WELCOME

from the MMAR 2021 Organizing Committee

I would like to invite you to Miedzyzdroje, Poland for the 25th International Conference on Methods and Models in Automation and Robotics. Almost 80 draft papers have been submitted, from which the International Program Committee, chaired by Professor Tadeusz Kaczorek, has selected 68 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 co-sponsored by the Committee of Automation and Robotics of the Polish Academy of Sciences and the Polish Society for Measurement, Automatic Control and Robotics.

The Conference starts on Monday afternoon, 23 August 2021. Every day of the conference begins with a plenary lecture delivered by a distinguished scientist, and further 9 papers are to be presented in the invited sessions organized by very active researchers from universities and industry. All other papers will be presented in two parallel regular sessions. Some of them in an on-line form. Moreover, all the MMAR 2021 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 Miedzyzdroje.

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

Prof. Zbigniew Emirsajłow

Chairman of the MMAR 2021 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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WWW SITE

The Final Program

of the MMAR 2021 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 2021 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 2021.

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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 25th in a series which started in 1994.

VENUE AND DATES

The Conference will be held at the Amber Baltic Hotel in Międzyzdroje, from Monday, 23 August till Thursday, 26 August 2021.

The Conference registration desk in Amber Baltic Hotel will be opened on the Monday morning, 23 August and during each day of the Conference.

The Conference will start on Monday, 23 August at 4:00 p.m.

PRESENTATION FACILITIES

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

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

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

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

The language of the Conference will be English.

TIME TABLE

Monday, 23rd August, 2021

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gamma**
11.00	Registration opens (Amber hotel main hall)	
16.00 – 16.30	Conference Opening	
16.30 – 17.30	Plenary Lecture (Marco Polo), Chair: T. Kaczorek **Online Optimization for Output-feedback Control** Speaker: **Joao Pedro Hespanha**	
19.00	Welcome Party (Amber hotel)	

Tuesday, 24th August, 2021

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gamma**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: A. Bartoszewicz **From Snapping Fixtures to Multi-Robot Coordination: Geometry at the Service of Robotics.** Speaker: **Dan Halperin**	
10.10 – 11.10	B2L-A **Control Applications I** Chair: Adam Gałuszka 8006, 8032, 8066	B2L-B **Control and Systems Theory I** Chair: Jerzy Klamka 8044, 8047, 8027
11.10 – 11.40	Coffee break	
11.40 – 13.00	B3L-A **Robotics I** Chair: Alexander Winkler 8070, 8073, 8074, 8078	B3L-B **Signal Processing** Chair: Rafał Różycki 8010, 8050, 8060, 8061
13.00 – 15.00	Lunch (Amber hotel)	
15.00 – 16.40	B4L-A **Robotics II** Chair: Igor Korobiichuk 8013, 8029, 8041, 8045, 8054	B4L-B **Advances in Vehicular Technology I** (Special Session) Chair: Paweł Skruch 8012, 8018, 8034, 8035, 8049
16.40 – 17.10	Coffee break	
17.10 – 18.50	B5L-A **Control Applications II** Chair: Andrzej Skulimowski 8004, 8021, 8022, 8033, 8038	B5L-B **Advances in Vehicular Technology II** (Special Session) Chair: Paweł Skruch 8053, 8057, 8058, 8068
19.30	**Conference Banquet** (Amber hotel, Christopher Columbus room)	

Wednesday, 25th August, 2021

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gamma**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: J. Klamka **Assignability of Numerical Characteristics of Discrete Time-varying Linear Systems.** Speaker: **Adam Czornik**	
10.10 – 11.10	C2L-A **Intelligent Systems and Methods I** Chair: Radosław Rudek 8020, 8031, 8037	C2L-B **Modelling and Simulaton I** Chair: Robert Piotrowski 8003, 8065, 8067
11.10 – 11.40	Coffee break	
11.40 – 13.00	C3L-A **Control and Systems Theory II** Chair: Krzysztof Oprzedkiewicz 8007, 8016, 8030, 8048	C3L-B **Control Applications III** Chair: Andrzej Bartoszewicz 8043, 8040, 8062, 8046
13.00 – 15.00	Lunch (Amber hotel)	
15.00 – 16.40	C4L-A **Intelligent Systems and Methods II** Chair: Rafał Langowski 8024, 8026, 8028, 8064, 8072	C4L-B **Modelling and Simulaton II** Chair: Ewa Pawluszewicz 8036, 8039, 8051, 8071
17.30	Touristic programme	

Thursday, 26th August, 2021

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gamma**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: Z. Emirsajłow **Traffic Control Using Automated Truck Platoons: Distributed Sensing, Actuation, and Learning.** Speaker: **Karl H. Johansson**	
10.10 – 11.10	D2L-A **Fractional Order Systems** Chair: Artur Babiarz 8002, 8023, 8076	D2L-B **Robotics III** Chair: Aleksandra Kawala-Sterniuk 8008, 8015, 8019
11.10 – 11.40	Coffee break	
11.40 – 13.00	D3L-A **Control Applications IV** Chair: Michał Niezabitowski 8011, 8055, 8075	D3L-B **Robotics IV** Chair: Marek Długosz 8025, 8052, 8063
13.00 – 13.15	Conference Program Committee Meeting (Young Author Prize Contest)	
13.15	The Young Author Award Ceremony and Farewell Lunch	

TECHNICAL PROGRAM

Monday

August 23, 2021

Day: Monday, August 23rd, 2021

Time: 16:00 – 17:30

Room: Marco Polo

Plenary Sesion, P-1

Day: Monday, August 23rd, 2021

Time: 16:30 – 17:30

Room: Marco Polo

Chair: T. Kaczorek

Author: J.P. Hespanha (University of California, CA, USA)

