WELCOME

from the MMAR 2024 Organizing Committee

I would like to invite you to Międzyzdroje, Poland for the 28th International Conference on Methods and Models in Automation and Robotics organized by the Faculty of Electrical Engineering of the West Pomeranian University of Technology in Szczecin and the Polish Academy of Sciences. Almost 120 draft papers have been submitted, from which the International Program Committee, chaired by Professor Andrzej Bartoszewicz, has selected 103 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, 27 August 2024. Four distinguished scientists will present their lectures in plenary sessions, other papers will be presented in two parallel regular sessions, some of them in an on-line form. 10 papers are to be presented in two special sessions, 37 in four poster sessions. All the MMAR 2024 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 2024 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

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Phone: (+48 91) 328 1000

WWW SITE

The Final Program

of the MMAR 2024 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 2024 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 2024.

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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 28th in a series which started in 1994.

VENUE AND DATES

The Conference will be held at the Amber Baltic Hotel in Międzyzdroje, from Tuesday, 27 August till Friday, 30 August 2024.

The Conference registration desk in Amber Baltic Hotel will be opened on the Tuesday morning, 27 August and during each day of the Conference.

The Conference will start on Tuesday, 27 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, 27th August, 2024

	Room 1 Marco Polo	Room 2 Vasco da Gama
11.00 – 15.00	**Registration opens** (Amber hotel main hall)	
15.00 – 15.30	**Conference Opening**	
15.30 – 16.30	Plenary Lecture (Marco Polo), Chair: Tadeusz Kaczorek **Application of recurrent neural networks and generalized inverses in optimization and design of perfect minimum energy control** Speaker: **Predrag Stanimirović**	
16.40 – 18.00	A1L-A **Special Session on the Occasion of the Jubilee of Prof. Zbigniew Emirsajłow Session** Chair: Józef Korbicz 6005, 6007, 6033, 6038	
19.00	**Welcome Party** (barbecue, On Deck Restaurant, Amber Baltic Hotel)	

Wednesday, 28th August, 2024

	Room 1 **Marco Polo**	Room 2 **Vasco da Gama**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: Andrzej Bartoszewicz **Using Delay for Control** Speaker: **Emilia Fridman**	
10.10 – 11.10	B1L-A **Robotics I** Chair: Dariusz Pazderski 6009, 6011, 6061	B1L-B **Control Applications I** Chair: Krzysztof Oprzędkiewicz 6016, 6026, 6041
11.00 – 13.00	B2P-C **Poster Session I** (Poster area) Chair: Krzysztof Okarma 6004, 6017, 6039, 6070, 6072, 6076, 6105, 6106, 6119, 6120	
11.10 – 11.40	Coffee break	
11.40 – 13.00	B3L-A **Robotics II** Chair: Przemysław Herman 6066, 6071, 6087, 6060	B3L-B **Modelling & Simulation I** Chair: Paweł Majewski 6010, 6069, 6088, 6013
13.00 – 15.00	Lunch	
15.00 – 16.40	B4L-A **Robotics III** Chair: Maciej Michałek 6002, 6019, 6021, 6036, 6042	B4L-B **Control Applications II** Chair: Andreas Rauh 6003, 6029, 6031, 6048, 6055
15.00 – 16.40	B5P-C **Poster Session II** (Poster area) Chair: Przemysław Orłowski 6020, 6023, 6049, 6053, 6063, 6064, 6079, 6086, 6116, 6114	
19.30	**Conference Banquet** (Amber Baltic Hotel, Christoper Columbus Hall)	

Thursday, 29th August, 2024

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gama**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: Józef Korbicz **Navigation of cooperative robotic teams** Speaker: **Ming Cao**	
10.10 – 11.10	C1L-A **Intelligent Systems & Methods I** Chair: Marcin Witczak 6065, 6110, 6111	C1L-B **Special Session on Nonlinear Control: Theory and Applications I** Chair: Witold Respondek 6034, 6067, 6115
11.00 – 13.00	C2P-C **Poster Session III** (Poster area) Chair: Paweł Latosiński 6015, 6028, 6035, 6045, 6057, 6062, 6082, 6101	
11.10 – 11.40	Coffee break	
11.40 – 13.00	C3L-A **Robotics IV** Chair: Wojciech Giernacki 6089, 6093, 6102, 6103	C3L-B **Control Applications III** Chair: Rafał Stanisławski 6018, 6080, 6047, 6118
13.00 – 15.00	Lunch (Amber hotel)	
15.00 – 16.40	C4L-A **Modelling & Simulation II** Chair: Ewa Pawłuszewicz 6121, 6008, 6040, 6078, 6112	C4L-B **Control & System Theory I** Chair: Jacek Kabziński 6022, 6032, 6046, 6095, 6094
15.00 – 16.40	C5P-C **Poster Session IV** (Poster area) Chair: Jerzy Baranowski 6006, 6013, 6058, 6090, 6091, 6098, 6099, 6107, 6108	
17.10	**Touristic Programme** (Trip to a golf club. Buses leave from Amber Baltic, duration: 3 hours)	

Friday, 30th August, 2024

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gama**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: Zdzisław Kowalczuk **Kinematics and Control of Articulated Vehicles** Speaker: **Maciej Michałek**	
10.10 – 11.10	D1L-A **Robotics V** Chair: Janusz Szpytko 6117, 6092, 6025	D1L-B **Special Session on Nonlinear Control: Theory and Applications II** Chair: Witold Respondek 6050, 6024, 6104
11.10 – 11.40	Coffee break	
11.40 – 13.00	D2L-A **Robotics VI** Chair: Ryszard Beniak 6051, 6056, 6083, 6084	D2L-B **Control & System Theory II** Chair: Jerzy Baranowski 6100, 6077, 6044, 6012
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 27, 2024

Conference Opening

Day: **Tuesday, August 27th, 2024**

Time: **15:00 – 15:30**

Room: **Marco Polo**

Plenary 1, A0L-A

Day: **Tuesday, August 27th, 2024**

Time: **15:30 – 16:30**

Room: **Marco Polo**

Chair: **Tadeusz Kaczorek**

Author: **Predrag Stanimirović (University of Niś , Serbia)**

Paper: **Application of recurrent neural networks and generalized inverses in optimization and design of perfect minimum energy control**

Special Session on the Occasion of the Jubilee of Prof. Zbigniew Emirsajłow Session, A1L-A

Day: **Tuesday, August 27th, 2024**

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

Room: **Marco Polo**

Chair: **Józef Korbicz**

Paper: **6005** **A1L-A**

Design of Linear Systems with Desired Poles and Zeros of the Transfer Matrices

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A new method for the design of linear systems with desired poles and zeros of their transfer matrices is proposed. Conditions for the existence of the solution to the problem and the procedure for computation of the desired matrices are given. The procedure is illustrated by numerical simple examples.

Paper: **6007** **A1L-A**

The Sensitivity Analysis of the Fractional Uncertain Order State Space Model of the One-Dimensional Heat Transfer Process

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The paper deals with the analysis of the sensitivity of a new, fractional interval order model of the heat transfer in one dimensional body. In the model the derivative with respect to time is described by the fractional Caputo operator (C operator). The order of the C operator is not exactly known and it is described by an interval. Such a model has not been proposed yet and it is expected to properly describe e.g. disturbed measurements. For this model new senstivitity functions are proposed and used to numerical analysis. Simulations are supported by experimental data.

Optimal control and optimum design of elasticity system: Topological derivative method for control problem

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We consider a class of boundary dynamic optimal control problems for elasticity system in geometric domain. The class of control problems admits the so-called Turnpike Property. The relation of optimal controls for static problem and dynamic problem is investigated. Thus, we consider the steady state problem in order to compute the optimal control. The cost is minimized with respect to boundary controls. At the same time the optimal cost of control is minimized with respect to the shape and topology of its domain of integration. The topological optimum design problem is solved by the topological derivative method for the steady state model. The level set function for the purposes of topology optimization is defined. The numerical results for topology optimization are presented.

Control and optimum design for networks with nonlinear state equations

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Optimal control problem for semilinear hyperbolic equations is considered on 3-star metric graph. The distributed controls on the edges are considered. The tracking type cost to steady state is considered for the control problem. Using the Turnpike Property the control problem is solved for the steady state equations. The necessary and sufficient optimality conditions are established for static control problems. Then the optimum design problem is considered for the topological perturbation of the graph. The small cycle of size $\varepsilon \to 0$ replaces the central node of 3-star graph. The distributed controls are introduced on the edges of the cycle. The topological derivative of the shape functional indicates the possibility of nucleation of the small cycle.

TECHNICAL PROGRAM

Wednesday

August 28, 2024

Day: Wednesday, August 28th, 2024

Time: 9:00 – 10:00

Room: Marco Polo

Plenary 2, B0L-A

Day: Wednesday, August 28th, 2024

Time: 9:00 – 10:00

Room: Marco Polo

Chair: Andrzej Bartoszewicz

Author: Emilia Fridman (Tel Aviv University, Israel)

Paper: Using Delay for Control

Day: **Wednesday, August 28th, 2024**

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

Room: **Marco Polo**

Chair: **Dariusz Pazderski**

Paper: **6009** **B1L-A**

Iot Towers of Resilience: A Revolutionary Approach to Weathering Climate Extremes and Enhancing Sustainability in Vulnerable Ecosystems

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This paper introduces an IoT-based system by North South University students to address climate change effects. It employs IoT for real-time monitoring and response to extreme weather, enhancing community resilience. Climate change poses significant risks, necessitating adaptive solutions. The system comprises three towers equipped with NodeMCU esp8266 microcontrollers, sensors, and actuators, placed strategically in urban and forest areas. Its goal is to offer a cost-effective, reliable solution for safety enhancement and climate risk mitigation. Real-time data facilitates informed decision-making during crises. Sensors relay data to a Raspberry Pi Pico, acting as the central hub, which then transmits information to a cloud server for analysis. The system's success relies on sensor accuracy and data processing algorithms, warranting real-world testing and future improvements. The IoT Towers of Resilience system marks a notable advancement in environmental monitoring, integrating technology and community engagement for a resilient future.

