous vehicle, that focuses on opposite traversing routes using a low-resolution LiDAR sensor.

Integration of Data Analytics in Operation of Enterprise Resource Planning Systems

Rafał Mularczyk, Edyta Kucharska, Katarzyna Grobler-Dębska, Jerzy Baranowski

Department of Automatic Control & Robotics, AGH University of Science & Technology
Kraków, Poland
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Proper control of the company's processes and making the right business decisions nowadays play a huge role in its competitiveness on the market. IT tools that enable analysis of data collected in ERP systems are supportive in this respect. ERP systems may have built-in elements facilitating data analysis, ranging from simple reports to solutions using data warehouses. These solutions provide only static dasbords, which significantly limits the possibilities of analysis. In this paper we present the use of external systems that enable people without programming skills to perform dynamic analyses and the use of machine learning, arfificial intelligence and natural language processing methods. We present case study the practical application of data analysis in ERP systems (IFS Application) using Power BI.

Day: **Tuesday, August 23rd, 2022**

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

Room: **Vasco da Gama**

Chair: **Robert Piotrowski**

Paper: **8081** **B2L-B**

Robust Control of a Duocopter by Discrete-Time Sliding Mode Techniques and an Extended Kalman Filter for Disturbance Compensation

Harald Aschemann

Chair of Mechatronics, University of Rostock,
Germany
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This paper proposes a discrete-time cascade control for a Duocopter which represents a two-rotor helicopter combined with a guiding mechanism: A nonlinear MIMO sliding mode control loop is responsible for the positioning of the Duocopter, while its rotation angle is controlled in a linear inner control loop. Feedforward control counteracts the nominal coupling forces related to the guidance. Moreover, an extended Kalman filter (EKF) estimates selected states and remaining errors concerning the nominal coupling forces. The sum of the feedforward part and the estimates can be used to robustly and accurately compensate for the impact of the guiding mechanism on the motion of the Duocopter. Thereby, an excellent tracking performance is achieved.

Paper: **8084** **B2L-B**

Iterative Learning Control for Vacuum Heat Treatment Process

Piotr Balik , Kamil Klimkowicz , Maciej Patan

Electrical and Control Engineering University of Zielona Góra
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Distributed parameter systems constitute an important class of modern industrial processes. However, in many practical applications the engineers still tend to adapt some classical control techniques developed for lumped systems totally neglecting the spatial dynamics of the investigated process. In a view of increasing demands imposed on system accuracy and performance, such conventional control algorithms simply become insufficient and there is a great necessity for novel identification and control methods taking into account both the temporal and spatial dynamics. This work reports a dedicated approach to control design for repetitive thermal processes consisting of the extension of the existing feedback control scheme with an intelligent data-driven component using the iterative

learning control technique. The characterization of the resulting control scheme is discussed together with control design and implementation details. In order to compare the quality of the regulation, the approach is illustrated with simulation on the realistic model of wafer heating in an industrial vacuum furnace.

Paper: **8097** **B2L-B**

Machine Learning for Self-Calibration Parameters of Data-Driven Models: Case Study of an Integrated Maintenance Digital Platform

Janusz Szpytko*, Yorlandys Salgado Duarte*, Lázaro Ramón Millares Barthelemy **

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In this paper, to address this controversial hidden challenge, we propose to use machine learning for on-line calibration by introducing smart layers based on comprehensive humans diagrams that filter and analyze historical data collected through monitoring systems and make all variables and parameters of the risk model ready for use. In particular, we focus the attention on one of the model components, the load modeling. This proposed organic connection ensures a feasible and practical solution to be used in a real system because address a potential challenge in technology integration.

Day: **Tuesday, August 23rd, 2022**

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

Room: **Marco Polo**

Chair: **Artur Babiarz**

Paper: **8038** **B3L-A**

Development of a Decision Model for Solving the Task Scheduling of Multiple Sequential Batch Reactors

Tomasz Ujazdowski, Robert Piotrowski

Faculty of Electrical and Control Engineering Digital Technologies Center, Gdańsk Tech, G. Narutowicza 11/12, 80-233 Gdańsk, Poland
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This paper considers the problem of scheduling the work cycles of multiple Sequential Batch Reactors. The paper proposes a decision model based on the Flow-Shop Scheduling Problem. Three tank sizes and tasks with variable number of phases were assumed. The application of the model for task scheduling has been tested using an optimisation algorithm. Task scheduling problems belong to NP-hard problems and are often solved by non-deterministic algorithms. The solution of the presented problem was realised by using the differential evolution algorithm for three different objective functions. Assuming both the criterion of minimising the maximum execution time (makespan) and the criterion of even operating time of the SBRs.

Paper: **8049** **B3L-A**

Mutual Influence of PID and FOPID Controllers on Different Axes of the 3D Crane

Jakub Żegleń-Włodarczyk, Klaudia Wajda

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The article presents 3D crane control with PID and FOPID (which is an extension of the classic PID with fractional parts) controllers in various configurations. 5 controllers are needed to control the crane - 3 for controlling the XYZ axes and 2 for influencing the angular position alpha and beta. 3 sets of simulations were prepared. The first version includes 5 FOPID regulators that serve as a benchmark for comparisons. In two subsequent sets, the FOPID controllers on one axis and the corresponding angle for this axis were replaced with PID controllers (X axis + alpha angle and Y axis + beta angle). Matlab/Simulink environment was used to prepare the simulation. Later in the article

all the results were compared with each other. GWO optimization was used to prepare the best coefficients for individual controllers.

Paper: **8054** **B3L-A**

Control of Unmanned Aerial Vehicles with Non-Minimum Phase Dynamics Using Parallel Differential Compensation

Agnieszka Pukacz, Jacek Kabziński

Institute of Automatic Control Lodz University of Technology,
Lodz, Poland
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A novel control approach is proposed for non-minimum phase systems. A differential compensator connected parallel to the plant is used to move RHP zeros to LHP positions. The proposed approach is applied to design a new autopilot – pitch angle controller for a tailless fix-wing drone. Examples demonstrate controller tuning and system performance.

Paper: **8082** **B3L-A**

Modelling and Simulation of an Autonomous Vehicle Ethical Steering Control System (ESCS)

Joshua D'Souza*, Keith J. Burnham, James Pickering*,**

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e-mail: K.Burnham@wlv.ac.uk

This research uses modelling and simulation tools to investigate a vehicle ethical steering control system (ESCS) for autonomous vehicles (AVs). The ESCS would be activated when unavoidable collisions are detected and an ethical decision in regard to the collision target needs to be made. The ESCS involves three stages with these being; kinematic bicycle model (to model an AV), angle control of the AV and velocity control of all AVs involved in the collision. In terms of the ESCS, the primary ethical approach is that of the utilitarian approach, i.e., steering into the path of least injury severity.