Paper: Online Optimization for Output-feedback Control

TECHNICAL PROGRAM

Tuesday

August 24, 2021

Day: Tuesday, August 24th, 2021

Time: 9:00 – 10:00

Room: Marco Polo

Plenary Sesion, P-2

Day: Tuesday, August 24th, 2021

Time: 9:00 – 10:00

Room: Marco Polo

Chair: A. Bartoszewicz

Author: Dan Halperin (Tel Aviv University, Israel)

Paper: From Snapping Fixtures to Multi-Robot Coordination: Geometry at the Service of Robotics

Day: **Tuesday, August 24th, 2021**

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

Room: **Marco Polo**

Chair: **Adam Gałuszka**

Paper: **8006** **B2L-A**

Design of Weighted PID Controllers for Control of the Stewart-Gough Platform

Justyna Kolasiewicz, Anna Perżyło, Robert Piotrowski

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Stewart-Gough platform (SGP) is a popular parallel type manipulator that involves a 6 degrees of freedom (DOF) motion. In this paper, the process of mathematical modelling of SGP is presented. Two selected control algorithms that use PID controllers and weighted PID controllers are designed. Both control systems using these algorithms are implemented in MATLAB environment as well as on the actual SGP. Parameters of the controllers are optimized with the use of different integral performance criteria. Tests of the designed control systems on the computer model and on the SGP are presented.

Paper: **8032** **B2L-A**

Predictive Control of a Two-Input Two-Output Current System for Permanent Magnet Synchronous Machines

Madalin Costin*, Corneliu Lazar****

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This paper presents a generalized predictive control (GPC) algorithm for the two-input two-output (TITO) current system of a permanent magnet synchronous machine (PMSM). This formulation, suitable for TITO coupled systems, assumes the decoupling of the permanent magnet synchronous machine in the d-q frame by using a multivariable GPC algorithm. Thus, the performances of the

current control system of PMSM are improved compared to the classic current control solution with SISO-PI controllers. Finally, the simulations were carried out to control the d-q currents of a PMSM using the proposed TITO-GPC algorithm and the results were compared with those obtained with the classical current control structure based on SISO-PI controllers, with and without zero cancelation. The corresponding data show the usefulness of the multivariable predictive control approach.

Paper: **8066** **B2L-A**

Optimization of the FOPID Parameters of the 3D Crane Control System by Using GWO

Jakub Żegleń-Włodarczyk , Klaudia Dziedzic

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This paper presents an example of tuning FOPID (Fractional Order Proportional Integral Derivative) controller with 3D crane. The GWO (Grey Wolf Optimizer) optimization algorithm is used to design FOPID for the system. Simulations are done in MATLAB platform. The results show comparison of fractional calculus to the conventional method.

Day: **Tuesday, August 24th, 2021**

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

Room: **Vasco da Gamma**

Chair: **Jerzy Klamka**

Paper: **8044** **B2L-B**

Reference Trajectory Tracking for Second Order Dynamical Systems

Paweł Latosiński , Andrzej Bartoszewicz

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Sliding mode control strategies are an excellent method of ensuring stability of plants subject to disturbance and model uncertainties. However, even though such strategies guarantee at least asymptotic stability of the controlled plant, they have no direct way of providing a specific state trajectory. This is particularly significant when the controlled system is operating under practical constraints, which typically cannot be enforced in sliding mode control. To remedy this issue, in this paper we propose a new approach to sliding mode controller design. The new method involves defining a reference trajectory, which can be tracked by all system states with minimal control effort. In particular, a reference trajectory based on the cosine function has been designed for a class of second order dynamical systems. It has been demonstrated that the sliding mode controller using this reference trajectory can satisfy the given state and input constraints.

Paper: **8047** **B2L-B**

Controllability of Singularly Perturbed Linear Time-Invariant Systems on Time Scales

Olga Tsekhan *, Ewa Pawluszewicz **

**Faculty of Economics and Management*
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Wiejska 45 C, Białystok 15-351, Poland

The problem of controllability of singularly perturbed linear time-invariant systems on any time model is considered. The robust on small singularity parameter rank-type sufficient controllability

conditions for these classes of systems are presented. For this aim the decomposition approach on the basis of the Chang-type transformation is applied.

Paper: **8027** **B2L-B**

Nonlinear Luenberger Observer for Systems with Quantized and Delayed Measurements

Branislav Rehák, Volodymyr Lynnyk

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A Luenberger-like observer for nonlinear systems with quantized measurements is proposed. The observer design is based on the solution of a certain partial differential equation that is solved numerically. Then, stability of this observer is proved even in presence of quantized measurements and de layed measurements. The results are illustrated by an example.

Day: **Tuesday, August 24th, 2021**

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

Room: **Marco Polo**

Chair: **Alexander Winkler**

Paper: **8070** **B3L-A**

Hybrid Control for Remote Surgery Subject to Time Delay

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

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Through the use of telerobotics, surgeons can perform operations on patients from a distance, via a communication network. However, a major issue to these procedures is the existence and effect of time delays, which are known to negatively affect performance. In addition, the forces that occur due to tooltissue interaction may also present problems during operations. This paper investigates and compares the use of Proportional-Integral-Derivative (PID) controllers and Model Predictive Controllers (MPCs) used in hybrid control, and their effects on the performance of the da Vinci™Patient Side Manipulator (PSM), a surgical robot, when subjected to different time delays. It was found that hybrid MPCs have better trajectory control, however hybrid PID controllers exhibit greater ability to adapt to undesirable external forces from contact. Further research into implementing a predictor with the PID controllers and comparing results, as well as integrating benefits of both controllers into a single hybrid control would provide great benefits for improving surgical telerobotic performance.