Systems of Digital Twins and Physical Systems: Interoperability, Decentralization, and Mobility in Robotic Applications

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Whereas digital twins are receiving an increasing attention, their implementation has been predominated by monolithic and static solutions. A resulting issue is the lack of a modular integration and seamless interplay of digital twins when it comes to adapt and support varying industrial and societal applications. We address these challenges by leveraging on the OPC-UA standard to develop portable data connectors that move with and give access to the data source. Our Raspberry-Pi driven connector encapsulates a digital twin of the corresponding system and its offered services to capture the loose coupling and decentralization of systems and systems even remotely and in motion. This opens up new opportunities for different monitoring modalities of large scale systems whose physical or/and virtual constituting subsystems are distributed across distinct geographical locations in the industrial and societal realm. We apply our framework to a mobile multi-arm robotic system and demonstrate the performance of its monitoring functionality from the cabin of a moving train. We provide experimental measurements results and highlight the usefulness and effectiveness of our approach.

Design and Implementation of a QR-Enabled Autonomous Bartender Using a User-Friendly Interface

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The QR-Enabled Autonomous Bartender system introduces a pioneering approach to revolutionize beverage service within the hospitality sector. The Makr Shakr is a notable example of robotic bartending systems, renowned for its sleek design and advanced automation capabilities. However, existing works in this domain are often characterized by their high cost and lack of customization options, making them inaccessible to many establishments. The proposed system objectives

encompass the design and construction of a stationary robotic bartender, the development of a user-friendly mobile website, the implementation of a personalized ordering system, and the optimization of beverage mixing and dispensing efficiency. The implementation of this initiative promises to advance automation and QR technology in the food and beverage industry, offering valuable insights into robotics, automation, and web development while enhancing customer experience and operational efficiency in bars and restaurants. As for validation, the system underwent rigorous testing, with a total of 210 trials resulting in 35 trials for each drink over a period of approximately 7 hours.

Day: **Wednesday, August 28th, 2024**

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

Room: **Vasco da Gama**

Chair: **Krzysztof Oprzędkiewicz**

Paper: **6016** **B1L-B**

Optimising Sequencing Batch Reactor Operation Cycle Planning Using Evolutionary Algorithm

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The objective of this research was to optimise the operation cycle of the Sequencing Batch Reactor (SBR). Appropriate time balances of aerobic to anaerobic phases, as well as a set dissolved oxygen level are the key to ensuring the quality of effluent from the wastewater treatment process. The proposal to solve this optimisation problem was based on multi-objective optimisation using an evolutionary multi-objective optimisation algorithm called ϵv-MOGA. Three indicators of effluent quality and a process cost factor were adopted as functions to be optimised. The results were tested using multi-level control system of a complex SBR simulation model. The research is based on a case study of the Water Resource Recovery Facility (WRRF) in Swarzewo, Northern Poland.

Paper: **6026** **B1L-B**

Discrete Quasi-Sliding Mode Control of a Two Rotor Aerodynamic System

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The paper deals with the implementation of the discrete time quasi sliding mode controller for the two rotor aerodynamic system. The work consists of six Sections. First one reviews the literature and describes basic principles of continuous as well as discrete variable structure systems with sliding modes. Section two presents the laboratory setup of the two rotor aerodynamic system and its

simplified continuous and discrete models. Third Section covers the synthesis of the DQSM controllers and stability analysis. In the following fourth Section the cascade control scheme with inverse static thrust characteristics , PID controllers and Kalman filters is proposed. The work is completed with fifth Section devoted to obtained experimental results and brief final conclusions in the sixth Section.

Paper: **6041** **B1L-B**

Model Reference Control for Wind Turbine Systems in Full Load Region Based on Takagi-Sugeno Fuzzy Systems

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This paper presents a novel Model Reference Control (MRC) approach for wind turbine (WT) systems in the full load region employing a fuzzy Parallel Distribution Compensation Controller (PDC-C) derived using a Takagi-Sugeno (TS) fuzzy System approach. Through first-order Taylor series expansion, local linear submodels are generated and combined via triangular membership functions to develop a TS descriptor model. From here, the MRC PDC-C is synthesized by a constrained LMI optimization procedure to track the desired rotor speed and generator torque based on the reference model dynamics. The controller is employed on the nonlinear WT model in simulation studies under various wind conditions, such as turbulent wind fields and wind gusts.

Poster Session I, B2P-C

Day: **Wednesday, August 28th, 2024**

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

Room: **Poster Area**

Chair: **Krzysztof Okarma**

Paper: **6004** **B2P-C**

Optimal Control of Unmanned Robotic Platform

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This paper proposes an infinite-time horizon suboptimal control strategy based on state-dependent Riccati equation (SDRE) to control of unmanned ground vehicle (UGV). Cruise control of unmanned robotic platform is modelled and simulated. For vehicle modelling purpose a full 6 DOF model is considered and described by nonlinear state-space approach. Also a stable state-dependent parametrization (SDP) necessary for solution of the SDRE control problem is proposed and presented. Solution of the SDRE control problem with adequate defined weighting matrices in performance index shows possibility of fast and optimal vehicle control in infinite-time horizon. The method in this form can be used for mission planning of each ground vehicle tracking and dynamics control.

Paper: **6017** **B2P-C**

Transforming Retail: Advancements in Autonomous Stores System Integration

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This article highlights the exceptional and rapid expansion of autonomous retail stores across Europe, representing a significant advancement in the retail industry. The impressive scale and speed of this rollout underscore the transformative impact of artificial intelligence and automation on the shopping experience. By bridging traditional retail with cutting-edge technology, this integration has redefined the shopping experience. This remarkable achievement not only exemplifies the industry's

responsiveness to technological advancements but also reinforces the paradigm shift in consumer expectations and retail operations.

Paper: **6039** **B2P-C**

Data Acquisition, Mathematical Model and Energy Saving Strategy for a Building Heated with the Central Heating System

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In the paper the heating system was presented that features the temperature profiling algorithm that reduces the amount of heat delivered to the building when no people are present inside it. The main focus of the paper is to calculate the amount of saved energy by using the mathematical model of the system. For the purpose of this analysis, data acquisition system was implemented. Measurements acquired from the system were used to create a mathematical model of the heating system, which was then applied to energy efficiency comparative analysis. Additionally, other application of this model was presented as a way to optimise the temperature profiling algorithm.

Paper: **6070** **B2P-C**

PDDL Optimal Planning as the Linear Programming Problem in a Seaport Container Terminal

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Planning problem considered is planning of shipping containers transportation among seaport yard containers' stack and arriving trucks. This planning problem is a part of the whole operation of Shanghai International Port, Shanghai, China. Containers are lifted from and dropped onto containers' stack and input/output buffer (buffer2) by an automated stacking crane (ASC). Automatically guided vehicles (AGV) transport containers between input/output buffer (buffer2) next to containers stack and input/output buffer (buffer1) next to truck stop. Automated loading crane (ALC) loads and unloads arriving trucks and lifts from and drops onto buffer. STRIPS planning instance finds a plan, but is computationally complex and takes long time to compute. Linear programming instance finds a plan. It's computationally simple and takes significantly shorter time to compute.

Efficient Heat Source Control with Transportation Delay Synchronization

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This paper presents the temperature control system designed for a heat source system in a form of electric flow heater ensuring high performance of output temperature stabilization in a presence of significant flow rate variations. For this purpose, PI controller was supplemented with gain scheduling technique and feedforward compensator based on simple dynamic model. Two approaches for designing of feedforward compensator are verified. Simulation studies and practical verification show that control performance can be increased by introducing additional transportation delay time synchronization in feedforward compensator.

Paper: **6076** **B2P-C**

Unmanned Aerial Vehicle Control Method Considering Optimal Compensation and Gusts of Wind

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In this paper, a control strategy based on a coupled Proportional and State-Dependent Riccati Equation (P-SDRE) controller, which ensures a quick stabilization for a given angular position of an unmanned aerial vehicle in three-dimensional space, is presented. The Hamilton-Jacobi-Bellman function and

the Riccati differential equation are used to develop the solution of the SDRE algorithm. Properly defined weighting matrices in performance index allow quadrotor's fast and precise positioning with optimal stabilization of angular speeds. Cruise control of unmanned aerial vehicle is modelled and simulated. In order to prove the effectiveness of the method, disturbances modelled as wind gusts are included in the simulation.

Paper: **6105** **B2P-C**

Development of a Real-Time Framework Between MATLAB/Simulink and SIEMENS PLC for Automated Relocation of Products in the Warehouse

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The control system design proposed in the article is a work platform that enables the implementation of control algorithms developed in many different programming languages. This functionality is made possible by integrating the MATLAB/Simulink and TIA Portal programming environments using tools such as: SIMATIC S7-1500 ODK 1500S and SIMATIC Target 1500S for Simulink. The combination of these software tools with the physical execution system implemented in the area of automated warehouse system with product relocation function is a new solution, not yet found in the literature. The above described configuration of software and devices provides the opportunity to implement advanced analytical tools in an industrial environment. Such a configuration also gives the possibility to use other programming languages, such as Python, C, C++, in the algorithm for controlling the automatic warehouse system. The proposed working environment gives the researchers the opportunity to develop and implement complex control algorithms faster in an industrial environment. This allows us to apply advanced artificial intelligence algorithms to control technology.

Paper: **6106** **B2P-C**

Weather-Based Reliability Analysis System for Automotive Electronics: Assessing Environmental Impact on Component Performance

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This study introduces an methodology aimed at augmenting critical safety systems within the automotive sector. The proposed approach entails incorporating real-time environmental conditions' impact on failure rates and involves continuously evaluating system reliability by leveraging sensor

data derived from diverse vehicle components. This method presents prospective advantages, including expedited product development, reduced production costs, and enhanced user safety.

Paper: **6119** **B2P-C**

Improving the Accuracy of Leak Localization Through the Use of an Equivalent Pipeline Model

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This study focuses on the localization of leaks in liquid transmission pipelines using the standard gradient-based leak localization procedure. This method relies on calculating pressure gradients using pressure measurements captured along the pipeline. Specifically, it focuses on the period following a leak occurrence, corresponding to a stable flow process. Usually, the procedure applies a basic model that considers the transmission pipeline in terms of global friction resistance effects (i.e., linear pressure losses) while often disregarding local resistance effects (i.e., local pressure losses). In this work, we verify the leak localization procedure by applying an equivalent model of the pipeline that accounts for both global and local pressure losses. Our investigations employ a computational flow model based on the geometry and flow conditions of an existing laboratory water pipeline. Notably, the local pressure losses constitute only approximately 0.8% of the overall losses caused by friction resistances. During our research, we consider leakages with intensities equivalent to 1%, 2%, 5%, and 10% of the nominal flow rate, situated at different points along the pipeline.