Day: **Tuesday, August 23rd, 2022**

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

Room: **Vasco da Gama**

Chair: **Przemysław Ignaciuk**

Paper: **8030** **B3L-B**

A Framework for Model Sailing Simulation in Gazebo

Adam Wolniakowski, Maja Czarna

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Recently there has been increased demand in wind power usage in maritime transportation. At the same time, due to numerous advances, interest in autonomous mobile platforms is at its all-time peak. The utilization of green Unmanned Surface Vehicle fleets could provide enormous benefits in research, security and transportation. The development of autonomous sailing vehicles can be greatly assisted with the usage of simulation where the control, planning and navigation systems can be tested and implemented. Furthermore, great synergy can be achieved through integration of software systems of such platforms with existing popular robotic frameworks, such as ROS. In this paper we propose a flexible ROS-based framework for simulation of customizable sailing vessels, focusing on small scale models.

Paper: **8035** **B3L-B**

Automatic Parameter Tuning via Reinforcement Learning for Crowd Simulation with Social Distancing

Yiran Zhao, Roland Geraerts

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We study the application of Reinforcement Learning in crowd simulation by proposing an automatic parameter tuning system based on Proximal Policy Optimization. The system can be used with any crowd simulation software to improve the quality of the simulation by automatically assigning parameters to each agent. Our experiments indicate that the automatic parameter tuning system can reduce unexpected congestions in counterflow scenarios. In addition, by utilizing the improved commonly used crowd simulation algorithms and our parameter tunning system, we can represent the

social distancing behavior of pedestrians under COVID-19, where pedestrians dynamically adopt social distances according to their surrounded environment.

Paper: **8064** **B3L-B**

Modeling of Thermal Processes in the Microcontroller System Using Fractional Order Transfer Function

Krzysztof Oprzędkiewicz, Maciej Rosół

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The paper proposes fractional order (FO) transfer function model describing thermal processes during work of a microcontroller system. Parameters of transfer function were identified by minimization of the MSE cost function, describing difference between step response of a model and real experimental system. The analytical step response of the proposed model is compared to experimental one. Temperature field of the tested circuit is measured using thermal camera. Comparison experimens vs simulations confirms the good accuracy of the proposed model in the sense of MSE cost function.

Paper: **8098** **B3L-B**

Simulation of Autonomous Decisions in Anticipatory Networks

Andrzej M.J. Skulimowski

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Anticipatory networks (AN) generalize and extend the theory of anticipatory systems of Rosen that experiences recently a rising popularity in autonomous robotics. The decision analysis in AN is based on an assumption that the preference model of decision makers linked by a causal relation takes into account the outcomes of certain future decision problems indicated by so-called anticipatory feedback relation. This paper presents a simulation algorithm that has been implemented to model the anticipatory behavior of a team of autonomous mobile robots. Their formations are anticipatory networks driven by a discrete event system with virtual supervisor. An illustrative example referring to finding an optimal formation evolution strategy for a team of autonomous field robots will also be presented.

Day: **Tuesday, August 23rd, 2022**

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

Room: **Marco Polo**

Chair: **Andrzej Bartoszewicz**

Paper: **8007** **B4L-A**

On Handling Discontinuities in Adjoint-Based Optimal Control of Multibody Systems

Maciej Pikuliński, Paweł Malczyk

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This paper presents the treatment of artificial discontinuities in a Hamiltonian-based optimal control of holonomically-constrained multibody systems. Discontinuities considered here are defined as artificial as they originate from particular actions taken against possible numerical issues. In the proposed approach, a general optimal control problem is formulated by approximating the optimal solutions with Chebyshev polynomials of the first kind. The optimal control problem is solved by employing an efficient adjoint-based technique. A derivation of jump conditions for both state and adjoint variables is shown. An example showcasing the implementation of the proposed method is included as well. This work presents an intermediate step in deriving a framework, which would directly operate on time functions instead of timeindependent parameters.

Paper: **8014** **B4L-A**

Event-Triggering in Model Reference Quasi-Sliding Mode Control

Katarzyna Adamiak

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This study considers a linear discrete time system subject to external disturbances and presents the design of event-triggered sliding mode control. The problem is organized in two main sections. First, we design a model-based reference trajectory. With application of a generalized non-switching type reaching law to the model, we achieve finite time convergence of the reference sliding variable to zero. Next, a model following reaching law is applied to the perturbed system in order to drive its representative point to the demand position in each step. However, we update the designed control

signal only when a certain triggering condition is met, therefore implementing an event-triggered control scheme. In the model following approach this condition is based on the error between the reference trajectory and the actual position of the system's representative point. As a result we not only limit the impact of external disturbances on the system but also reduce the need for communication between the system elements and provide more time for the intersampling calculations.

Paper: **8025** **B4L-A**

Model Parameters Variation in Constrained Discrete Time Sliding Mode Control

Marek Jaskuła, Piotr Leśniewski

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In this paper we take into account the variation of the model parameters, during the regulation process, in the discrete time sliding mode control approach. Moreover, the system is affected by unknown, but bounded external disturbances that do not need to satisfy the matching conditions. The controller guarantees the fastest, monotonic and finite time convergence of the representative point to the switching hyperplane, simultaneously ensuring constraints satisfaction on both state and input signal. Sufficient condition that assures all mentioned properties is formally proved and the simulation example demonstrates advantages of the theoretical considerations.

Paper: **8028** **B4L-A**

Observability of Singularly Perturbed Linear Time-Varying Systems on Time Scales

Olga Tsekhan*, Ewa Pawluszewicz**

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The problem of observability of singularly perturbed linear time-varying systems on any time model is considered. The robust on small singularity parameter sufficient conditions for complete observability of these classes of systems are presented. To this aim the decomposition approach on the basis of the Chang-type transformation is applied.

Extremal Problems for Hyperbolic Systems with Boundary Conditions Involving Time-Varying Delays

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Extremal problems for time-varying delay hyperbolic systems are presented. The optimal boundary control problems for hyperbolic systems with the Neumann boundary conditions involving time-varying delays are solved. The time horizon is fixed. Making use of Dubovicki-Milutin scheme, necessary and sufficient conditions of optimality for the Neumann problem with the quadratic performance functionals and constrained control are derived.

Day: **Tuesday, August 23rd, 2022**

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

Room: **Vasco da Gama**

Chair: **Jacek Kabziński**

Paper: **8016** B4L-B

Multi-Sensor Fusion for Navigation of Ground Vehicles

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In this paper, a navigation solution for a ground vehicle is developed by fusing navigation data from Inertial Navigation System (INS), Visual Odometry (VO), and Global Positioning System (GPS) using a Dual Extended Kalman Filter (DEKF) algorithm. The research contributions are divided in two stages. The first stage presents VO navigation system termed as Modified Stereo Visual Odometry (ModSVO) which modifies the pose estimation and pose optimization segments of the traditional stereo vision pipelines to provide an algorithm which is shown to improve accuracy when compared with the tradition Stereo Visual Odometry (SVO) approach. The second stage presents the development of INS/VO/GPS integrated navigation system using DEKF. The developed navigation solution is shown to outperform the INS/VO integrated system in case of VO failure and outperform the INS/GPS integrated system in case of GPS failure. The experimental evaluation is conducted on the well-known KITTI (Karlsruhe Institute of Technology and Toyota Technological Institute) real-world dataset.