Paper: **8073** **B3L-A**

Automation of a Surface Reconstruction Process of a 3D Scanned Surface by Using an On-Operation Modifiable System Control

Luis Trucios , Jesus Castillo , Arias Mavix , Yover Castro, Andree Salazar

Perception Multipacha Mechatronics, Lima, Peru
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To automatize the scanning process of mining stock-piles and the estimation of its volume, a mechatronic module, called ScanTec, with a dedicated lidar-processing and communi cation

pipeline was developed for scanning, meshing and volume tracking of large stockpiles of mining material. Because of price limitations, the module includes a 2d Quanergy LiDAR that is rotated to achieve a 3d scanning of the stockpiles, a robust controller defined by a set of on-operation modifiable PID controllers, based on current rotation state, was proposed to achieve a high-precision scanning. The proposed pipeline also includes a sequence of filters and algorithms to perform a properly 3d surface reconstruction and volume estimation of stockpiles scans. This method was tested and tracked over large mining stockpiles. A bidirectional protocol was implemented on the ScanTec module to share information between the process results and the User Interface (UI) both properly connected on a local IP switcher.

Paper: **8074** **B3L-A**

A Novel Software Architecture of Anticipatory Harvesting Robot Teams

Andrzej Skulimowski*, Przemysław Pukocz*, Inez Badecka, Mehmet Kara*****

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This paper presents a novel application of anticipatory coordination and optimization principles, previo-usly developed for autonomous inspection robot teams. The core tenet behind our research is to build a team of agile and relatively small robots, each equipped with two synergistically operating robotic arms, one arm with a soft gripper, the other arm with a set of cameras and a fruit cutting mechanism, all controlled by innovative anticipatory network (AN) algo-rithms. This allows the plantation management to efficiently supervise the team, coordinated and optimized by an adaptive anticipatory decision engine. Another key component of the robotic software architecture that allows the team of robots to efficiently harvest soft fruits such as strawberries or raspber-ries is a package of information fusion algorithms in the world model, associated with a knowledge base and a digital twin of the cover crops. We will show that AN coordination principles ensure the reliable operation of robots in case of communica-tion disturbances or when uncertain or incomplete instructions are entered by the operator in the management and supervision system. The flexible design of the overall robotic architecture will make it possible to further develop the robot teams to respond to additional needs such as harvesting other fruits and working in various horticultural environments.

Self-Rearrangement in a Group of Differentially-Driven Mobile Robots Changing Shape of the Formation

Wojciech Kowalczyk, Krzysztof Kozłowski

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This paper presents control for a large group of differentially driven mobile robots that is able to efficiently selfrearrange if desired shape of the formation changes. Distributed Goal Assignment (DGA) is used to speed up the convergence and reduce number of inter-robot collision avoidance interactions. In this approach, pairs of agents uses an analytical criterion to give a verdict on whether swapping goals between them will result in a better system performance. Peer-to-peer communication is used to allow decision-making process and possible goal swapping. Limited range of the both on-board sensing system and the inter-agent communication is considered. This is the main novelty of the paper. The effectiveness of the proposed algorithm is illustrated by numerical simulations conducted on a large group of non-holonomic mobile platforms. Formation shapes were designed to ensure that the new assignment of agents to goals is non-trivial. In addition, a scenario is shown in which a significant number of agents, performing steady-state tracking, change goals assignments due to the appearance of a new agent in the close vicinity of the reference trajectory.

Day: **Tuesday, August 24th, 2021**

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

Room: **Vasco da Gamma**

Chair: **Rafał Różycki**

Paper: **8010** **B3L-B**

Correlation Mathematical Model of Video Images with Measuring Information About Geometrical Parameters

Igor Korobiichuk*, Yurij Podchashinskiy**

**Warsaw University of Technology, Institute of Automatic Control and Robotics, Warsaw, Poland; e-mail: igor.korobiichuk@pw.edu.pl*
***Zhytomyr State Technological University Zhytomyr, Ukraine; e-mail: ju.podchashinskiy@gmail.com*

The article discusses the correlation of mathematical models of video images with measuring information about the geometric parameters of objects. A method for identifying the parameters of these models was proposed, and experimental results were obtained using the example of video images of the surface of products for which the quality of manufacture is controlled. The study results can be used to develop methods for the digital processing of video images and algorithmic compensation of errors of measuring information about the geometric parameters of objects. Such methods are part of the software and algorithmic support of automated systems that use video images as a source of measuring information about mechanical quantities and control the quality of industrial products.

Paper: **8050** **B3L-B**

Error Accumulation Effect in Xsens Based Manipulator Teleoperation

Tomasz Grzejszczak, Adam Gałuszka, Natalia Bartosiak, Martyna Wojnar

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The purpose of this paper is to find and examine the impact of error of MTw Xsens IMU sensors. The sensors are used for manipulator control by means of teleoperation. The serial connection of the sensors generates the effect of error accumulation such that the orientation of last element of kinematic chain is measured with cumulative error of all sensors. In this paper the results of test is presented where the sensors are connected in series for yaw and roll error calculations. Two types of

errors are present: constant accumulated over time and temporary error in form of spikes. Final discussion presents the possible accuracy of the kinematic chain depending on the number of used sensors.