Paper: **6120** **B2P-C**

Remote Control of Computer Motherboards Using ISM Band

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The paper describes a device that allows the computer to turn on, off, and reset. This is achieved through the use of 868MHz RF modules. The proposal includes a single transmitter for multiple receivers (PCs). The paper also discusses other similar solutions and further suggestions for project development. The proposal outlines the issues with WoL (Wake on LAN) and addresses them. It resolves problems such as time-consuming configuration, limitations to operating within a single LAN, and the requirement for LAN functionality to execute commands.

Robotics II, B3L-A

Day: **Wednesday, August 28th, 2024**

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

Room: **Marco Polo**

Chair: **Przemysław Herman**

Paper: **6066** **B3L-A**

Path Planning with Obstacle Avoidance for a Mobile Robot Supporting Industrial Processes

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The rapid development of mobile robotic platforms significantly influences the research of appropriate path planning algorithms. These algorithms must consider not only obstacle avoidance but also path length and shape, both of which impact the final trajectory the robot follows when navigating a designated path. In the presented research, our focus was on generating paths that avoid assumed obstacles while also minimizing the trajectory length produced by the robot when following a waypoint-based path. To evaluate our approach, we utilized several scenarios sim- ulating industrial processes involving the processing of trapezoid- shaped frame. These scenarios designate a start point and final points based on the position and orientation of the processed object, and different distribution of obstacles.

Fault Detection Robotic System: Controlling and Experimental Validation of Overhead Crane Climbing Robot

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The involvement of robots has increased rapidly in the last few years in many applications. A variety of robot performs numerous type of task in a hazardous environment. In order to prevent server damage to the infrastructures of overhead cranes in an industrial environment, a Fault Detection System (FDS) and Structural Health Monitoring (SHM) has a significant role. Mainly enhancing the safety, reliability, and availability of industrial overhead cranes requires timely continuous monitoring. This research proposes a wide approach for inspection that applies to various types of physical machines by mainly focusing on overhead crane bridges. The study of fault detection using a robotic system by NDT & SHM is relatively new, as only a few types of research has been performed. To be more specific, this paper provides a detailed insight into an autonomous robot for crack detection in overhead cranes bridges and girder using an array of GMR (Giant magneto resistive) sensors and magnetic climbing mechanisms.

Motion Planning for Mobile Robots Using the Safety Acceleration Velocity Obstacle Method

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In this paper, we introduce a novel motion planning algorithm, the Safety Acceleration Velocity Obstacle (SAVO) method that can result in a collision-free motion for the mobile agent in a dynamic environment considering safety and speed at the same time. The introduced method can be used for omnidirectional mobile agents, and additionally for car-like and differential-driven mobile robots after introducing the exact linearization, taking into account the flatness. Our study compares the

results of the SAVO method for the different types of mobile agents and presents simulation results to demonstrate its effectiveness.

Paper: **6060** **B3L-A**

Comparative Study of Two Sky Hook Strategies Analyzed from a Control Theory Perspective

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In the context of active vehicle suspensions, this work presents a comparative study between two Sky Hook strategies focused on vibrational comfort: the optimal Sky Hook strategy and the CRONE Sky Hook nominal strategy. This comparative study is conducted for a control theory perspective using a quarter-vehicle model. The proposed analysis provides a deeper understanding of why the nominal CRONE Sky Hook suspension yields better results than the optimal Sky Hook suspension. The results show that the proposed approach yields better vibrational comfort.

Day: **Wednesday, August 28th, 2024**

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

Room: **Vasco da Gama**

Chair: **Paweł Majewski**

Paper: **6010** **B3L-B**

Newton-Euler Modeling of Robot Dynamics Using Geometric Algebra

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In this work, we present the modeling of the dynamics of a robot manipulator using the Newton-Euler algorithm in the conformal algebra framework. The modeling of the dynamics of robot manipulators is currently done using the Euler-Lagrange formulation which is a batch type of computation. In contrast, in this paper, we propose a recursive algorithm for the modeling of the dynamics of robot manipulators using the Newton-Euler algorithm in the conformal geometric algebra framework.

Paper: **6069** **B3L-B**

Real-Time Simulation of Ship Movements for a Robot-Assisted e-Fueling Process: A Pathway to Decarbonization Through Sector Coupling

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In this paper, we propose an approach to reduce the carbon footprint of maritime transportation by implementing a testbed for an autonomous, robot-assisted e-fueling process for vessels. The core of

our approach is a real-time simulation of ship movements in waves with the use of the development environment Unity. We implement an interface between the simulation PC and the controller of a collaborative robot kinematic. For investigations on a robot-assisted e-fueling process, the robot kinematics emulate the motion of the vessel.

Paper: **6088** **B3L-B**

Development of a Treatment System for the Production and Distribution of Purified Water for Water-Scarce Communities in Southern Peru

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Global population growth and climate change have exacerbated the lack of access to potable water, a challenge that has become especially critical in regions of Peru, where drinking water shortages or service interruptions are common problems. This article presents the development of a purified water treatment and bottling plant designed to provide a sustainable and affordable solution to water-scarce communities. The plant uses advanced purification technologies, such as reverse osmosis and activated carbon filtration, to transform water from non-potable sources into water suitable for human consumption. In addition, the bottling system ensures the integrity and safety of the purified water for distribution. This project not only addresses the immediate challenge of supplying purified water to the affected communities but also promotes sustainability by incorporating this treatment system into groundwater sources and minimizing the consumption of contaminated water. It is hoped that this study can provide a theoretical and practical framework for future research and projects related to water management in disadvantaged communities.

Drive Modeling and Dynamic Control in Mössbauer Spectroscopy for Space & Terrestrial Applications

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This paper deals with drive modelling and control in Mössbauer spectroscopy. The equations of motion of the linear drive are derived and compared in different versions. In this context, the single-mass representation proves to be a sufficiently accurate model, which shows almost identical results compared to multibody models. This leads to a reduction of the system order from n = 6 to n = 2, which greatly simplifies the evaluation steps in this context and the further controller design modalities. Based on this, a heuristic control concept is developed that fundamentally revises common design approaches and opens up a broad spectrum of research. The controller design provides for a combination of signal-smoothing and signalamplifying low-pass filtering in combination with dynamic input vector normalisation. This achieves the desired frequency and amplitude response of 1.1485 · 103 rad s and 0.3 mm and optimises the dynamics for real laboratory use.

Robotics III, B4L-A

Day: **Wednesday, August 28th, 2024**

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

Room: **Marco Polo**

Chair: **Maciej Michałek**

Paper: **6002** **B4L-A**

Harmony Orchid Unleashed: Single-Rate Control for Superior Circular and Figure-8 Tracking in Stepper Motors

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This paper presents a novel control approach for accurate circular and figure-8 trajectory tracking of a stepper motor. The methodology combines nonlinear feedback, feedback linearization, PID control, a single-rate sample data system, and the Harmony Orchid algorithm. Leveraging the stepper motor system's inherent nonlinearities, a combined nonlinear feedback and feedback linearization strategy is employed. The PID controller fine-tunes performance, with coefficients optimized using the Harmony Orchid algorithm for dynamic adjustment based on system behavior. Adopting a single-rate control scheme streamlines the process, offering benefits like simplified stability analysis, reduced timing jitter, and enhanced adaptability. Simulation studies, focusing on circular and figure-8 tracking scenarios, validate the proposed methodology. Results demonstrate that integrating the Harmony Orchid algorithm with nonlinear feedback, feedback linearization, and PID control achieves precise and robust trajectory tracking. This approach holds promise for enhancing motion control applications requiring accurate and adaptable tracking.

Identification of the Sources of Radiated Electromagnetic Disturbances in Mobile Robots

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The article describes the development of the method for locating sources of radiated electromagnetic disturbances generated in the units of some specific class of mobile robots. In the analyzed case, the source of disturbances was a radiating slot, that has formed due to poor electromagnetic tightness of the housing, which caused a negative result of radiated emission tests. The slot was created artificially in the shielded housing in order to simulate the actual problem. The paper describes the testing method and the configuration and construction of the test stand for locating sources of disturbances using an EMC scanner placed in a dedicated EMC testing chamber with ferrite plates covering the walls inside.

An Analysis on the Impact of Approximation of Scaling and Manipulability Approaches in Dimensional Synthesis of Robots

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Dimensional synthesis of robots is often performed with approximated performance indices due to the large computation involved. These approximations often undermine the performance of the robot and hence a study on the impact of these approximations gives the designer a better insight on the trade-off between the robot's performance and the computational investment. Motivated by this, the current study focuses on the impact of scaling of Jacobian and manipulability index by comparing the ellipsoid-based manipulability index with polytope-based manipulability index and the three-point scaling of Jacobian with linear-angular-separated conditioning of Jacobian. Optimisation problems are formulated for performance around a single point for four manipulators, and the results are presented. The results show that there is a significant impact on the approximation, which suggests the designers to adopt more accurate performance parameters for dimensional synthesis.

Implementation of the Neuro-Fuzzy Controller for Delayed Position-Position Teleoperation System Using Arduino Due Board

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This paper presents the control of a teleoperation system with transmission delay using an Adaptive Neuro-Fuzzy Controller (ANFIS) implemented on an Arduino Due board. Transmission delay causes instabilities and poor performance, and poses a major problem in controlling teleoperation systems. To solve this problem, we need an appropriate control strategy and an adaptive and robust controller. The ANFIS controllers proposed in this article, are capable of adapting to variations in the parameters of the system to be controlled by automatically modifying the neuro-fuzzy network's output through the use of a non-linear learning algorithm. These ANFIS controllers are developed in the Matlab/Simulink environment and implemented on a one degree of freedom teleoperation platform using an Arduino Due Board given its advantages in terms of speed and ease of implementation. The experimental results of position tracking demonstrate that the proposed control algorithm delivers better performance than conventional control methods (PID).

Warehouse Automation Solution Through a Goods-to-Person AMR

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The use of goods-to-person robotic systems in a warehouse enhances storage density by devoting specific areas for Automated Mobile Robots (AMRs). Nevertheless, operation in narrow aisles and confined spaces presents notable challenges. This study outlines a comprehensive approach for AMRs to autonomously navigate within narrow aisles of a warehouse, ensuring safety and streamlining order completion. The goal is to independently collect and transport bins with products referred to the order, to the workstation area, where workers finalize order packing. Precise positioning of fiducial markers on the floor, initiates a fusion-based localization system that merges information from wheel odometry and fiducial detection. The markers are organized as an undirected graph to facilitate navigation purposes and Dijkstra algorithm is employed to successfully generate both safe and optimal paths. A pipeline has been established for the retrieval and positioning of bins from shelves or workstations to optimize the order picking process. The proposed method has been tested on a simulation environment with realistic constraints stem from the development of an autonomous warehouse environment.