Droneport: from Concept to Prototype

Lukáš Bláha*, Ondřej Severa*, Petr Barták, Tomáš Myslivec*, Arnold Jáger*, Jan Reitinger***

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The paper deals with the development of an experimental mechatronic system for battery management of drones called Droneport. It was developed as a cooperative system with battery swapping and recharging feature set outside the drone, allowing a quick return to mission. The paper presents its mechanical design, installed instrumentation and softwareenvironment. It is dedicated to the description of the individual hardware components and design process, highlighting particular problems that had to be solved to optimize the size, weight and robustness demands.

Implementation of Predictive Control for Remote Surgery Subject to Time Delay

Vivian Chai*, Dan-Sorin Necsulescu*, Jurek Sasiadek**

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This paper investigates the use of predictive control in a surgical setting when subjected to time delay. The performance of two controllers is explored, namely the PID and Smith predictor pair and the adaptive MPC, and shown to be successful for delays of up to 800ms. The PID and Smith predictor have superior performance, however, the MPC shows the ability to adapt to unexpected external forces. Future plans include further investigation into the effects of increased contact on the performance of these controllers.

Application of Tiny-ML Methods for Face Recognition in Social Robotics Using OhBot Robots

Eryka Probierz, Natalia Bartosiak, Martyna Wojnar, Kamil Skowroński, Adam Gałuszka, Tomasz Grzejszczak, Olaf Kędziora

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The aim of this paper is to show the possible application of Tiny-ML family neural networks to social robots for face recognition. Social robotics is a constantly developing field that allows the production and development of robots whose task is to accompany humans, participate in social situations and perform specific educational, entertainment and therapeutic tasks. For this purpose, solutions from the Tiny-ML stream are used. The paper uses a YOLOv4-tiny network, which was compared to a YOLOv5s solution, both in terms of efficiency and processing time. The proposed networks were tested on social robots of the OhBot type and with extended capabilities, by using Neural Sticks. The results obtained show the highest efficiency of the implemented YOLOv5s network using a Raspberry Pi along with an accelerator.

Path Planning for Automobile Urban Parking Through Curve Parametrization and Genetic Algorithm Optimization

Renan Porto Vieira, Téo Cerqueira Revoredo

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Parking a car is a difficult task and may be frustrating and stressful for the driver, while commonly causes a traffic jam. One way to mitigate such negative effects is to provide vehicles with self-driving capabilities. As a cornerstone of an automobile ability to move autonomously stands path planning, which despite many works in the literature, is still considered an open problem, especially with regard to nonholonomic vehicles. Based on this scenario, this work presents a path planning algorithm to parallel park an automobile based on polynomial parametrization and genetic algorithm optimization. The aim is to define a law of motion to lead the vehicle from an initial pose near a parking space to a final pose within the latter smoothly, with no interruption and avoiding any obstacles in the way. Simulation results in 3D physics simulation environment are presented to validate the feasibility of the proposed algorithm, which lay the foundation to broader studies.

Day: **Tuesday, August 23rd, 2022**

Time: **17:10 - 18:50**

Room: **Marco Polo**

Chair: **Harald Aschemann**

Paper: **8029** **B5L-A**

Improving the Detection of Noisy Labels in Image Datasets Using Modified Confidence Learning

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Verifying labels in the numerous available databases remains a complicated and laborious task. In this article, we present a MultiNET approach that allows for efficient verification of labeled image datasets. We adapt a state-of-the-art technique, namely Confidence Learning, extending its flexibility and improving the effectiveness by combining outcomes from various DNN architectures. Thanks to the proposed modification, it is possible to automatically detect incorrect labels while minimizing the number of false positives, thus making the verification process much less burdensome. The technique may be of use for researchers and software engineers dealing with externally supplied image datasets.

Constrained Control for Heterogeneous Vehicle Platoons

Felix Seeland, Fritz Miekautsch, Alexander Fay, Joachim Horn

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A control scheme for heterogeneous vehicle platoons is presented. A linearized homogenization controller is derived based on an algorithm to identify the required communication topology. This nominal controller is constrained by (higher order) zeroing barrier functions to enforce state constraints, such as actuator saturation, speed limits and safe inter vehicle distances. The results are demonstrated by means of numerical simulation.

Automatic Classification of Specification of ERP Modifications Documents

Katarzyna Grobler-Dębska*,, Bartłomiej Żak***, Marcin Ciurla***, Adam Domagała***, Adam Czarnołęski***, Jerzy Baranowski***

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Producing ERP software modifications during implementation is one of the longest lasting and most expensive stages of implementation.Although methodologies for conducting implementation projects are constantly being refined due to changing customer demands or technology, there are no tools to support the automation of implementation work. The paper presents the results of the InfoConsulting research and development project related to development of an NLP solution for implementation documentation in order to significantly shorten work and costs by automatically searching for similar solutions in previous implementations.

Logistics Processes Optimization in ERP Systems

Katarzyna Grobler-Dębska*,, Bartłomiej Żak***, Mateusz Fijas***, Marcin Kowalski***, Małgorzata Kopa***, Edyta Kucharska*, Jerzy Baranowski***

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Supply chain planning is a difficult task for organizations and both crucial for their profits and for market penetration. Many processes belonging to supply chain planning and management belong to discrete optimisation problems. Although science provides many methods for discrete optimization, business cannot apply them. The main software supporting management in companies are ERP systems. ERP support decision-making at the strategic, tactical and operational level. Most ERP systems, even at the leading edge, do not have complex optimisation algorithms implemented to support supply chain decision-making. The paper presents the results of the InfoConsulting research and development project related to design and implementation of a solution that allows modelling and simulation of logistic processes, material area, in a company and the implementation and optimisation of material logistics processes, which will communicate with typical ERP systems using communication of mobile devices.

Day: **Tuesday, August 23rd, 2022**

Time: **17:10 - 18:50**

Room: **Vasco da Gama**

Chair: **Grzegorz Bocewicz**

Paper: **8048** **B5L-B**

Active Speed and Cruise Control of the Mobile Robot Based on the Analysis of the Position of the Preceding Vehicle

Olaf Kędziora, Tomasz Grzejszczak, Eryka Probierz, Natalia Bartosiak, Martyna Wojnar, Kamil Skowroński, Adam Gałuszka

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The aim of this study was to implement a vision system on board of a Nvidia Jetson Nano along with a camera, and to implement the Jetracer platform control. To introduce the theoretical background, literature related to image processing, active cruise control, and autonomous vehicles was reviewed. The image processing and vehicle control methods used in this paper are then described. The remainder of the paper focuses on presenting an implementation of the described algorithms. This implementation was used to conduct tests, which show that the image processing methods investigated were sufficient to control the platform. Factors affecting thequality of control have also been described, these include vehicle speed and steering control gains. Comparative time dependencies of speed and steering level were plotted for selected trials, allowing the system delays to be noted.