Paper: **8060** **B3L-B**

Pilot Study on Using Innovative Counting Peaks Method for Assessment Purposes of the EEG Data Recorded from a Single-Channel Non-Invasive Brain-Computer Interface

Natalia Browarska*, Jarosław Zygarlicki*, Mariusz Pelc*,, Michał Niemczynowicz*, Małgorzata Zygarlicka*, Aleksandra Kawala-Sterniuk***

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This paper presents an innovative method for counting peaks on EEG signal. In this particular case it was applied for the purpose of efficiency assessment of smoothing filtering. The analysed data recorded with the NeuroSky Mindwave EEG headset, obtained from the open source data-base. The best results gave Moving Average filtering with the score of over 96% peaks coverage. Promising results of this methods are consistent with the conclusions based on visual assessment. This method can be treated as an introductory method for intelligent machinebased reasoning.

Paper: **8061** **B3L-B**

The Use of Counting Peaks Method for the Purpose of Smoothing Filtering Efficiency Assessment in Analysis of Electroencephalography Data

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In this paper an innovative counting peaks method applied for the purpose of efficiency assessment of smoothing filtering applied on electroencephalography data was presented. The proposed method gave promising results and can be treated as an introductory method for intelligent machine-based reasoning. The analysed data were obtained from the open source data-base and recorded with the OpenBCI EEG headset. The comparison focused on Moving Average and Savitzky-Golay (SG) filter. The best results were obtained with the use of the Moving Average filtering.

Day: **Tuesday, August 24th, 2021**

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

Room: **Marco Polo**

Chair: **Igor Korobiichuk**

Paper: **8013** **B4L-A**

General Dynamic Neural Networks for the Adaptive Tuning of an Omni-Directional Drive System for Reactive Swarm Robotics

Hanqing Zhao, Marco Dorigo, Michael Allwright

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We demonstrate the use of general dynamic neural networks (GDNNs) for the online tuning of an omni-directional drive system for reactive swarm robots. The drive system used in this work consists of four motor-encoder-microcontroller modules each constituting a single-input single-output (SISO) proportional, integral, and differential (PID) control system. For a given target velocity, a neural network generates the parameters for each PID control system. In this paper, we evaluate and compare two different network structures for generating the PID parameters for the control systems using a hardware platform that we also presented in this paper. We analyze the performance of the system with respect to ISO performance indicators, our results show that both network structures are able to learn and tune the parameters for each PID control system to increase the accuracy of the drive system in comparison to fixed untuned PID parameters that are close to the output of a randomly initialized network.

Paper: **8029** **B4L-A**

Design of a Phantom Device with a Safety System Based on a Non-Invasive Method of Monitoring Blood Flow Within an Operator's Arm

Kamil Kamieński, Maciej Rećko, Kazimierz Dzierżek

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Paper presents the design process of a safety system for an exoskeletal phantom device. The device would enable remote control of a mobile robot equipped with a robotic arm. Systems creation is backed by an analysis of oxypulsometer based measurements using Cross Recurrence Plots,

Recurrence Quantification Analysis and Principal Component Analysis. Studies provided clear answers to potential viability and use case of solution.

Paper: **8041** **B4L-A**

Non-Uniform Sampling Period of the Discrete PID Controller and its Performance Indexes in Case of the FLHex Robot Leg

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Practical implementation of a discrete PID controller for FLHex robot leg position control system with non-uniform sampling is presented. Studies starts with concept of FLHex robot that can operate in terrain and fluid regimes. Usage of non-uniform sampling in PID controllers can provide similar performance and stability of mobile robot with reducing the computational load of the robot control unit. In the case of systems such as the FLHex, where multiple PID controllers are used, this advantage is even greater. Presented comparison of classical and non-uniform discrete PID controller in FLHex robot's leg positions control in underwater movement with varied coefficients shown differences in integrals of the squared error (ISE) and integrals of energy consumption (IEC).

Paper: **8045** **B4L-A**

Particle Filter-Based Perception Method for Obstacles in Dynamic Environment of a Mobile Robot

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The state perception problem for obstacles occurring in the workspace of a mobile robot is a challenging task. The main goal of this work is to introduce a novel concept of the Particle filter algorithm where not only the positions but also the velocities of static and moving obstacles can be perceived using measurement data of an onboard LiDAR sensor. Next to the well-known resampling methods, a novel resampling algorithm was also introduced where the effective number of the particles can be considered. The introduced algorithm can generate an appropriate solution for both the position and velocity perception task.

Fixed Wing Deflection Measurement Using Sensor Fusion

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The system presented in this paper integrates measurements from Deflection-Detection-Vision-System (DDVS) and strain gauge sensors to calculate the dynamic performance of the unmanned aerial vehicle (UAV) fixedwing. The fusion results are more accurate and reliable than the measurement from the single sensor alone, and this is used to design an advanced control system. Unscented Kalmar Filter (UKF) is the choice of fusion method because it gives better performance in dealing with nonlinear systems and deals with white and color Gaussian noise. The presented novel measurement and control system gives accurate shape and deflection of the fixed-wing, which will be used to calculate the aerodynamic performance. The DDVS was verified in extensive experiments with the system installed in the wind tunnel. The objective of experiments conducted was to determine the wing's deflection in flight parameters' function. The results of the camera and strain gauges integration resulted in accurate measurements in comparison with results obtained from one sensor only.

Day: **Tuesday, August 24th, 2021**

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

Room: **Vasco da Gamma**

Chair: **Paweł Skruch**

Paper: **8012** B4L-B

Highway Pilot Training from Demonstration

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As driving task has been and still is the domain of humans, they are a relatively good model of how to behave on road. However, as we would like to constantly raise standards of safety and efficiency of transportation by automated driving, simple imitation of human driving seems not to be good enough. In this paper, we present a method for learning a baseline agent represented as a neural network, which is responsible for planning the behaviour of an automated car, based on a set of expert demonstrations. We show that imitation learning could be a promising way for achieving initial policy, which is almost as effective as human. The generated policy could be then finetuned by the reinforcement learning methods. We show that such an approach suits well for an automated driving task and allows faster training of the RL-based artificial driver.