Day: **Wednesday, August 28th, 2024**

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

Room: **Vasco da Gama**

Chair: **Andreas Rauh**

Paper: **6003** **B4L-B**

Prescribed-Time Attitude and Altitude Stabilization of Hexarotor UAV with External Disturbances

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This paper addresses the prescribed-time attitude and altitude stabilization problem of hexarotor unmanned aerial vehicles (UAVs) with external disturbances and model uncertainty. A novel sliding surface based on prescribed-time convergence is introduced for the proposed controller. The presented controller ensures the convergence of the hexarotor states to the origin in the prescribed time. The controller design is independent of the initial state parameters and free from singularity. Moreover, a fixed-time disturbance observer is implemented with the control law to enhance the performance of the control design. The stability of the presented prescribed time sliding mode control is analyzed using the Lyapunov theorem. Finally, the efficacy of the controller is demonstrated using numerical simulations compared to the existing finite and fixed-time controller design.

Adaptive Obstacle Avoidance of UAV Leader/Followers with Nonlinear Logarithm Quaternion Control

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The idea based on potential field as obstacle avoidance algorithm, with adaptive techniques for determining obstacle avoidance parameters. These parameters are dynamically adjusted based on the distance between the UAV and the obstacle through a non-linear adaptation function. The comprehensive implementation of these methods is rigorously evaluated by employing a predefined reference path for the leader and conducting numerous scenario-based tests. Random directions of followers were used in case of stuck in local minimum to avoid it; this was applied in case when potential filed force is less than small value. Experiments to test some scenarios of obstacle avoidance were conducted. The final results conclusively demonstrate the stability of the control law even in the presence of obstacles. The effectiveness of the adaptive obstacle avoidance approach is clearly evident from the trajectories of the UAV followers.

LPV Control of Systems via Nonlinear Actuator Dynamics Mapping

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The nonlinear nature of industrial actuators pose a major challenge in the design of mechatronical components. For a majority of large-scale industrial applications common to employ sophisticated AC motors with nonlinear dynamics. Moreover, load is rarely, if ever known, introducing uncertainty in the actuator dynamics. This paper is concerned with a controller design scheme, in which nonlinear actuators are described as subsystems embedded into a higher level control system. The nonlinear actuator can be represented as a linear system by coordinate transformation coupled with linearizing feedback. However the inclusion of technical limitations prevents exact linearization. Therefore, an alternative approach is presented in which the nonlinear character is mapped into a series of simple first-order systems and is subsequently handled by an LPV control structure. The control scheme is

completed with an Unscented Kalman Filter as a load estimator. The design technique and validation tests are performed in a simulation environment.

Paper: **6048** **B4L-B**

Design of Hysteresis Control Based Adaptive Sliding Mode Control and Cuckoo Search Based Pi Control for DC-DC Boost Converters

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Due to the underlying complexities and nonlinear behavior of the DC-DC boost converters, its control becomes a difficult operation. The non-minimum phase behavior of the DC-DC boost converters also makes it tough to control. This paper proposes two different techniques based on hysteresis based adaptive SMC and Cuckoo Search (CS) based Proportional-Integral (PI) control methods for controlling DC-DC boost converters. The two techniques applied in this research are compared in terms of various performance indices such as Integral of Absolute Error (IAE), overshoot, rise time and settling time. The effectiveness of the two proposed controllers are evaluated in relation to changes in input voltage, reference voltage and load. The two proposed methods are also compared against a conventional PID tuned by Internal Model Controller (IMC). The hysteresis control based adaptive sliding mode controller performs better than CS based PI controller and IMC based PID controller with lesser IAE against fluctuations in terms of reference voltage, load, and input voltage.

Paper: **6055** **B4L-B**

A Criterion for the Transient Stability of the PLL-Based Grid Synchronization

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A successful grid synchronization is essential for grid-following converters. Usually, a phase-locked loop (PLL) is applied to synchronize the converter to the grid, but this process can fail in weak grid scenarios, resulting in an unstable converter controller. Studies have been carried out to investigate this issue, but there are no applicable conditions that guarantee the stability in the transient case. The PLL-based grid synchronization of a grid-side converter with output filter of LC-type and grid impedance of RL-type is investigated in this work. A transient stability condition is known for this system, but its evaluation requires the time domain solution of the underlying differential equations. In this paper, a criterion is derived, that shows the fulfilment of the condition without the need for the time domain solution. Since the criterion is based on conservative estimates, it provides only a sufficient proof of stability. The criterion is implemented and validated in numerical simulations.

Poster Session II, B5P-C

Day: **Wednesday, August 28th, 2024**

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

Room: **Poster Area**

Chair: **Przemysław Orłowski**

Paper: **6020** **B5P-C**

Hough Transform for Detection of 3D Point Cloud Rotation

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In the field of mobile robotics, point clouds are widely used as an environment representation merged into a map. However, point cloud registration can be challenging when rapid movements occur. In indoor environments, plane-like features such as walls, floors, and ceilings are dominant and can be used to aid cloud merging. These features need to be extracted from point clouds. In this paper, we present an open-source Hough transform implementation in Python. The Hough transform is a technique used for detecting shapes in images. We have adapted this method to be applied to point clouds and to detect planar features. To illustrate the point-cloud Hough transform algorithm, we generated synthetic point clouds. Additionally, we collected LiDAR measurements in the corridor. We used the code to align the point cloud rotation to the fixed frame.

Local Path Planning Algorithm Based on Artificial Potential Field with Adaptive Scaling Factor

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The paper presents an adaptive local path planner based on the Artificial Potential Field algorithm and the Widrow-Hoff rule. The proposed algorithm maintains the required distance from obstacles. The limitation of the scaling factor of repulsive potential allows for proper continuous operation. It provides smooth, collision-free, and goal-reaching operation of mobile robots. The impact of adaptation gain and the required distance from obstacles on robot movement have been examined in randomly generated environments.

ROS2 Based Monocular SLAM Architecture with Cascade Optimization

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Visual Simultaneous Localization And Mapping (V- SLAM) research is increasingly using machine learning methods to extract information from images. One application of machine learning in V-SLAM is the prediction of depth information from camera images, which can be used to reduce scale drift in monocular SLAM. The drift in the map scale originates from estimation error propagation and can be reduced by using machine learning for depth prediction in monocular SLAM. A significant drawback of this approach is the high computation time on low-cost systems with limited CPU resources, which prevents machine learning methods from being used for each camera image. In this work, Cascade Optimization is introduced as an approach for using learned depth perception in monocular SLAM. However, in order to apply this novel approach to a modern SLAM system, some adjustments have to be made to the system architecture, since the information flow during image processing can no longer be unidirectional only. Thus, a modular SLAM system architecture based on the ROS2 interface is also presented, which allows the integration of functionally and structurally novel methods such as Cascade Optimization.

Controlling and Programming a Robot Using Virtual Reality

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The paper presents software that allows a user to control and program a robot using virtual reality. The user will be equipped with a Virtual Reality kit and will be able to use it to manipulate the robot arm as if they were physically interacting with it. One key feature of the software will be the ability to set the robot in a specific position, allowing the user to create and execute complex movement sequences for the robot to follow. The use of VR technology in this context offers a unique and immersive way for users to interact with and program the robot, making it an exciting and innovative approach to robotic control.

Task-Oriented Trajectory Optimization for Planar 3R Robot

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In robotic writing, trajectory following tasks typically assume a constant tip orientation, with the pen held perpendicular to the surface. This assumption often stems from datasets containing only planar path data, without recording pen tilt. However, replicating such writing movements with industrial robot arms poses challenges due to their inertia and varying kinematic structures. This work addresses the problem of generating tip orientation in the absence of dataset information, while the main added

value is presented in reducing torque requirements on the robot arm and improve writing profile accuracy. using a proposed set of objective functions and a numerical method utilizing genetic algorithm. The algorithm's performance is verified in a simulated scenario involving a 3-DoF planar robot and a set of sample paths.

Paper: **6064** **B5P-C**

Overview of selected teleoperation positioning systems for controlling a robot arm operating in Remote Centre of Motion (RCM) mode

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This paper describes partial results of ongoing research at the Department of Automatic Control and Robotics Faculty of Electrical Engineering, Bialystok University of Technology, Poland, in the field of application of industrial robots for the improvement of robotic surgical procedures by the doctors, analogous to procedures performed on expensive surgical systems class of the Da Vinci system from the Intuitive Surgical Company. Selected issues related to force feedback teleoperation are discussed. The problem of positioning the surgical instrument (the tool of a surgical robot) in remote centre of motion mode was defined. Developed applications controlling the UR5 industrial cobot from company Universal Robots in teleoperation mode were discussed: definition of application problems on the industrial cobot platform, used and custom-built subsystems for positioning and learning by demonstration.

Reference Model Based Sliding Mode Control of a Platoon of Vehicles

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In this paper, a reference model based sliding mode controller for the task of platoon control is developed. Among its advantages are: maintaining a safe distance between the vehicles, rapidly achieving the maximum allowable speed, and arriving at the exact desired position in minimum time. The approach has no limits on the platoon size, moreover only local information is used. Each vehicle only needs to monitor the distance and relative speed to its predecessor. This makes the solution easily scalable. The properties are demonstrated analytically and verified in numerical simulations.

An Intelligent Vision System for the Detection and Classification of Heterogeneous Objects Moving on a Belt Conveyor

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In this paper, a newly developed author's vision system allowing identification of packages moving on the conveyor belt and their classification is presented. An important aspect is that the mentioned objects move at relatively high speeds, which is challenging for any vision system. The methodology used in the plant is based on a hybrid combination of algorithmic determination of the features of a given object with artificial neural networks performing the classification process. An essential aspect of the work is using the advanced camera, which provides three-dimensional image analysis. The obtained verification results confirm the system's usefulness not only for research purposes but even for implementing industrial automation tasks.