Control of a Soft Actuator Using a Long Short-Term Memory Neural Network

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Soft robots offer new opportunities because of their compliant physical structure and their wide range of applications. Currently the development of such robots is hampered by their low controllability. One of the main constituents of soft robots are soft actuators. The aim of this project is to improve the control of a non-linear system, the soft actuator, and its interaction with the environment, by training a long short-term memory (LSTM) neural network to accurately predict the actuator's position in space, its curvature, and the force applied by its end-effector on an external object. The increased performance of the trained network resulted in an error as low as 0.01 ± 0.005 N in estimating the force applied by the end effector on the external object. The results show significantly superior performance (on the order of 10 times) in the positional and curvature predictions of the LSTM network when using one marker per air-chamber.

Bouncing Robots in Rectilinear Polygons

Onur Çağırıcı*, Yeganeh Bahoo*, Steven LaValle**

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In this paper, we describe a bouncing strategy (smart strategy) for a mobile robot that uses one bit of memory for feedback, and guarantees that the robot will traverse all the rooms (and corridors) of a 2D environment. The environment is modeled as a rectilinear polygon (also called orthogonal polygon), and the rooms and the corridors are defined by the decomposition algorithm we describe. Such a decomposition helps the robot to not go back to a room after leaving. We also define the notion of ``virtual doors" that have the ability to let the robot through, or make the robot bounce from them. We compared three different types of bouncing rules: smart, random, billiard. The smart strategy grantees to reach to target. Although the random strategy on average behaves the same as the smart strategy, there are rectilinear polygons in which the robot cannot reach the target in the expected time steps. On the other hand, the billiard bouncing strategy can cause the robot to become trapped.

TECHNICAL PROGRAM

Wednesday

August 24, 2022

Day: Wednesday, August 24th, 2022

Time: 9:00 – 10:00

Room: Marco Polo

Plenary Sesion, P-3

Day: Wednesday, August 24th, 2022

Time: 9:00 – 10:00

Room: Marco Polo

Chair: Harald Aschemann

Author: Wei Ren (University of California, CA, USA)

Paper: Distributed Control, Estimation & Optimization in Multi-agent Systems: Algorithms & Applications

Day: **Wednesday, August 24th, 2022**

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

Room: **Marco Polo**

Chair: **Wojciech Giernacki**

Paper: **8074** **C2L-A**

Early Fusion Based CNN Architecture for Visual Servoing Systems

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The goal of this work is to increase the performance of CNNs in visual control expanding neural input arrays with extra available data. For this, extra maps created via region-based segmentation are considered as input in an early fusion based architecture. These ready-to-use descriptions of the initial and final layouts can help CNN understand the scenes, and compute accurate velocities. The role of segmented maps is investigated on two different architectures that exemplify the suggested idea. The results show that CNNs with input fusion offer a better approximation of the linear and angular velocities, and proper robustness to segmentation errors.

Paper: **8066** **C2L-A**

Force-Control Capabilities for Lightweight Industrial Robots

Christian Thormann, Mohammad Ehsan Matour, Alexander Winkler

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This paper investigates the capabilities of lightweight industrial robots with respect to force/torque control. Two robots were chosen for this investigation. One robot was equipped with an internal force/torque sensor, while the other used motor current values to measure forces and torques. The robotic system used in this paper included a precast functions for force control. In particular, we analyzed the forces where the end-effector made contact with its environment (coming from free space). In the case of persistent contact, the desired contact force was altered, and the step responses were investigated. In addition, a more complex task involving force control was developed and presented to evaluate the quality of the precast force-control functions.

Design of One Degree of Freedom Rotating Platform Applied in Leader-Follower Autonomous Robot Control

Wojciech Kowalczyk, Arpit Joon

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This paper describes the design of one degree of free- dom rotating platform for an Intel RealSense sensor and a leader- follower control algorithm. The rotating platform will be placed on the follower robot to track the ArUco markers on the leader robot. Four ArUco markers will be placed on the leader robot in different directions. The proportional–integral–derivative con- troller (PID controller) helps the rotating platform track the ArUco marker independently from the motion of the follower robot itself. The pose of the leader robot will be calculated by the follower robot from the ArUco marker detection. This paper involves the simulation of the experiment in gazebo software in the Robot Operating System (ROS).

Day: **Wednesday, August 24th, 2022**

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

Room: **Vasco da Gama**

Chair: **Joachim Horn**

Paper: **8072** **C2L-B**

A Heatmap-Based Approach for Analyzing Traffic Sign Recognition and Lane Detection Algorithms

Bartosz Nieroda*, Tomasz Wojakowski*, Paweł Skruch*, Marcin Szelest**

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A heatmap is an efficient and convenient way to condense the information into a single snapshot. It can be also used in analysis of the high dimensional data structures that are representative for big datasets generated by the vehicle sensory systems. In this paper, we show how to generate such heatmaps from the vision data recorded by the front camera in the vehicle. We present two algorithms that can be applied to build heatmaps representing detection status of traffic signs and road lanes. The resulting graphs can be then used to evaluate in qualitative and quantitative way Traffic Sign Recognition and Lane Detection functionalities that are part of Advanced Driver Assistance Systems. The effectiveness of the presented approach is illustrated on several application use cases.

Paper: **8079** **C2L-B**

Metaheuristics for Scheduling on Parallel Machines Under Deteriorating and Maintenances

Tomasz Marchel, Radosław Rudek

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In this paper, we consider the parallel machine scheduling problem with the deteriorating effect and maintenances to minimize the makespan. The involvement of condition based maintenance activities

not only gives a potential to construct better models and more accurate decision support systems for real-life issues, but it also implies difficulties on search space traversal techniques to guarantee feasibility of results and not omitting optimality. Therefore, we propose well known and reliable metaheuristics that proved their efficiency for various combinatorial optimization problems, i.e., simulated annealing and tabu search. However, our implementations are based on a representation that due to multiple redundant solutions gains its significant advantage to cover all feasible schedules, therefore, the related optimization algorithms guarantee that the optimum is not excluded from the search space. The efficiency of our approach is verified on the basis of computational experiments.

Paper: **8088** **C2L-B**

Recognizing Commutator Motors Fault from Acoustics Signals Using Bayesian Functional Data Depth

Waldemar Bauer, Adrian Dudek, Jerzy Baranowski

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Effective and reliable monitoring and diagnostics of commutator motors is of utmost importance, as they are used in many domestic and industrial devices. Algorithms for fault detection and isolation allow extension of system lifetime, reduction in operation interruption and can lead to significant savings. In this paper we are presented how use Bayesian functional data depth to fault detection.

Day: **Wednesday, August 24th, 2022**

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

Room: **Poster Area**

Chair: **Krzysztof Okarma**

Paper: **8024** **C3P-C**

Incident Management Process Model for Automotive CyberSafety Systems Using the Business Process Model and Notation

Piotr Piątek

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Full cybersecurity in the vehicle industry is difficult to achieve without tight coordination with Functional Safety and SOTIF. Aside from the design and production stages, the dependencies also reach the maintenance phase. The study provides a complete model of the CyberSafety Incident Monitoring Process that meets all industry criteria. The article proposes utilizing Business Process Model and Notation (BPMN) to develop a comprehensive process model. The phantom attack scenario is used to assess the likelihood of realistic implementation. Described solution decreases time and effort required for a faster response to various vehicle threats when time is critical.