Paper: **8018** **B4L-B**

Adversarial Trajectories Generation for Automotive Applications

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The development of Advanced Driver Assistance Systems (ADAS) with a high level of autonomy requires immense testing efforts to ensure the safety and robustness of developed algorithms in critical situations. Unfortunately, exploration of difficult situations through test drives in natural traffic is ineffective due to the rarity of such events. While scenariobased testing in a virtual environment is often proposed as an effective method that helps to evaluate system performance in difficult situations, the manual definition of virtual test scenarios poses a significant challenge itself. Performance drops in tested systems, especially ones containing machine learning components, may

be related to situations that are not necessarily considered challenging for a human driver and thus are difficult to predict in a test design. In this paper, we propose a method that allows to generate a variety of virtual test scenarios for ADAS through an adversarial trajectories generation. The method generates scenarios by finding trajectories of the road users in the proximity of the vehicle controlled by the tested algorithm that result in safety-critical events, such as collisions. We demonstrate the effectiveness of the presented method on an example of a critical scenario generation for a vehicle control policy based on Reinforcement Learning methods.

Paper: **8034** **B4L-B**

Fault Injection in Optical Path - Detection Quality Degradation Analysis with Wasserstein Distance

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The goal of this paper is to present results of analysis of artificially generated disturbances imitating real defects of camera that occurs in the process of testing autonomous vehicles both during rides and later, in vehicle software simulation and their impact on quality of object detection. We focus on one perception module responsible for detection of other moving vehicles on the road. Injected faults are obliteration by particles and pulsating blinding. At the same time, we want to propose an examination approach scheme that will provide detailed information about distribution of quality in this comparative experiment. The method can be reused for different perception modules, faults, scene sets and also in order to compare new releases of main recognition software. To do so we combine statistical methods (Welch's ANOVA) and topological analysis (Clusterization over space of distributions, Wasserstein metric). Work provides a summary of the experiment for all data used and described by mentioned tools and examples of certain cases that illustrate general conclusions.

Paper: **8035** **B4L-B**

Weight Perturbation as a Method for Improving Performance of Deep Neural Networks

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Learnable weights in very deep neural networks are not utilized in an efficient way i.e. the variance of weights in some non-performing layers is close to zero. One approach taken to mitigate this problem, has been the connection pruning, in which some of the weights in a network are masked with zeros, without negatively affecting the network performance. The drawback of such approach is that in the GPU implementations of neural networks, pruning the weights does not affect the

network training or inference speed. In this paper we propose an alternative solution to the problem of inefficient utilization of network learning capability - perturbing the weights of the network during training with additive, zero-mean noise. It causes the variance of weights in non-performing layers to rise, and can improve the performance of neural networks. In this paper we show the effect of the weight perturbation on the performance of five well known network architectures, while testing them on the task of CIFAR100 classification.

Paper: **8049** **B4L-B**

An Approach for Evaluating the Completeness of the Test Scenarios for the Vehicle Environmental Perception-Based Systems

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An environmental perception aims to detect and classify objects existing in the vehicle's surroundings to build a virtual representation of the world. It can be considered as an essential building block in modern advanced safety and automated driving systems. These systems implement functionalities that are very often classified as safety-critical. Testing is actually the only method to assure the required system quality and compliance with safety standards. Testing the safety aspects of automated driving systems creates a number of challenges related to the adequacy and completeness of the test cases being developed. This is because the number of possible test scenarios on the road is actually infinite and such scenarios are time- and spacedependent. In this paper, we define a qualitative and quantitative measure that can be used to evaluate the completeness and adequacy of the test scenarios and consequently limit the amount of tests needed. The measure allows to consider static aspects of the perception systems such as detection and classification, as well as dynamic aspects related to object tracking.

Day: **Tuesday, August 24th, 2021**

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

Room: **Marco Polo**

Chair: **Andrzej Skulimowski**

Paper: **8004** **B5L-A**

Power and Water for an Off-Grid Resort

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The feasibility of replacing fossil fuel energy with a hybrid renewable energy system is studied for a case study in the hospitality industry. More precisely, the analysis concerns an isolated accommodation establishment, not connected to the electricity grid, which has to meet its needs for water and electricity. The proposal is evaluated for a specific case study with positive results.

Paper: **8021** **B5L-A**

Multi-Agent System for Closed Loop Model-Based Control of Dissolved Oxygen Concentration

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This paper presents a proposition of Multi-Agent System design dedicated to control dissolved oxygen concentration inside reactor with activated sludge. Designed Multi-Agent System is able to switch between multiple available control algorithms to reach the best possible control quality. Design goal was to create encapsulated agents where modification of one agent's code would not cause the necessity to change any other agent in system. Created Multi-Agent system was tested in laboratory setup with a well-mixed bioreactor. Experimental comparison with conventional on-off controller showed improvement in control precision.

On the Problem of Optimised Allocation of Water Quality Sensors and Actuators in DWDS

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The problems of water quality sensors and actuators placement in drinking water distribution systems (DWDSs) are addressed as separate, primarily. However, against the background of control systems theory, the nature of DWDSs dynamics indicates that these both problems are interdependent and impact the design of related water quality monitoring and control structures and algorithms. The research work presented in this paper is to investigate the state-of-the-art in this field and discuss the problems of water quality sensors and actuators placement within DWDS and to highlight the potential benefits of considering the joint task of their allocation.