Design of Iterative Learning Control for a Subclass of Robotic Systems with an Alternative Reference Signal Setting

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In this paper new results on the application of the Iterative Learning Control (ILC) schemes applied to the Gantry robot are presented. The main result given refers to the situation where the reference signal pre-defined for ILC can be extended by some quantity that genuinely does not appear in the model but is important for the practical application of such system. In a case of considered system - the Gantry robot - its original state space model output refers to the robot position that in turn defines the robot's movement trajectory. For many practically-relevant applications it is enough to define the reference signal for the ILC in terms of this trajectory. This is not always ideal, as for some tasks it is easier (at least in terms of wear of the robot parts) to include additional requirements for the reference signal. The results presented in this paper allow to extend it by an additional factor - which, in this case, is the robot velocity. In what follows the ILC scheme is designed and implemented for such a combined reference signal.

Multi-objective iterative learning control with application to vacuum heat treatment process

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Paper tackles identification and control methods that account for both temporal and spatial dynamics, realizable in practical scenario. Work presents an approach that competes with existing on-line feedback, using predictive iterative learning control. The approach qualitatively tackles the nearly opposing goals of accurate parametric identification and trajectory tracking. Simulations supplying are modeled after vacuum wafer heating in a furnace.

TECHNICAL PROGRAM

Thursday

August 29, 2024

Day: **Thursday, August 29th, 2024**

Time: **9:00 – 10:00**

Room: **Marco Polo**

Plenary 3, C0L-A

Day: **Thursday, August 29th, 2024**

Time: **9:00 – 10:00**

Room: **Marco Polo**

Chair: **Józef Korbicz**

Author: **Ming Cao (University of Groningen, The Netherlands)**

Paper: **Navigation of cooperative robotic teams**

Day: **Thursday, August 29th, 2024**

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

Room: **Marco Polo**

Chair: **Marcin Witczak**

Paper: **6065** **C1L-A**

Genetic algorithm for automatic construction, optimization and testing of multi-input forked convolutional neural networks used for diagnostics of rotating agricultural machines

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The third decade of the 21st century can undoubtedly be called the smart decade. Manufacturers of all devices try to integrate the functions of their products with methods based on artificial intelligence as much as possible. This trend has also reached industrial and agricultural machine manufacturers, where neural network diagnostics is no longer just a thing of the future and is becoming something every day. As developing AI methods requires a high degree of expert knowledge and is time-consuming, we propose a method to automate the entire process. Thanks to the use of a three-step genetic algorithm, we managed to create a system that can create the appropriate AI architecture based on neural networks, optimise it, and test it completely unsupervised. We confirmed its effectiveness by using our method to develop a multi-input, forked convolutional network capable of recognizing nine different states (healthy and eight different damages) of an agricultural rotary tedder with an accuracy of approximately 98%.

Paper: **6110** **C1L-A**

Diagnosing faults in electric motors using B-splines and Bayesian Mixture Model

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Diagnosing faults in electric motors is crucial for various applications, from everyday devices to industrial machinery. We propose a method for identifying motor faults using acoustic signals, which are easy to capture with microphones. Our approach involves analyzing these signals using Functional

Data Analysis (FDA), representing frequency patterns with B-splines and Bayesian Mixture Model as classifier. In this paper, we develop a classifier to categorize five motor fault types based on these transformed signals. By focusing on frequencies up to 2500 Hz relevant to motor issues, we aim to detect faults without needing complex equipment and greatly shorten computation time. This approach yields promising results.

Paper: **6111** **C1L-A**

Feature Evaluation for the Purpose of Biofouling Diagnostics in Tidal Turbines

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One of the very relevant topics of today is renewable energy, which we search for in bio-fuels, solar power, wind and water. An interesting concept, that has a great potential in harnessing nature energy sources are tidal turbines. These submerged devices use the power of waves to create electricity. Being submerged, however, exposes them to a particular way of degradation which is bio-fouling. This is an accumulation of bio-materials on the device causing it performance to degrade. Efficient diagnostics and degradation analysis require proper understanding and analysis of available data. In this paper we consider what kind of features can be extracted from the current and voltage signals available. We use different frameworks allowing such analysis and extraction of features for such applications.

Day: **Thursday, August 29th, 2024**

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

Room: **Vasco da Gama**

Chair: **Witold Respondek**

Paper: **6034** **C1L-B**

A Triangular Normal Form for x-Flat Control-Affine Two-Input Systems

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This paper is devoted to normal forms for x-flat control-affine systems with two inputs. We propose a general triangular normal form which contains several other normal forms discussed in the literature as special cases. We derive conditions under which a system with given x-flat output can be transformed into the proposed triangular form. Based on the triangular form we motivate a simple algorithm for identifying candidates for flat outputs.

Paper: **6067** **C1L-B**

Trajectory Tracking for an Adaptive Cruise Control System Using Differential Flatness and Gaussian Processes

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In this paper, we explain how differential flatness combined with Gaussian Processes can be applied for the adaptive cruise control system under external, unknown dynamics, to attain accurate trajectory tracking. The proposed approach employs differential flatness for controller design, along with

Gaussian Processes to estimate the unknown components in the dynamics. In order to ensure robustness to this data-driven technique, a robust control law is also introduced, that further exploits the Gaussian Process framework. In the recent publication [Jeloka et. al. 2024], we showed the effectiveness of the proposed control methodology for set-point regulation. In the current paper, we generalize it to trajectory tracking and show numerically that the error dynamics converge to zero.

Paper: **6115** **C1L-B**

Mechanical input-output linearization and decoupling of mechanical control systems

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In this paper, we present a mechanical counterpart of the problem of simultaneous input-output feedback linearization and decoupling that is designed for control systems that posses a mechanical structure. We show how our problem differs from the classical one and what are the supplementary conditions for preserving the mechanical structure of the system. Unlike our previous works, here we treat a mechanical control system \ms as a control system on $\T Q$ with a special structure of the drift and control vector fields.

Poster Session III, C2P-C

Day: **Thursday, August 29th, 2024**

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

Room: **Poster Area**

Chair: **Paweł Latosiński**

Paper: **6015** **C2P-C**

Trajectory Tracking with Generalized Active Disturbance Rejection Control Using Kalman Filter-Based Extended State Observer

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This paper addresses trajectory tracking in a stochastic environment. Active disturbance rejection control (ADRC) in a generalized approach was designed for a two degrees of freedom (DoF) mechanical system, a ball balancing table (BBT). A modification of the extended state observer (ESO) tuning based on the Kalman filter (KF) gains was presented. The experiments were carried out for different levels of measurement noise. Using the proposed modification of the ESO gains selection, a better quality of trajectory tracking under measurement noises was achieved compared to the standard pole placement (PP) tuning method.

Numerical Method for Stability Testing of Fractional Exponential Delay Systems

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A numerical method for stability testing of fractional exponential systems including delays is presented in this contribution. We propose the numerical test of stability for a very general class of systems with a transfer function, which includes polynomials and exponentials of fractional powers of the Laplace variable s combined with delay terms. Such a system is unstable if any root of its characteristic equation, which usually involves transcendental functions, is localized on the right half-plane of the s-domain. Due to the infinite size of the right half-plane, the bilinear transformation is employed to map it onto the unit disc on the complex plane. Then, the global roots and poles finding algorithm based on phase analysis is executed on the unit disc. In order to demonstrate the efficiency and applicability of the proposed numerical method, we executed stability tests for fractional exponential delay systems, which are considered benchmarking cases in other publications. It occurs that, each time, our method correctly evaluates the system stability. However, unlike other methods, it is a very general technique that allows stability evaluation of almost any system.

Neural network model of ship magnetic signature for different measurement depths

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This paper presents the development of a model of a corvette-type ship's magnetic signature using an artificial neural network (ANN). The capabilities of ANNs to learn complex relationships between the vessel's characteristics and the magnetic field at different depths are proposed as an alternative to a multi-dipole model. A training dataset, consisting of signatures prepared in finite element method

(FEM) environment Simulia Opera was constructed. A feedforward neural network was developed through a comparative analysis of different activation functions available in MATLAB's Deep Learning Toolbox and the grid search method. Verification was performed using the leaveone-out cross-validation method (LOOCV). The model proved to be highly effective in predicting the magnetic signature for the northward direction in any measurement depth, with prospects to expand it to estimate other directions.

Paper: **6045** **C2P-C**

Towards experimental insight into magnetic flux distribution within the air gap of permanent magnet synchronous drive

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This report explores the experimental identification of magnetic flux density within the motor air gap, focusing on the development of a robot-based approach to automate the scanning procedure. Emphasis is placed on analyzing the distribution of magnetic flux within the motor's spatial air gap, as well as the amplification of harmonics resulting from changes in air gap orientation. Drawing upon experimental findings, a model is proposed to illustrate the three-dimensional distribution of magnetic flux within the gap.

Paper: **6057** **C2P-C**

On Some Properties of Padé Approximations for Fractional Order Transfer Function (FOTF)

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The issue of identifying and designing control systems of fractional order models involves the necessity of their approximation to integer order. The most popular techniques include: Oustaloup's method, Matsuda's method, CFE (Continued Fraction Expansion) method, M-SBL method and different more. It is also possible to use the Padé approximation. This method has not often been mentioned in the context of fractional order models, so this article examines some of its properties for this area of research. The case of the fractional power term (complex variable transfer function raised to a fractional power) is the main focus since it serves as a basis for approximating more intricate

fractional order systems. The article's innovation is in using the nonlinear least squares method to obtain a mathematical description of the behavior of the zeros and poles of the chosen component after approximation. Relying on the gathered statistics, it was found that a very good fit was produced. The approximation of the behaviour of zeros and poles also allowed for the presentation of a new, alternative notation for the Padé approximation.

Paper: **6062** **C2P-C**

Modelling and Simulation of a Synchronous Generator Connected to Infinite Bus in a Bond Graph Approach

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Synchronous generators are the main sources of electrical energy supply in power plants (thermoelectric, hydroelectric) because of this, it is important to know the implications of its connection through transmission lines to the infinite bus. In this paper, the modeling of a synchronous generator and its connection to the infinite bus considering decoupled transmission lines in bond graph is presented. Due to the characteristics of bond graph, it is shown that the model is more compact compared to what is traditionally done in other modeling techniques for three-phase electrical systems. In order to verify the effectiveness of the proposal, simulation results are shown.