Paper: **8031** **C3P-C**

Adaptation of Ultra Wide Band Positioning System for Adaptive Monte Carlo Localization

Sławomir Romaniuk, Adam Wolniakowski, Adam Pawłowski, Cezary Kownacki

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Self-localization problem of mobile robots is a crucial part of autonomous navigation, especially indoor environments, where the usage of GNSS technology is impossible. There is a lot of studies that focus on this issue, starting from those based on the Monte Carlo Localization (MCL) method, and ending on a variety of SLAM approaches. The UWB (Ultra-Wide Band) technology allows for improvement of these methods since a local positioning system based on it becomes available in

indoor environments. This paper proposes an innovative approach to Adaptive Monte Carlo Localization (AMCL) method, which adapts UWB transceivers as a local positioning system. The advantages of applying UWB in AMCL are proved by experimental tests with Automated Guided Vehicle (AGV) in indoor environment. Local positioning system based on UWB transceivers was substituted for a standard odometry source through a modification of original AGV's ROS (robot operating system) setup. Further advantage of the proposed approach is to enable the standard ROS navigation stack use in cases where no odometry information is available.

Paper: **8033** **C3P-C**

Comparison of Mobile Platform Teleoperation Systems Using a Force-Torque Sensor and a Joystick

Adam Pawłowski, Adam Wolniakowski, Sławomir Romaniuk

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Teleoperation is therefore a very important topic. There is an extensive research covering the problem of the Human-Machine Interface (HMI) aspect of teleoperation. Numerous devices exist that allow for human control of robotic platforms. These devices offer various advantages and disadvantages that make them suited for different modes of operation. In this work, we focus on implementing a mobile platform teleoperation system with the use of a force-torque sensor. We present the configuration of such system using ROS and compare experimentally the performance of the proposed device with a typicalapproach using joystick control.

Paper: **8077** **C3P-C**

Method of Evaluation of Effectiveness of the Radio Communication System in Conditions of Non-Deterministic Environment

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The article proposes a method for evaluating the effectiveness of the radio communication system in conditions of a non-deterministic environment and gives an example of its application. The developed method allows to evaluate the efficiency of the radio communication system depending on its composition, the coordinates of the location of mobile and stationary means, the structural distribution of radio communication means by communication center for different environmental conditions.

Recognition of Colonial and Multicellular Microplankton Organisms in Surface Waters Using Computer Vision

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A method is proposed for increasing the accuracy of an information-measuring system that measures the concentration of microplankton in a running stream. The article considers the problem of accuracy increasing in recognition and counting of colonial and multicellular microplankton organisms in determining the biological indicators of water quality in natural reservoirs. In the paper was presented a method has been developed to improve the recognition accuracy of colonial and multicellular organisms of microplankton, which is notable for low computational complexity and allows increasing the accuracy of measuring the concentrations of various groups of microplankton.

Optimization of the Stabilization Problem for the Vehicle Active Suspension System Using Linear Dynamic Feedback Control

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In this paper, a vehicle suspension system in the form of the quarter vehicle suspension model is investigated. Such model consists of two mass bodies connected via springs and dampers. The principle of the active suspension control is to design effective algorithm aimed to reduce vibrations of the masses. From the application point of view, effectiveness of the algorithm is related to fast implementation, usually on embedded platform with limited resources and performance metrics such as settling time and maximum overshoot. To meet these objectives a linear dynamic control law is proposed which parameters are selected to minimize defined performance index. The stability property of the closed-loop system is proved by the use of a Lyapunov functional and LaSalle's invariance princple. Effectiveness of the proposed stabilization approach is compared against the PID controller.

Discrete Fractional Order PID Controller in Case of the FLHex Robot Leg Position Control System

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Practical implementation of the fractional-order PID (FOPID) controller for the FLHex robot leg position control system with a comparison of selected performance indexes for different controller's coefficients. In the case of systems such as the FLHex mobile robot, where multiple PID controllers are used, more advanced control algorithms such as the FOPID controller can improve quality of control and energy consumption, which is extremely important in the case of mobile robots. Presented comparison of FOPID controllers with varying coefficients in case of leg underwater movement for step sequence setpoint shown differences in parameters of averaged step response, integrals of the squared error (ISE) and integrals of energy consumption (IEC).

Hybrid VTOL UAV Autonomous Operations from Mobile Landing Pad

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Flight missions carried out from mobile landing pads are a challenge for hybrid VTOL UAVs. An approach to precise landing on a moving pad requires implementing an appropriate control system supported by accurate relative positioning. The paper presents the results of real conditions test on such a UAV system, which is a combination of hybrid VTOL UAV and dedicated landing pad navigation station that was developed to allow UAVS to take off and land on a mobile platform. Tests were carried out by employing a mobile landing platform mounted on a trailer pulled by a car. During the tests, the hybrid VTOL UAV was able to take off and land on the landing platform moving at a speed up to 25 km/h, and all flight trials ended with success. These tests improved the UAV system before the final test on maritime conditions.

Machine Learning Methods for Anomaly Detection in Computer Networks

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With a large increase in the amount of data that are transferred through publicly available computer networks, the global demand for new protection and prevention methods could be observed in recent studies of many research groups. The paper deals with anomaly detection, focusing on cybersecurity applications, as there are only few papers that address this topic. Four methods, such as DBSCAN, One-class SVM, LSTM and Isolation forest were used to solve this problem. During the experimental part, the implementation and experiments were performed to examine the performance on common dataset to assess the ability and further possible applications.

Day: **Wednesday, August 24th, 2022**

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

Room: **Marco Polo**

Chair: **Dariusz Pazderski**

Paper: **8006** **C4L-A**

Simulation and Optimization of Industrial Disassembly Paths Using Position Based Dynamics

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In this paper, we propose a postprocessing method for industrial assembly paths. Our method is based on Position Based Dynamics (PBD) and is able to simulate and optimize given assembly paths. We use the PBD framework to simulate and measure the object deformation along the assembly path. For the optimization of the path, we compare the deformed object to the original rigid object and we apply small corrections to the path that decrease the overall deformation. We show the effectiveness of our approach on industrial disassembly scenarios.

Paper: **8009** **C4L-A**

Inverse Kinematics for Serial Robot Manipulator End Effector Position and Orientation by Particle Swarm Optimization

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This paper investigates the use of Particle Swarm Optimization (PSO) approach in solving the inverse kinematics problem for serial robotic manipulators. Inverse kinematics is a fundamental problem in robotics: a set of joint angles must be calculated so that the robot arm can be manipulated to the

corresponding desired end effector position and orientation. Traditional solution techniques include analytical methods which may or may not exist for a particular robot, numerical methods such as Newton-Raphson, Jacobian inverse and other techniques using swarm intelligence have been developed. Many of the reviewed robotic manipulator inverse kinematics solutions using swarm intelligence only deal with end effector position and not its orientation. Our PSO approach provides the convergence of a complete end effector pose and will be demonstrated using the Baxter Research Robot which has two seven-joint arms although the method can be applied to any general serial robotic manipulator.