A Case Study of Robust Sliding Mode Control Applied to Inverted Pendulum on a Cart

Mateusz Czyżniewski, Rafał Łangowski, Dawid Klassa, Mateusz Matwiszyn

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A control problem of an inverted pendulum on a cart has been addressed in this paper. In particular, a synthesis of alternative sliding mode control for stabilisation of an inverted pendulum at an upper equilibrium point has been investigated. Hence, the feasibility of implementing the developed control system, taking into account primarily the friction of the cart against the gantry and the limited length of the gantry, in a real plant has been given. The proposed control system has been tested by simulation in Matlab/Simulink environment and satisfactory performance of its operation has been obtained.

Application-Based Analysis of Transformations of Uncertain Dynamical Systems Into a Cooperative Form

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Uncertainty in dynamical system descriptions can have different sources. Whether it be mathematical model simplifications, manufacturing tolerances, and imperfect measurements resulting in parameter uncertainties or be it some kind of time-varying uncertain parameters as an interpretation of state dependencies in quasi-linear state-space representations. On the one hand, uncertainties can be represented as probability distributions in the stochastic case, which can be handled, for example by Monte-Carlo methods. However, those do not allow for the computation of worst-case bounds of the sets of reachable states. On the other hand, interval representations do allow this, which is why we will use those as a bounded error framework in the presented paper. When dealing with interval uncertainty, the rigorous computation of guaranteed state enclosures is a difficult task. Due to conservatism and/or the wrapping effect, overestimation is a common problem. The paper discusses not only a suitable control approach based on LMIs to stabilize an uncertain system but also a cooperativity-enforcing approach, which acts as a countermeasure to the wrapping effect. This simplifies the computation of guaranteed state enclosures in comparison with different methods to get the least conservative hull of the reachable state intervals. This is all done for a boom crane as a real-life application scenario.

Day: **Tuesday, August 24th, 2021**

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

Room: **Vasco da Gamma**

Chair: **Paweł Skruch**

Paper: **8053** **B5L-B**

Virtual Simulation Environment of an Autonomous A-EVE Vehicle

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The base condition which has to be met by autonomous cars is the guaranteed safety of passengers and other participants. Therefore, it is necessary to intensively test devices and algorithms for autonomous driving, what generates high costs. In order to reduce costs, it is necessary to perform as many tests as possible in a virtual environment with the use of simulators. The article describes the virtual simulation environment of an experimental autonomous vehicle called AEVE. The GAZEBO simulator was used to implement the dynamic and kinematic model and sensors of the A-EVE vehicle. The use of the virtual GAZEBO environment enables rapid prototyping and testing of new functionalities of the A-EVE vehicle and the reduction of the number of practical experiments to the necessary minimum.

Paper: **8057** **B5L-B**

Analysis of Microphone Use for Perception of Autonomous Vehicles

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Many teams focus on the implementation of vehicle perception with the help of artificial intelligence using data from cameras, lidars or radars. A less common approach is to use sound sensors like microphone arrays for this purpose. The use of these data sources can make positive impact on active safety providing additional information about the vehicle and environmental condition. In this article a system for vehicle detection and determination of the arrival angle is presented. It can be used to improve the vehicle safety on road intersections where not always other vehicles can be detected by sensors such as lidars or cameras due to line of sight occlusions. The

system makes use of sound source localization (SSL) methods like MUSIC, CSSM, WAVES, TOPS and SRP-PHAT which are briefly described further. The performance obtained by use of each method is compared with others. Presented results from experiments in real environmental conditions offer reasons for further work in this topic.

Paper: **8058** **B5L-B**

Method for Road Occlusions Handling in Generic Sensor Models

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Due to the increasing complexity of Advanced Safety systems, a strong endeavor is required to acquire realistic and real-time capable simulations, in order to enable robust and easily reproducible system verification in virtual environments. To make simulations reliable, high-fidelity sensor models are required. One of the approaches is to implement a generic sensor model that explicitly emulates the output of an object detection algorithm, based on high-level simulation data. However, such a model has to accurately handle object-based occlusions, to assure that shadowed objects are not detected. Various generic sensor models available in the literature already solve the problem of how to estimate occlusions, given a set of objects. Nevertheless, none of the models takes into account a road profile, i.e. hills. The method proposed in this paper provides an accurate and easy to implement road profile estimation using a set of bounding boxes. Thanks to the generated structures, a road-based shadowing can be enabled in any of the object-based generic sensor models. The obtained results clearly show the robustness and usefulness of the proposed methodology.

Paper: **8068** **B5L-B**

A Simple Vision-Based Navigation and Control Strategy for Autonomous Drone Racing

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In this paper, we present a control system that allows a drone to fly autonomously through a series of gates marked with ArUco tags. A simple and low-cost DJI Tello EDU quadrotor platform was used. Based on the API provided by the manufacturer, we have created a Python application that enables the communication with the drone over WiFi, realises drone positioning based on visual feedback, and generates control. Two control strategies were proposed, compared and critically analysed. In addition, the accuracy of the positioning method used was measured. The application was evaluated on a laptop computer (about 40 fps) and a Nvidia Jetson TX2 embedded GPU platform (about 25 fps). We provide the developed code on GitHub.