Paper: **6082** **C2P-C**

Multilayer Extended Dynamic Mode Decomposition for Coupled Van der Pol Oscillators

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Extended dynamic mode decomposition (EDMD), which is the data-driven method based on the Koopman operator approach, is one of the valuable methods when treating nonlinear dynamical systems. However, the accuracy of linearization deteriorates when the technique is applied to a high-dimensional nonlinear dynamical system such as robots and flying vehicles. To overcome the problem, we propose the multilayer extended dynamic mode decomposition (MEDMD) for the high-dimensional nonlinear system divided into low-dimensional subsystems. The proposed method is applied to a mathematical system model that consists of subsystems in numerical simulation. The results show that MEDMD has good linear accuracy compared to conventional EDMD.

Formation Control of Three Mobile Robots with Varying Distances

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This paper focuses on distributed formation control, a task in which the desired formation shape is controlled by maintaining relative distances between robots. This task is based on the acyclic directed triangular formation with distance-based control. The novelty proposed in this work is the possibility of varying distances that need to be tracked in the formation control task. The focus is on the case where some distances are not constant values but a function dependent on the leader's velocity. An example application, serving as motivation for the analysis conducted, is the vehicles moving in urban traffic, which should maintain a distance between preceding vehicles proportional to their speed for safety reasons.

Day: **Thursday, August 29th, 2024**

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

Room: **Marco Polo**

Chair: **Wojciech Giernacki**

Paper: **6089** **C3L-A**

Robustifying a Reinforcement Learning Based Grasped Object Slippage Prevention Controller Through Adaptive Sliding Mode Control

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Maintaining a stable grasp on objects is a critical challenge in the realm of robotic hands and upper-limb prostheses. External disturbances often disrupt grasp stability, leading to slips. This paper explores the application of reinforcement learning (RL) for intelligent slippage control. However, RL-trained policies are susceptible to failure in perturbed environments due to dynamic variations. To address this limitation, we propose an approach of augmenting a pre-trained RL policy with an adaptive sliding mode controller, particularly suited for systems with continuous state and action spaces. Leveraging the invariance property of the sliding mode algorithm against uncertainties, our approach enhances the robustness of RL policies trained without accounting for diverse, dynamic variations in either simulated or real-world settings. Numerical experiments validate the effectiveness of our method in robustifying RL policies trained in simulated environments.

Innovative Development of a Terrestrial Robot for the Accurate Assessment of pH in Barley Crops in Southern Peru

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Soil pH is a key parameter that directly influences crop health and productivity, as well as the ability of the soil to support plant life. However, measuring this parameter can often be an arduous and laborious task due to spatial and temporal variations and the need for repeated sampling. In addition, conventional techniques for sample collection and laboratory analysis are costly, time-consuming, and can be environmentally damaging. This paper presents the design and implementation of an innovative ground robot to measure the pH level in barley cropland. The robot has an adapted pH measurement system, which is complemented by an autonomous navigation system and a real-time data processing system. This system consists of a robust and accurate pH electrode capable of penetrating different types of soil and accurately measuring its acidity or alkalinity. Results from field tests indicate that the robot can handle a wide variety of soils and climatic conditions, and the pH measurements obtained correlate closely with those obtained by traditional methods. This study proposes that the adoption of ground robots for pH level measurement.

Paper: **6102** **C3L-A**

Multi-Camera Multi-Robot Visual Localization System

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The article presents a general framework for detecting the boundaries of, stitching, adjusting perspective and finally localizing robot positions and azimuth angles for any rectangular map designated with AprilTag markers in the corners and possibly in the interior area. At the same time, the focus of the researchers was to minimize the configuration required for the algorithm to operate - here limited to just the orientation and data of markers, dimensions of the map, markers and robots. The location of cameras can be freely changed without the need to reconfigure anything or restart the

program. This work has been tested on and turned out to be especially helpful for working with the DuckieTown project.

Paper: **6103** **C3L-A**

Computationally Effective Approximation of Integral Curves Lengths for Target Assignment of Mobile Robots Moving in Task-Space with Obstacle

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The paper proposes a new approach to distributed target assignment for a group of robots operating in a space with a circular obstacle. The simple approach of comparing functions of Cartesian distances, which works well in free space, does not give good results if a static obstacle exists. The authors aimed to find an approach that is as computationally effective as possible and yet produces a sufficiently good result. The proposed solution makes use of city block distance expressed in a specific reference frame that depends on the mutual positioning of the robot, the target, and the obstacle. In addition to presenting the idea, the results of numerical simulations were given to confirm the effectiveness of the proposed algorithm.

Day: **Thursday, August 29th, 2024**

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

Room: **Vasco da Gama**

Chair: **Rafał Stanisławski**

Paper: **6018** **C3L-B**

Trajectory Tracking for UAVs: An Interpolating Control Approach

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Building on our previous work, this paper investigates the effectiveness of interpolating control (IC) for real-time trajectory tracking. Unlike prior studies that focused on trajectory tracking itself or UAV stabilization control in simulation, we evaluate the performance of a modified extended IC (eIC) controller compared to Model Predictive Control (MPC) through both simulated and laboratory experiments with a remotely controlled UAV. The evaluation focuses on the computational efficiency and control quality of real-time UAV trajectory tracking compared to previous IC applications. The results demonstrate that the eIC controller achieves competitive performance compared to MPC while significantly reducing computational complexity, making it a promising alternative for resource-constrained platforms.

Paper: **6080** **C3L-B**

Model-Predictive Control of a Two-Switch Forward Converter

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A forward converter is used for high-efficiency dc to dc converter applications. Modeling and control of a two-switch forward converter suitable for a wide range of input voltage applications is presented in this work. The third-order model for continuous conduction mode operation of the converter is considered for closed-loop operation for achieving output voltage regulation. The performance of a model-predictive controller vis-a-vis conventional proportional-integral and sliding-mode controllers is evaluated through simulation of the closed-loop forward converter with voltage variation of 550V to 1000V as input and fixed output voltages of 15V and 24V.

Minimax Regret Optimization for the Scheduling-Location Problem

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We propose novel algorithms for the Scheduling and Location problem (called ScheLoc problem) that combine fields of job scheduling with the makespan criterion on unrelated machines and machine deployment. This research's fundamental aim and distinguishing feature is the application of robust (nondeterministic) optimization with interval data for the ScheLoc problem (deterministic problem with precisely defined input parameters). The minimax regret criterion is considered as the measure of robustness, and the release dates of jobs are represented as well-defined intervals. We show that the algorithms designed for the robust optimization problem with interval release dates determined based on the ScheLoc problem can achieve a lower makespan than a schedule obtained by the greedy algorithm intended for the deterministic ScheLoc problem.

A neighborhood search relaxation towards railway maintenance optimization

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In this paper, we consider the cyclic job scheduling problem of railway vehicles under preventive maintenance to minimize their unavailability, i.e., the total days on maintenance activities of all vehicles in the given time horizon; it is equivalent to the maximization of their total availability. The analysed problem is strongly NP-hard, whereas its solution space is spanned by the combination of permutations. Thus, it causes addition difficulties to traverse it efficiently by local search methods. Therefore, we propose the optimization algorithms, which are based on the Nawaz-Enscore-Ham's method and the simulated annealing metaheuristic, both equipped with our relaxed search of a neighborhood. The numerical experiments reveal that our idea to enhance the algorithms translates into visible improvements of their efficiency to search solution space and to gain crucial benefits for railway industry in the number of days saved comparing to their earlier basic versions. We also confirm once again the strength and robustness of these applied techniques for various combinatorial optimization problems and possibilities of their further augmentation.

Modelling & Simulation II, C4L-A

Day: **Thursday, August 29th, 2024**

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

Room: **Marco Polo**

Chair: **Ewa Pawłuszewicz**

Paper: **6121** **C4L-A**

Estimation of Faults for Some Class of Fractional-Order Systems

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In this paper, a robust simultaneous actuator and sensor faults estimator design for the purpose of the Fault Diagnosis (FD) of some class of fractional-order digital systems is considered. The proposed methodology of designing a H_∞ estimator guaranties a predefined disturbance attenuation level and convergence of the designed estimator, which can be used for both fault diagnosis and fault tolerant control purposes.

Paper: **6008** **C4L-A**

Applying Inertia Matrix Decomposition to Determine Controller Gains for Marine Vehicles

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This work concerns an attempt to solve the problem of selecting controller gains based on decompositions of the inertia matrix. The results presented are limited to the task of trajectory tracking by fully actuated underwater vehicles. The proposed approach uses properties of inertial quasi-velocities (IQV) known from the literature. The novelty is to show that by means of the examination of vehicle dynamics, it is possible to tune the controller described by classical variables and to show the effects of disturbances not adequately taken into account due to the displacement of the vehicle's center of mass. An algorithm for conducting gain selection and simulation examples of its application for a 6 DOF underwater vehicle model are proposed.

Paper: **6040** **C4L-A**

Effect of Network Size on Fractional-Order Dynamics in Large, Scale-Free Robotics Swarms and Platoons

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This paper studies the effect of the size of a large scale robot network on the fractional order of the dynamics of the step response of the system. We show that, for a scale free network with certain parameter values, as the number of robots increases the fractional order also increases up to certain size network, after which the order plateaus. In contrast, for a much more structured platoon network, the opposite happens. This paper presents those results and discusses some hypotheses attempting to resolve the apparent contradiction. We are interested in investigating the presence of fractional order dynamics in systems of this type because they are becoming increasingly common for large scale engineered systems. Very large scale systems can be difficult to design, analyze and control and understanding various approaches to determine effective and accurate reduced order models is important. A concise fractional order description of the dynamics offers insight into the nature of the system that may not otherwise be available through either the full, very large scale system dynamics or other types of reduced order models.

Paper: **6078** **C4L-A**

Poles sequence selection in implementation of fractional-order difference via Takenaka-Malmquist functions

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The paper presents a new algorithm for the selection of poles for modeling fractional-order difference based on Takenaka-Malmquist functions. The main advantage of the proposed approach to the selection of poles is better approximation accuracy in the chosen frequency adequacy range as well as in the time domain of finite-length implementation of the Takenaka-Malmquist-base fractional-order difference. The proposed Takenaka-Malmquist-based difference implementation can also be applied to model fractional-order integrators and non-commensurate state-space systems.

Identification of the Thermal Model Parameters of Industrial Supercapacitors

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This paper presents the results of determining thermal model parameters of the supercapacitors used in industrial applications. The energy losses inside the supercapacitor were determined based on measured current and voltage during the charging and discharging cycles. Based on them and measured temperatures, the thermal resistances of conduction and convection and the heat capacities were calculated. Thermal model parameters were derived for different charging and discharging currents leading to supercapacitor heating. Results will allow the temperature of supercapacitor housing and terminals to be calculated, depending on the charging and discharging currents at a constant ambient temperature.