Paper: **8020** **C4L-A**

Simulated Annealing-Based Energy Efficient Route Planning for Urban Service Robots

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The work provides global route planning to an autonomous municipality – dustbin – emptying robot MURMEL and its assistance vehicle. The dustbins are the waypoints, distributed over the path network of Berlin. The route planning is based on cost function of energy expenditure and derived with the help of Simulated Annealing approach. The results in our work lead to a reduction of 11% energy consumption and supports MURMEL in utilizing its maximum garbage collection capacity with the mothership. This work generalizes the global path planning for various other such urban service robots in outdoor environments with multiple targets.

Paper: **8021** **C4L-A**

Sim2Real Deep Reinforcement Learning of Compliance-Based Robotic Assembly Operations

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In this paper, we present an approach to learn a contact-rich pegin-hole assembly task utilizing DRL and a compliant robot controller. The DRL-Agent learns directly in the Cartesian space and not in the joint space of the robot. To further increase the robustness of the policy, geometric limitations are imposed by introducing a trajectory generator. Furthermore, these limitations result in nearly identical behavior in the simulation and on the real robot, allowing the DRL training process to be purely simulative. The learned policy is experimentally investigated in the simulation environment and on a real robot, to evaluate the sim2real transfer.

Day: **Wednesday, August 24th, 2022**

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

Room: **Vasco da Gama**

Chair: **Jerzy Klamka**

Paper: **8045** **C4L-B**

Petri Net Approach to Automated Modelling and Performance Evaluation for Robotic Assembly Systems

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The paper presents a method of automated modelling and performance evaluation of concurrent production flows carried out in robotic assembly systems. The method allows for quick assessment of various variants of such systems, considering their structure and the organization of production flow of possible ways of their implementation is carried out. The reference model follows the Petri net theory formalism framework. Its essence is the conditions imposed on the designed model, limiting the space of possible variants of the production flow only to deadlock-free variants. The practical usefulness of the model implemented in the proposed method illustrates the example describing the simultaneous assessment of alternative variants of the assembly system's structure and the planned multi-assortment production. Finally, its capacity to focus on feasible solutions offers attractive perspectives for guiding the Digital Twin like scenario in situations caused by the need to change the production flow.

Differential Game to Evaluate the Worst Case Influence of a Varying Disturbance on the Minimal Time Solution for a Small Vehicle Movement

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The problem of an autonomous agent moving on a planar surface can be treated as navigation between a series of points. During planning the agents have to take into account both discrete and continuous changes, as well as temporal constraints. While nominally the movement between each pair of points can be treated as a 1D projection of the movement on the vector connecting the two points, in the presence of disturbances, the full problem on the plane must be considered. The minimum-time optimal solution is dependent on the value and direction of the disturbance which in this paper is assumed to be a sum of a constant velocity of the medium (wind or current, respectively) and a bounded time-varying part with uncertain but bounded time derivative. We address the minimum time problem of a movement on a 2D plane with quadratic drag, under norm state (inertial vessel velocity), and norm control (acceleration) constraints. The worst case influence of an uncertain disturbance is evaluated by consideration of a differential game with state and control constraints. The structure and properties of the optimal solution are found and analyzed.

Scheduling Jobs with Machine-Dependent Release Dates on Unrelated Machines

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This paper considers the job scheduling problem with varying release dates on unrelated parallel machines. Our model involves the machine-dependent release dates and the makespan criterion. The two developed and presented constructive deterministic algorithms use different decomposition strategies that ,resulting logically from exploiting the problem structure. The approximation factor of the greedy polynomial algorithm depends on the machines. An efficient adaptation of the well-known brute-force technique to solve Rm|r_{i,j}|C_max is also considered in this paper. A series of numerical experiments are conducted to compare the quality of schedules.

A Note on a Minimum Detectable Actuator Fault of Dynamic Systems Under Ellipsoidal Bounding

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The paper deals with the estimation of actuator faults for dynamic systems along with assessing their uncertainty. In particular, it is assumed that the external disturbances are bounded within an ellipsoidal domain. For the purpose of further deliberations, H-infinity performance is also imposed. As a result, a set of complementary fault uncertainty intervals is obtained, which are minimised in such a way as to obtain a minimum detectable actuator fault. The final part of the paper show a numerical example concerning fault estimation of a multi-tank system.

Day: **Wednesday, August 24th, 2022**

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

Room: **Marco Polo**

Chair: **Milica Petrovic**

Paper: **8010** **C5L-A**

Extended State Observer Based Parameter Identification of the Hovercraft System

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In this paper, a problem of online identification of the dynamic parameters of the hovercraft system is considered. A novel approach is presented which employs an extended state observer and takes advantage of the total disturbance estimate as a basis of gradient identification method. This enables simultaneous estimation of both the state of the plant and the values of the system parameters.

Paper: **8069** **C5L-A**

Practical Implementation of Anti-Skew Fuzzy Logic Controller for Semi-Gantry Crane

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This paper presents a case study of a 4 input 1 output Fuzzy Logic Controller implementing the anti-skew control for a semi-gantry crane. It was necessary due to the wear and tear caused by the skewed movement and the braking resistor overheating. The control system is designed to monitor two analog proximity sensors, measuring the carriage-to-rail distance as well as the torque feedback from the drives. The fuzzy algorithm is implemented on a Programmable Logic Controller and controls the Variable Frequency Drives through digital and analog signals. The proposed control system performed as intended, by preventing the traveling motors from the generator work and the crane from skewing.

New Approach to Functional Safety Work Products for Advanced Automotive Projects

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ISO 26262 is a standard aimed at the possibility of its wide application (also for the simplest products), unfortunately for highly complex products such as integrated safety systems, such high-level work products can be too general without contributing key information at the start of the project. The article presents a list of additional, more precise work products dedicated specifically to highly advanced safety systems in automotive projects. It can be used at the request for quote stage when building documentation for functional safety. In addition, the list of work products listed and introduced to the additional process helps to determine the scope of responsibilities in the organization at the beginning of the project. Especially where the issues of functional safety and safety of the intended functionality are presented. This helps to avoid the risk of security liability gaps with potentially fatal consequences for the end-user.

Two Points Classical Identification Methods on the Example of a Three-Tank Interacting and Non-Interacting System

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This paper mainly focuses on various two-point methods of identifying the First Order Plus Time Delay (FOPTD) model, and their impact on control quality. The following criteria were used to match the identification method: ISE between the response of the real system and the model and the normalized delay time. The work used two different tuning techniques: QDR and pidtune. A three-tank interacting and non-interacting system was used as a model for the tests. All tests were simulated in Matlab environment, ISE and settling time were used to assess the quality of control.

Frequency-Based Identification Routine for the Inertial Parameters of an Industrial Robot

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This paper presents an identification routine for the inertial parameters of a 6-degree-of-freedom IR based on the frequency response measurements of the SCS and a genetic algorithm conditioning approach. These measurements are less susceptible to noise and offer the possibility to incorporate friction effects using phase information. In addition, the presented identification model is independent of the joint speed and acceleration, allowing for the optimization of the observation matrix exclusively through the pose. The GA is used to define an optimal set of poses while considering possible collisions at the same time.