TECHNICAL PROGRAM

Wednesday

August 25, 2021

Day: Wednesday, August 25th, 2021

Time: 9:00 – 10:00

Room: Marco Polo

Plenary Sesion, P-3

Day: Wednesday, August 25th, 2021

Time: 9:00 – 10:00

Room: Marco Polo

Chair: J. Klamka

Author: A. Czornik (Silesian University of Technology, Poland)

Paper: Assignability of Numerical Characteristics of Discrete Time-varying Linear Systems

Day: **Wednesday, August 25th, 2021**

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

Room: **Marco Polo**

Chairs: **Radosław Rudek**

Paper: **8020** **C2L-A**

Transmitter Discovery Through Radio-Visual Probabilistic Active Sensing

Luca Varotto, Angelo Cenedese

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Multi-modal Probabilistic Active Sensing (MMPAS) uses sensor fusion and probabilistic models to control the perception process of robotic sensing platforms. MMPAS is successfully employed in environmental exploration, collaborative mobile robotics, and target tracking, being fostered by the high performance guarantees on autonomous perception. In this context, we propose a bi-Radio-Visual PAS scheme (Ra$_2$ViPAS) to solve the transmitter discovery problem. Specifically, we firstly exploit the correlation between radio and visual measurements to learn a target detection model in a self-supervised manner. Then, the model is combined with antenna radiation anisotropies into a Bayesian Optimization framework that controls the platform. We show that the proposed algorithm attains an accuracy of 92%, overcoming two other probabilistic active sensing baselines.

Paper: **8031** **C2L-A**

Traffic Lane-Changing Modeling and Scheduling with Game Theoretical Strategy

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The lane-changing models and methods become an essential issue to ease traffic congestion, which is also a critical part in developing an Intelligent Transportation System (ITS). This paper presents a novel model of the lane-changing system with multiple traffic lanes based on game theory approach, where the system can be regarded as multi-player (i.e., 2-5 players in this system) non-zero-sum non-cooperative sub-games and the individual vehicles can be considered as players. The traffic road map is divided into cells, and each cell can only contain one vehicle, each row forms a sub-game and the vehicles will take the actions which are generated by solving Nash equilibrium

solutions in this sub-game. This approach aims at producing an effective and efficient routes schedule leading the vehicles to approach the target lanes (i.e., the lane where the drivers can complete the intended turn) as many as possible in each time period. The collision constraints are propagated among these subgames to avoid crash accidents. Meantime, the gap acceptance strategy (i.e., the drivers only take the turning action when it has an acceptable gap in the adjacent lane) is presented in this paper, which is examined and compared with the game theoretical strategy in the proposed model. The performance indicates that the proposed model with the game theoretical strategy shows more efficiency in lane-changing than the other strategy.

Paper: **8037** **C2L-A**

Demand Response of Multiple Households with Coordinated Distributed Energy Resources

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The optimal energy consumption of aggregated smart households is presented in this paper. The households are assumed to be equipped with distributed energy resources (electric vehicle, energy storage system, photovoltaic panel) besides the grid. The model is established to shift major loads and to allow energy exchangeability among the households. The common objective is to minimize the total electricity costs by maximizing local energy usage at the household and neighborhood levels. A noncooperative game-theoretic model, combined with a mixedinteger-programming model, is developed to satisfy the neighborhood's economic and energetic needs. The neighborhood's total electricity costs are reduced using the proposed method, and it is verified through simulation results.

Day: **Wednesday, August 25th, 2021**

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

Room: **Vasco da Gamma**

Chairs: **Robert Piotrowski**

Paper: **8003** **C2L-B**

Generalized Proportional Integral Observer Approach for Trajectory Tracking Control of Autonomous Underwater Vehicles

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Marine sciences require the use of Autonomous Underwater Vehicles (AUV) for their missions in order to perform unmanned duties like deep-sea explorations. AUV require to reject turbulence disturbances while regulating their trajectory. In this paper, a position controller applying the Generalized Proportional Integral (GPI) observer to an Autonomous Underwater Vehicle (AUV) in order to maintain the desired trajectory and reject the environment perturbations is given. The mathematical model and the performance of the GPI shows a precise and fast tracking control through simulations.

Paper: **8065** **C2L-B**

Evaluation of Hybrid Particle Swarm Optimization in the Multi-Door Cross-Docking Problem

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The paper deals with a cross-docking problem which is an example of real-word logistics problem and belongs to the class of NP-hard optimization problems. Cross-docking is a transshipment platform, where products from suppliers to several destinations are deconsolidated, sorted, consolidated based on the customer's orders, and shipped out to the end customers using outbound trucks. In particular, multiple inbound and outbound doors cross-docking is under consideration.

The aim is to optimize the sequence of inbound and outbound trucks and truck dock assignment in cross-docking systems with multiple inbound and outbound dock doors. A particle swarm optimization hybridized with simulated annealing is proposed to solve this problem. The paper also presents the results of computational experiments.

Paper: **8067** **C2L-B**

Transient Anomaly Detection Using Gaussian Process Depth Analysis

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Effective and reliable monitoring and diagnostics of process control installations is of utmost importance, as they are important part of world's economy. Detection of faulty behavior fits really well into this problem. Most of known results provides good techniques for analysing steady states, but have issues with the transients. In this paper we propose a new method for detecting anomalies in transient states using combination of Gaussian Processes and data depth functions. We create a model of a transient signal and using its parameters also a model for candidate for fault analysis. Their similarity is verified using data depth. We present how such application works for a water tank system and different types of data depth.