Control & System Theory I, C4L-B

Day: **Thursday, August 29th, 2024**

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

Room: **Vasco da Gama**

Chair: **Jacek Kabziński**

Paper: **6022** **C4L-B**

Output Feedback Sliding Mode Control of Discrete-Time Systems

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Sliding mode control strategies are useful for counteracting unpredictable disturbance affecting the plant. However, they are not devoid of shortcomings, as they typically require full state information to calculate the control signal. Moreover, such strategies are typically focused on the evolution of a virtual sliding variable and provide only indirect information about the actual state of the plant. Motivated by these issues, in this paper a new approach to sliding mode control of discrete time systems is proposed. This approach only requires information about the output of the plant to synthesize a robust control strategy. Furthermore, it is shown to guarantee boundedness of this output while the system is operating in the sliding phase.

Paper: **6032** **C4L-B**

Robust Consensus Control for Linear Descriptor Multi-Agent Systems Using Output Information

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This work addresses the issues of robust consensus in descriptor multi-agent systems. The interaction topology among agents is considered as a directed graph and the proposed distributed consensus protocol is output feedback-based. The robust consensus control problem is reformulated through a unified framework model into a robust stability problem for a single agent. The controller gain parameters are obtained by solving a set of linear matrix equality constraints and strict linear matrix

inequality constraints. These constraints are derived from the bounded real lemma. The effectiveness of the proposed methodology is illustrated through a numerical example.

Paper: **6046** **C4L-B**

Stabilization of fractional order linear discrete-time control systems

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The paper focuses on the stabilization of fractional order linear discrete-time systems with the Grunwald-Letnikov type fractional operator. The Z-transform, a highly effective method for stability analysis of linear control systems, is used to examine the behavior of the system's solutions. Given the crucial importance of stability in automatics, the primary concern is the stabilization of control systems. Stabilization involves determining the appropriate feedback that ensures the asymptotic stability of the system. In cases where the system is not initially asymptotically stable, stabilization is achieved through a state feedback. This feedback mechanism is derived from the eigenvalues of the matrix linked to the closed-loop system. The outlined asymptotic stability conditions offer guidance in eigenvalue placement to guarantee system stability.

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

Analysis of the decoupling control loop for a plant with input dynamics in the ADRC structure

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This study addresses the decoupling issue within the Active Disturbance Rejection Control (ADRC) framework, taking into account the existence of additional dynamics in the plant input path. These additional dynamics are not directly incorporated into the observer equations. The paper proposes a compensation strategy that employs a filter to shape the observer's input signal. The transfer function forms for the structure under analysis, as well as the matching conditions in the input path, have been established. The findings indicate that while the use of an input filter can enhance the stability of the decoupling loop, it may also reduce the disturbance attenuation. The conclusions drawn from analytical studies and numerical simulations are validated by experimental results.

A Constraint Based Control Architecture for Urban Autonomous Vehicles

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This study explores the application of Control Bar- rier Function (CBFs) for a dynamic constrained control for autonomous vehicle addressing road rules such as lane-keeping, lane changing, overtaking, and right-of-way. In particular, it shows the suitability of CBFs in encoding specific driving styles and strategies. This architecture doesn't need Vehicle-to-Vehicle (V2V) communication, relying only on vehicle and infrastructure sensors. Results from experiments in a simulated urban scenarios highlight the feasibility and efficiency of the proposed approach.

Poster Session IV, C5P-C

Day: **Thursday, August 29th, 2024**

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

Room: **Poster Area**

Chair: **Jerzy Baranowski**

Paper: **6006** **C5P-C**

Artificial Intelligence models for prediction of passengers' flow in rail transport

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Nowadays, one of the most popular and ecological forms of passengers' transport is rail. In the last couple of years (especially after COVID-19 pandemic) many more passengers selected this type of transportation rather than cars or even airplanes. It is connected with much higher travel comfort as well as the possibility of effective work on the train. However, due to the higher popularity, one extremely important problem was observed. It is connected with the passengers' flow that can lead even to traffic. Sometimes it is hard to select an appropriate type of train to effectively serve all the interested people. In this work, we would like to propose not only the survey under the latest AI-based models for prediction of passengers' pileups but also provide information about possible ideas that will be tested on the real data, collected from one of the trains stations in Poland.

Time series for rail passengers flow prediction: a survey

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Nowadays, rails are one of the most popular forms of transportation. It is related to the relatively lower costs of the tickets in comparison to airplanes or even costs connected with travelling by car. It needs to be pointed out that this type of transportation has also one important issue that must be addressed. It is connected to the selection of the appropriate train type for all interested passengers. It is extremely hard especially when passengers' pileups are observed. In this work, we would like to propose an idea to consume time-series data for prediction of the passengers' flow in one, selected train station that is Łódź, Poland. Diversified algorithms that can be used directly in these data were presented and our own ideas are given. We would like to also propose our own pipeline built on the basis of all analyzed approaches.

Acceptance tests of BIM models using the IDS standards with in openBIM

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The article explains an interoperable method for the exchange construction information, particularly concerning civil infrastructure projects. Open BIM standards offer a neutral platform for information exchange, enhancing data integration throughout all construction and operation phases. The Information Delivery Specification Standard (IDS), a component of open BIM standards, along with the Information Delivery Manual (IDM), facilitates the timely and organized exchange of information. The research was aimed to determine if generating requirements for open BIM models could be automated in accordance with IDS standards. It was also assumed that the input data are the requirements from the BIM Execution Plan (BEP). The research results show the ability to generate IDS files automatically, which improves model verification and enables quick adjustments. Despite the challenges, the use of IDS as an element of open BIM standards enhances the construction processes.

Understanding the passengers' behaviour as a key element of multimodal transport design

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Designing multimodal transportation requires understanding passenger behavior, habits, and needs. The article presents the results of a study aimed at distinguishing the most frequent combinations of selected modes of transportation from the place of residence to the destination point with an intermediate means such as rail transport. The data used in the analysis refers to 1102 passengers of the Lodz Agglomeration Railway ("Łódzka Kolej Aglomeracyjna" sp. z.o.o.), which surveyed passengers in 2021. The survey made it possible to distinguish the most common behaviors among passengers and to identify differences in the choice of means of transportation among the identified groups of passengers. The results can support decision-making in the development of multimodal transportation modes taking into account different passenger behaviors.

Modeling the structure of efficiency indicators in railway station management

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The authors attempted to build a structure of efficiency indicators for managing railway station assets. The study aims to answer the following research question: how to model the structure of performance indicators for railway station management? This study focuses on the station and the assets of the Premium station. The article proposes a general model for calculating KPIs, which, when supplied with data, will enable a unified comparative assessment of station asset management at various railway stations.

Predictive maintenance for electrical motors: Current approach and usage of artificial intelligence algorithms

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The article presents the current approach in artificial intelligence methods used in predictive maintenance for electrical motors. The study focuses on presenting data classification methods for fault detection and isolation using data from condition monitoring systems. We discuss the advantages and disadvantages of using machine learning methods like perceptron and Support Vector

Machine (SVM) for fault classification problems. Our conclusion shows great interest in machine learning methods combined with condition monitoring systems. Our future research will focus on comparing SVM, perceptron networks, and other methods, such as K-nearest neighbors, with their possibility for implementation in embedded firmware systems.

Paper: **6099** **C5P-C**

Towards developing and maintaining digital twin for railwa y stations

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The main objective of the paper is to indicate proposals for combining technologies allowing the creation of a digital twin of a railway station. The current development of technology was taken into account through the analysis of research projects carried out in the field of digital twin and the current state of development of standards. Attention was paid to acquiring incremental information, both for design and measurement data. In addition, the method of their processing was presented, as well as the suggested architecture of the digital twin and its dataframe. Finally, an example of data analysis for a digital twin was given, consisting in providing georeference for measurement data.

Paper: **6107** **C5P-C**

Strategic Maintenance Optimization for Enhanced Operational Efficiency of Railway Station Infrastructure

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Effective maintenance is a hard but very important task allowing keeping assets in operation. In particular this is something very relevant for critical infrastructure that are railways and railway stations. European wide analyses show, that there is no harmonization in data standards nor there are good solutions allowing to assist station operators in maintenance management. In this paper we focus on handling available data streams, integrating them with a data lake based centralisation and using it to provide a decision support system. Such system, based on dashboards created with Business Intelligence software, can provide significant help in managing of assets. As an example we provide appropriate routing mechanisms allowing to use the available maintenance personnel with more efficiency.

Paper: **6108** **C5P-C**

Concept of a data centralization system for a railway transportation and station management systems

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This paper advocates for the digitization of transportation enterprises, focusing on the railway industry's need for integrated ticketing and asset management systems. It introduces Data Lake technology as a solution for centralized data management, enabling railway companies to enhance operational efficiency and improve decision-making processes. By integrating diverse data sources within the Data Lake framework, the paper demonstrates the potential for achieving holistic insights and predictive analytics to optimize railway operations. Practical implementation of Data Lake in the MOTIONAL project exemplifies its efficacy in real-world applications, underscoring its pivotal role in modernizing railway transportation and station management systems.

TECHNICAL PROGRAM

Friday

August 30, 2024

Day: Friday, August 30th, 2024

Time: 9:00 – 10:00

Room: Marco Polo

Plenary 4, D0L-A

Day: Friday, August 30th, 2024

Time: 9:00 – 10:00

Room: Marco Polo

Chair: Zdzisław Kowalczuk

Author: Maciej Michałek (Poznan University of Technology, Poland)

Paper: Kinematics and Control of Articulated Vehicles

Robotics V, D1L-A

Day: **Friday, August 30th, 2024**

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

Room: **Marco Polo**

Chair: **Janusz Szpytko**

Paper: **6117** **D1L-A**

Model-Based Design of Distributed ROS2 Systems Using IEC 61499

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ROS2 systems are distributed applications built from strongly isolated components (nodes). Communication is realized through a publish/subscribe mechanism. Despite having these modern software architecture elements, ROS2 has no canonical modelling language that captures overall application design and helps in mapping nodes across distributed platforms. We propose a model-based design approach based on the graphical programming language IEC 61499, mapping ROS2 constructs to native IEC 61499 model elements. Code generation creates native ROS2 nodes from IEC 61499 code. As an additional benefit, this approach also eases integration of ROS2 systems with non-ROS components.