Day: **Wednesday, August 24th, 2022**

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

Room: **Vasco da Gama**

Chair: **Per-Olof Gutman**

Paper: **8005** **C5L-B**

Self-Supervised Task Learning for Robotic Underfloor Insulation

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Effective under-floor insulation (UFI) of residential buildings to reduce their energy consumption and CO2 emissions is a substantive challenge in retrofitting existing homes. Traditional UFI installation techniques require suspended floors to be taken up, damaging and disrupting the living space for several days. To deliver the low-disruption insulation of suspended floors, a robot has been developed for accessing and spraying the insulation to the underside of a suspended floor. However, one of the challenges that the robotic spray system needs to address is autonomously identifying the spray location to apply insulation, navigating the robot to the optimum location, and applying the insulation. In order to address this challenge a learning-based approach that learns the task of spraying insulation foam in underfloor voids from experience is proposed. The system is trained on data gathered from real-world underfloor void sites without any simulation or human supervision. It can adapt to various operator preferences, generalize to novel building crawl spaces, and improve with more data.

Actuator Fault Detection and Isolation System for Multirotor Unmanned Aerial Vehicles

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The article presents a new method of detecting and isolating damages to actuators for unmanned aerial vehicles. The process of preparation of the discussed method and its implementation was demonstrated. The features of accelerometer measurements were used to train the artificial neural network. The network model has been implemented in a microcontroller. The tests were carried out on data collected during the actual flight. The overall accuracy of the proposed method was 98.08% with no presence of false alarms. Real-time classification has been proven. The results were compared with another method.

Elitism Mechanism in the Genetic Optimization of Networked Distribution Systems

Lukasz Wieczorek, Przemyslaw Ignaciuk

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This paper addresses the inventory control problem in distribution systems with a non-trivial, networked connectivity structure and goods relocation with delay. The distributed (r, Q) inventory management policy is applied to control the replenishment process at network nodes in response to uncertain market demand. The non-dominated sorting genetic algorithm (NSGA) is used to solve a nonlinear three-objective optimization problem focused on reducing operational costs and providing high customer satisfaction. The performed numerical studies confirmed the effectiveness of the NSGA in adjusting the parameters of the (r, Q) policy in the considered class of logistic systems. The consequences of applying the elitism mechanism are discussed via observation of various performance indicators commonly considered in multi-objective optimization problems. The obtained Pareto set approximations have been compared in terms of cardinality, convergence, and diversity of potential solutions.

Implementation and Analysis of Sparse Random Search Adversarial Attack

Piotr Satała, Krystian Radlak

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Adversarial attacks have shown that deep neural networks can drastically change their output based on a relatively small input perturbation. One of the most promising adversarial attacks is based on random search (RS). RS algorithm iteratively moves the current solution to the better one in the search space, which is sampled from a hypersphere surrounding the current solution. In the case of adversarial attacks, RS randomly modifies a given number of pixels in an input image to change the network's original prediction. This paper presents the implementation and analysis of the Sparse-RS algorithm for adversarial attacks generation. Furthermore, we study and compare several extensions of the original algorithm to improve its effectiveness. In the performed experiments, (1) we analyze the impact of limiting attack search space to the edges of the image and to the most significant pixels indicated by saliency maps, (2) we evaluate the process of greedily minimizing the number of perturbed pixels in a successful attack, (3) we propose a novel schedule to dynamically adjust how many pixels should be replaced in the next iteration.

Implementation Aspects of Q-Learning Controller for a Class of Dynamical Processes

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This paper presents a new approach to the general-purpose self-improving controller based on Q-learning control strategies. The previous approach was based on a three-dimensional Q-matrix, significantly slowing down the learning process and limiting the ability of practical implementation in industrial practice. The proposed new algorithm solves this problem by reducing the size of the matrix and the number of tuning parameters of the method without sacrificing its accuracy and learning capabilities. The algorithm is validated by simulation on the two second-order dynamics models and the results show significant improvement compared to the previous version of the developed method.

Thursday

August 25, 2022

Day: **Thursday, August 25th, 2022**

Time: **9:00 – 10:00**

Room: **Marco Polo**

Plenary Sesion, P-4

Day: **Thursday, August 25th, 2022**

Time: **9:00 – 10:00**

Room: **Marco Polo**

Chair: **Józef Korbicz**

Author: **Jacek Kluska (Rzeszow University of Technology, Poland)**

Paper: **Interpretable Fuzzy Rule-Based Systems for Adaptive Control & Data Classification**

Day: **Thursday, August 25th, 2022**

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

Room: **Marco Polo**

Chair: **Krzysztof Oprzędkiewicz**

Paper: **8068** **D2L-A**

Control System for an Innovative Electrostatic Enameling Process of Water Tanks' Interiors

Michał Jurkiewicz*, Robert Janicki*, Wojciech P. Hunek, Krzysztof Bartecki**, Paweł Majewski****

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In this paper, a PLC-oriented control system dedicated to the real-life technological line of the enameling process is presented. Following the recently built industrial device employing the electrostatic method, the complex control layer is proposed and its advantages are deeply discussed. In addition, the entire safety mechanism is suggested in order to maintain a set of correct operations. The next step of the advanced studies will be focused on the different practical tests finally leading to the process and product innovation observed in the Elektromet Company.

Paper: **8085** **D2L-A**

Frequency Weighted Model Reduction in Approximation of Nabla Difference-Based Discrete-Time Fractional-Order Systems

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The article presents new results in terms of Frequency Weighted (FW) model reduction method in application to approximate LTI discrete-time non-commensurate fractional-order systems based on the Grunwald-Letnikov nabla fractional-order difference. The method applies the Fourier-based

decomposition of the system and the FW model order reduction method. The main advantage of the proposed modeling approach is the specific representation of the fractional-order system enabling a simple, analytical formula for the determination of the Gramians. This significantly improves the computational efficiency of the proposed FW reduction method. The simulation experiments confirm the low computational effort of the introduced processing and its high modeling accuracy.

Paper: **8086** **D2L-A**

Forecasting Models for Polish Coal Mining Accidents

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In paper, forecasting models using exponential smoothing for Polish coal mining safety accidents are presented. Prior to this, data is analyzed and approach for building forecasting models in Tableau is described in details. Three forecasting models are revealed, respectively for all accidents in coal mines, fatal accidents and employment. Received results are promising and confidence intervals cover the predictions well. Improved forecast accuracy with presented models might provide coal mine enterprises more precise data, supporting safety management in those organizations.

Day: **Thursday, August 25th, 2022**

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

Room: **Vasco da Gama**

Chair: **Radosław Rudek**

Paper: **8052** **D2L-B**

Multi-Objective Population-Based Optimization Algorithms for Scheduling of Manufacturing Entities

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In this paper, the authors present the comprehensive analysis of population-based multi-objective optimization algorithms utilized for scheduling of manufacturing entities. The output of multi-objective optimization is a set of Pareto optimal solutions in the form of production scheduling plans with transportation constraints. Three state-of-the-art population-based algorithms i.e., Genetic Algorithm (GA), Particle Swarm Optimization (PSO), and Whale Optimization Algorithm (WOA) are employed for optimization, and the experimental results show the effectiveness and superiority of the WOA algorithm.