Multi-Talker Verbal Interaction for Humanoid Robots

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Working in multi-talker mode is viable under certain conditions, such as the fusion of audio and video stimuli along with smart adaptive beamforming of received audio signals. In this article, the authors verify part of the researched novel framework, which focuses on adapting to dynamic interlocutor's location changes in the engagement zone of humanoid robots during the multi-talker conversation. After evaluating the framework, the authors confirm the necessity of a complementary and independent method of increasing the interlocutor's signal isolation accuracy. It is necessary when video analysis performance plummets. The authors described the leading cause as insufficient performance during dynamic conversations. The video analysis cannot derive a new configuration when the interlocutor's speech apparatus moves beyond the expected margin and the video frame rate drops.

Excitation signals to state-space realization and linear-regression identification methods applied to a MIMO system

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This work presents a new approach in the comparative analysis of three excitation signals applied in a system identification process. The excitation signals employed are Pseudo-Random Binary Sequence (PRBS), Sine Sweep (CHIRP), and Gaussian White Noise (GWN). Moreover, with comparative purposes, two algorithms are used to identify a Multiple-Input-Multiple-Output (MIMO) system of 100 degrees of freedom: a State-space identification method based on the traditional Eigensystem Realization Algorithm (ERA) and the linear-regression method ARMAX. The MIMO

system is submitted to five levels of additive measurement noise: 1%, 1.5%, 2%, 2.5%, and 3%. The results are statistically analysed composed by 100 simulations for each set of algorithm parameters. The simulations show that, apart from the GWN, well-known as an appropriated excitation signal for application in systems with the characteristics portrayed in the present work, the PRBS can be another feasible signal to identify the MIMO system simulated accordingly with the identification method chosen.

Special Session on Nonlinear Control: Theory and Applications II, D1L-B

Day: **Friday, August 30th, 2024**

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

Room: **Vasco da Gama**

Chair: **Witold Respondek**

Paper: **6050** **D1L-B**

Regularised Homotopy Continuation Method for the Motion Planning Problem

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We address the motion planning problem for smooth control-nonlinear systems by presenting a regularised version of the well-established homotopy continuation method. The proposed approach (inspired by Tikhonov regularisation in the Moore-Penrose pseudo-inverse theory) deal with the two issues of the classical method: the singularities of the endpoint map of the nonlinear control system and the global existence of solutions of a differential equation posed on the control space, the path lifting equation (PLE). We analyse the properties of our method and show that it is always well-posed and that the regularised PLE always possesses a global solution. We additionally examine the effect of the regularisation and we give conditions under which the regularized solution converges to the initial solution. Finally, we illustrate the potential of our method through several numerical examples.

Paper: **6024** **D1L-B**

Robust Control of Duffing Oscillators with Unknown Parameters

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A new approach to designing controller of Duffing oscillator is proposed. The problem of tracking control is considered. The control aim is defined as a nonlinear, time-varying 'funnel' which must contain the tracking error. The control is based on investigation of tracking error extension which includes information on both state variables. A new, bounded control is derived, reacting when the trajectory approaches the curves constraining the 'funnel'. The presented approach can be used for chaos synchronization, suppression or for 'chaotification' of Duffing oscillators as well as other

chaotic systems. The proposed approach is based on a simple robust control concept and does not require complicated stability investigation typical for nonlinear adaptive control.

Paper: **6104** **D1L-B**

The polynomial approach to accessibility of nonlinear fractional order difference system

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The focus of the paper are local accessibility conditions for nonlinear control systems with the Gr{u}nwald-Letnikov fractional order h-difference operator. These conditions are presented in terms of the greatest left common divisors of shifted polynomials associated with the given system. The obtained results extend the polynomial approach to accessibility problem of nonlinear discrete-time control system on fractional case.

Day: **Friday, August 30th, 2024**

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

Room: **Marco Polo**

Chair: **Ryszard Beniak**

Paper: **6051** **D2L-A**

Remote Monitoring and Control of Mobile Robots in Real-Time Using Multimodal Digital Twins

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Although digital twins have been playing a pivotal role in the management of the lifecycle of physical robotic systems of systems, they have hardly been employed to actively guide mobile robots in real-time. In fact, the guidance of such systems requires functionalities, including the perception of environmental constraints and avoidance of collisions. A spatial information stream beyond the internal robot state measured using proprioceptive sensors is therefore needed. Exteroceptive sensors help meet this demand. Nevertheless, such sensors have received little attention thus far in the development of digital twins. On the other hand, various mobility objectives, such as reverse motions, might require the awareness of the historical internal state of the distant robot. For instance, the current energy budget is likely to constrain the reachability of the initial robot location, even when spatially and kinematically feasible. We therefore develop a web-based framework to monitor and actively steer mobile robots while leveraging on multimodal digital twins. We collect data about the internal state and camera-captured neighborhood of the robot in real time.

AMCL hybrid localization through the incorporation of visual rectangular landmarks

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The increasing integration of robots into daily life requires enhanced autonomy capabilities and better levels of robustness. To address robot localization, this work proposes Hybrid AMCL, an extension of the original Adaptive Monte Carlo Localization (AMCL) algorithm, incorporating visual cues in the form of natural rectangles, usually present indoors, to overcome difficulties posed by scenarios lacking geometric features such as corridors. To this end, this work also introduces Rectangle Intersection-based Detector using Graphs and Elongation (RIDGE), a novel algorithm based on the idea of finding quadrilaterals in images, corresponding to real-world rectangles. The effectiveness of Hybrid AMCL is validated both in simulation using Isaac Sim and in a real-world environment. Our results show its potential for more accurate localization in challenging situations.

Multi-Robot Path Planning for Comprehensive Area Coverage in Complex Environments

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Multi-robot coverage path planning (mCPP) involves devising efficient motion sequences for robots to cover all positions within a workspace, excluding obstacles. This paper focuses on addressing the path-planning challenge of a Divide Area based on Robot's Initial Positions (DARP), where a group of mobile robots is tasked with covering a predefined area containing obstacles. This work proposes an improved DARP algorithm for efficient coverage. The proposed algorithm, combined with the A$*$ and the spanning tree coverage algorithm, assigns tasks to robots to optimally achieve full coverage of the desired area. It transforms the initial mCPP problem into individual coverage path planning tasks of single-robot, combining their solutions to form the optimal solution for mCPP. This method significantly improves performance by reducing coverage time, minimizing the number of turns taken by robots, and enhancing overall coverage efficiency.

Development of criteria for the selection and investigation of PEMFC stacks as components of hybrid energy sources for UGVs

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This paper focusses on the development of the methodology for the selection of polymer exchange membrane fuel cell (PEMFC) stacks as the main energy source to supply a unmanned ground vehicle (UGV). The first part of the paper presents the experimental investigations of the electrical load profiles recorded for the PIAP PATROL UGV during both vehicle movement or manipulator operation. The numerical simulation of the energy demand profile was performed for various terrains and roads. The 2 kW PEMFC stack is proposed and investigated as an electrochemical energy source to supply the medium - size tracked vehicle. In addition, the preliminary test of the 2 kW PEMFC stack performance in powering the electric motor while travelling is demonstrated.

Day: **Friday, August 30th, 2024**

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

Room: **Vasco da Gama**

Chair: **Jerzy Baranowski**

Paper: **6100** **D2L-B**

A Zonotopic State Estimation Approach for Nonlinear Uncertain Systems with Bounded Uncertainty in the Measurement Time Instants

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The use of zonotopes has gained in popularity for the implementation of state estimation procedures for systems with bounded uncertainty due to their capability to better capture correlations between individual state variables in comparison with more simple shapes such as axis-aligned interval boxes. However, many zonotopic state estimation procedures are limited to linear (uncertain) dynamics or to polytopic overapproximations of nonlinear system models to make observer structures applicable that perform the correction step with the help of a linear feedback of the output error. In this work, linearity assumptions are removed by implementing a predictor-corrector technique which - as a generalization of classical assumptions - does also not suppose that the measurement time instants are precisely known. To cope with such scenarios and to allow for a refinement of a-priori knowledge about the uncertainty of the measurement time instant in a model-based framework, this work makes use of an augmented state-space representation in which time is interpreted as a further state variable. Two simulation case studies conclude this paper and demonstrate the effectiveness of the estimator.

Robust GMVC algorithm undermining the employment of the Moore–Penrose inverse

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In the paper, a set of new findings derived from the application of the nonunique $sigma$-inverse into the generalized minimum variance control (GMVC) algorithm is given. In such a way, the robust instance of the discussed control strategy is proposed strictly devoted to the right-invertible LTI systems defined in the discrete-time transfer-function-originated framework. The alternative inverse-based control procedure clearly outperforms the classical one giving rise to the introduction of the generalized σ-inverse rather than the Moore-Penrose (MP) one. Two numerical examples address a huge impact of the so-called degrees of freedom at least in the minimum-energy considerations.

Numerical methods for solving the linearized model of a hinged-free reduced plate arising in flow structure interactions

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The problem of partially hinged partially free rectangular plate that aims to represent a suspension bridge subject to some external forces (for example the wind) is considered in order to model and simulate the unstable end behavior. Such a problem can be modeled by a plate evolution equation, which is nonlinear with a nonlocal stretching effect in the span-vise direction. The external forces are periodic in time and cause the vortex shedding on the structure (on the surface of the plate) and thus it may cause damage to the material. Numerical study of the behavior of steady state solutions for different values of the force velocity are provided with two finite element methods of different type.

Transfer Function Analysis and Algorithm Order Reduction for Active Disturbance Rejection Control

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This paper presents the transfer function analysis of the closed-loop system with an active disturbance rejection control (ADRC) algorithm. Although the classical interpretation of the extended state observer (ESO) and control algorithm (state feedback) in the state space usually allows for achieving satisfactory control quality, the presented analysis enables calculation of the obtained pole values in the closed-loop system. Furthermore, reduction of the algorithm order by omitting the non-dominant poles of the control plant has also been proposed. The experiments were carried out on a third-order mechanical object, a ball balancing table (BBT) setup. In addition to reducing computational complexity, the presented order reduction procedure allows one to improve the properties of a closed-loop system in the case of poles with large modules affecting the control quality.

Index of Authors

SESSIONS

NOTES

NOTES

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.