Real-Time Path Planning for Autonomous Navigation Systems of Unmanned Surface Vehicles

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The paper presents results of research on the development of collision avoidance algorithms dedicated for the application in the Autonomous Navigation Systems of Unmanned Surface Vehicles. Autonomous vehicles constitute a dynamically developing area of research. One of the main issues related to this technology is the ability to avoid collisions with obstacles. Deterministic and non-deterministic algorithms developed for the purpose of the Unmanned Surface Vehicle real-time path planning are briefly introduced and results of tests carried out in order to evaluate the proposed methods are presented.

Genetic Algorithm for Resource Leveling Problems Under Various Objective Functions

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In this paper some resource leveling problems for project scheduling under resource constraints are considered. In this problem activities of a project are to be scheduled in a way that all precedence and resource constraints are satisfied, and a given objective function describing the fluctuations of resource usage is minimized. Activities are nonpreemptable, and resources are renewable. Several various objective functions for the problem are analyzed. A genetic algorithm is proposed to solve this strongly NP-hard problem. The performance of the algorithm is examined and compared to other simple heuristics on a basis of a computational experiment performed on a set of standard benchmark instances.

Day: **Thursday, August 25th, 2022**

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

Room: **Marco Polo**

Chair: **Paweł Skruch**

Paper: **8036** **D3L-A**

Benchmarking Nonlinear Model Predictive Control with Input Parameterizations

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Model Predictive Control while being a effective control technique can become computationally demanding when a large prediction horizon is selected. To make the problem tractable, one technique that has been proposed in the literature makes use of control input parameterizations to decrease the numerical complexity of nonlinear MPC problems without affecting the performances. In this paper, we review the use of parameterizations and propose a simple Sequential Quadratic Programming algorithm for nonlinear MPC. We benchmark the performances of the solver in simulation and compare them with state-of-the-art solvers. Results show that parameterizations allow to attain good performances with lower computation times.

Paper: **8039** **D3L-A**

Force Controlled Deburring Using a Collaborative Robot

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This paper proposes a novel approach to robotic deburring. The novelty of our work lies in the use of a simple deburring tool, which is usually used for manual deburring. Moreover, we have used as the manipulator a collaborative robot working in hybrid motion-force control. Since the force and velocity of the robots play a decisive role in deburring, we have investigated the minimum and maximum

limits of these parameters through various experiments. To our knowledge, this is the first scientific work using a cobot and a simple hand-deburring tool.

Paper: **8042** **D3L-A**

On a Hypergraph Structuring Semantic Information for Robots Navigating and Conducting Their Task in Real-World, Indoor Environments

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Robotic systems operating in the real world would benefit from a clear semantic model to understand their interactions with the real world. Such semantics are typically captured in an ontology. Unfortunately, existing world models in robotics focus on its navigation task. They adopt a hierarchical structure decomposing the environment from large spaces into small objects having a position, thereby limiting the robot's interactions as a ``go-to-object'' task. To allow a richer understanding of the real world this hierarchical structure should be replaced with an ontology, yet one that does not limit the real-time requirements of the robot when it is queried or updated with new observations extracted from sensors. Such an ontology is presented in this article. For now the ontology also focusses on the navigation aspect of robots, yet it is open to model other aspects of the real world as well. Experiments show that multiple environments are successfully modelled supporting the robot to go from on room to another to search for humans.

Paper: **8043** **D3L-A**

Indoor Navigation System of Mobile Robot with Trajectory Optimization

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This paper proposes a navigation system for mobile robot working in indoor environment, which includes mapping and trajectory generation for the motion tracking problem of the real mobile robot. The mapping process comprises a Gaussian model to improve the accuracy of the environment representation. With this new mapping method, the mobile robot knows the obstacle in the environment around robot itself. For the trajectory generation process, a multimodality method is used to explore all feasible paths to reach the target point by estimating the density of distribution of the objective function. Finally, the experiments show the effectiveness of this navigation framework.

Day: **Thursday, August 25th, 2022**

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

Room: **Vasco da Gama**

Chair: **Paweł Majewski**

Paper: **8019** **D3L-B**

A New Sliding-Mode Control Law for a Planar Dielectric Elastomer Actuator to Track Wide-Band Trajectories

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Dielectric Elastomer Actuator (DEA) based soft robots are gaining widespread recognition for numerous applications such as; medical devices, bio-inspired systems and flexible prosthetics to name but a few. Due to their nonlinearity relating mostly to hysteresis and creep, most DEAs are subject to precision positioning challenges. To enable precise positioning, control-enabling DEA models and controllers are developed to curb the issues of their nonlinear dynamics. This paper presents a new Sliding-Mode Control (SMC) based on reaching law for precise position tracking of an adopted simplified and experimentally validated DEA model. The proposed reaching law incorporates a high-slope saturation function with an exponential denominator to drastically reduce chattering and enhance fast and finite convergence. The sliding-mode controller stability is validated using a Lyapunov candidate for asymptotic stable. Finally, Closed-loop simulations demonstrating the controller's effectiveness at suppressing chattering and tracking wide-band trajectories (triangular and sinusoidal) were implemented.

A Remark on Cascaded Energy Based Trajectory Tracking Control of a Quadrotor

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Considering the cascaded energy based trajectory tracking control of a quadrotor, the first and second time derivative of the orientation of the desired thrust force are derived, that are required for the trajectory tracking of the attitude of the quadrotor in the inner control loop. A simulation of the control system shows that the closed-form expressions of the orientation of the desired thrust force and the first and second time derivative are consistent.

A Note of a Legless Capsubot Robot Control

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The presented paper contains comparison two controllers applied to the control system of capsubot robot. We show application of fractional order PID (FOPID) and integer order PID controllers with tuning parameters by particle swarm optimization (PSO). A criteria of optimization is Integral of Time multiplied by Absolute Error (ITAE). Finally, the comparison of obtained result for control system with standard PID and FOPID controllers of capsubot robot using PSO algorithm tuning in Matlab is presented. To the best of author's knowledge, no study has been conducted to investigate control systems with PID and FOPID controllers for presented type of capsubot.

Design of an ADCs Test Stand for Nanosatellites

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ADCS test stands are used for on-the-ground testing of satellite altitude determination and control systems. Their main purpose is to simulate time-vaying conditions similar to those found in outer space on a geocentric orbit. The paper presents the main component of the ADCS test stand – a Helmholtz cage used to simulate the orbital magnetic field. The design and integration of mechanical,

electrical, electronic and software components that led to a highly uniform and precisely controlled magnetic field is described here. The validation process, including 3D scanning of the magnetic field, is presented. Remarks on the employed technology, limitations of the proposed solution, some design recommendations, and plans for future work are provided.

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SESSIONS

NOTES

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.