Day: **Wednesday, August 25th, 2021**

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

Room: **Marco Polo**

Chairs: **Krzysztof Oprzedkiewicz**

Paper: **8007** **C3L-A**

On Polynomial Root Distribution with Respect to a Sector

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This paper extends previous results of the same authors on the determination of the polynomial root distribution with respect to a sector by means of elementary vector analysis. Specifically, it is shown how the overall phase variation of any real or complex polynomial along the radii of a sector accounts for the number of roots inside and outside the sector. The method applies to both symmetric and asymmetric sectors with respect to the real axis. Its practical application only requires plotting a Nyquist-like diagram (a hodograph). The procedure proves particularly useful in the stability analysis of fractional–order systems. A pair of examples is worked out to show how the method operates.

Paper: **8016** **C3L-A**

Stability Investigation of PLL-Based Grid Synchronization

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This contribution investigates the grid synchronization procedure of grid-side inverters, i.e. the correct determination of the grid voltage frequency. A phase-locked loop (PLL) can be seen as the standard method for grid synchronization. Due to the grid impedance, the grid voltage cannot be measured directly and the measured voltage is a superposition of the grid voltage and the inverter voltage. Therefore it is possible that the PLL loses synchronism with the grid and tracks the inverter voltage instead. In stiff grid scenarios this effect may be neglected, but in the case of a weak grid, a failure of the PLL to synchronize with the grid is likely.

Since the grid synchronization procedure depends not only on the grid impedance but also on the filter impedance of the inverter as well as on the point of operation, a comprehensive analysis under what circumstances the loss of synchronism occurs is needed. In this paper the described scenario is studied and a necessary condition for a successful grid synchronization in the stationary case is derived. The condition depends on all parameters of the system model and is verified in numerical simulations.

Paper: **8030** **C3L-A**

On Assignment of the Upper Bohl Exponent for Linear Discrete-Time Systems in Infinite-Dimensional Spaces

Evgenii Makarov*, Michał Niezabitowski, Svetlana Popova***, Vasilii Zaitsev***, Marina Zhuravleva*****

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In this paper we study linear discrete-time control systems in infinite-dimensional spaces with periodically timevarying bounded input and output operators. For such systems we consider a problem of arbitrary assignability of the upper Bohl exponent by non-stationary linear static state feedback and by non-stationary linear dynamic output feedback. This is a generalization of the stabilization problem, which has been well studied for systems of various types. The main results present sufficient conditions for considered types of assignability.

Paper: **8048** **C3L-A**

Extremal Problems for Time Lag Hyperbolic Systems

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Extremal problems for time lag hyperbolic systems are presented. The optimal boundary control problems for hyperbolic systems in which constant time lags appear both in the state equations and in the Neumann boundary conditions are solved. The time horizon is fixed. Making use of Dubovicki-Milutin scheme, necessary and sufficient conditions of optimality for the Neumann problem with the quadratic performance functionals and constrained control are derived.

Day: **Wednesday, August 25th, 2021**

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

Room: **Vasco da Gamma**

Chairs: **Andrzej Bartoszewicz**

Paper: **8043** **C3L-B**

Model Predictive Control as an Industrially Applicable Approach for Power Control of Solid Oxide Fuel Cells

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In this paper, a model predictive control (MPC) combined with a discrete-time stationary Kalman filter as an observer for non-measureable states and input disturbances is presented as a simple and industrially applicable approach for controlling the electric power of a solid oxide fuel cell (SOFC). The developed controller was tested in a simulation in terms of its robustness under consideration of model uncertainties and measurement noise. The results were compared with a PI output-feedback controller combined with a feedforward control and an internal model control (IMC). For the MPC the framework conditions are equal to the PI controller and the IMC. Since these conditions can be reproduced by simulations, we can omit a rerun of the experiments. As a result, the MPC provides comparable results and presents as the better of the two alternative controllers.

Paper: **8040** **C3L-B**

Universal Approach to Implementation of Three-Phase Induction Motor Control Algorithms Using Microcontrollers: Preliminary Results

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This paper describes process of building a universal digital system to control commonly used three-phase asynchronous motors. Considerable effort was devoted to a universal approach, which will allow further extension of the system with advanced algorithms and also the use of other control

units. A test bench was designed and created with an interface board connecting all the components. The system includes two programs: a motor controller and a graphical user interface controller. The created system allows controlling the motor without being connected to a personal computer and operates a power bridge evaluation board and an industrial inverter installed in the test bench. Prepared control structure provide possibility to fast change of algorithm. Preliminary results of real experiments are demonstrated for real two example processes. Further development of the system including advanced control algorithms was also indicated.

Paper: **8062** **C3L-B**

A Fractional LQI Controller for a Magnetic Levitation System

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A magnetic levitation plant is a fast, unstable, nonlinear mechatronic system vulnerable to measurement noise and external interference. Designing a high-performance and robust controller for such system, immune to noise and disturbances, and ensuring a wide operating region, is a challenging task. One can chose a well-know LQI controller, designed based on a linearized plant model, to stabilise the system and to eliminate the steady-state error. However, large plant-model mismatch and considerable non-linearity of the system may limit the control quality provided by such a solution. To improve the system performance one can introduce some additional degrees of freedom by replacing the integer order integrator with a fractional one. For practical implementation, the latter may be approximated with an integer-order realisation obtained with the time-domain Oustaloup method. The paper explains the idea of an LQI_controller, presents selected results of simulation tests of the closed-loop control system behaviour, and provides discussion of possible applications and advantages of the proposed approach.

Tracking Differentiator-Based Sliding Mode Velocity Control of a Hydrostatic Transmission

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This paper presents study results on the application of sliding mode control (SMC) for velocity tracking of a hydrostatic transmission system. The design deploys the idea of an almost model-free control to obtain the basis for an SMC implementation that does not rely on a complete system model. In a decentralized control structure, the control of the bentaxis angle of the hydraulic motor is performed by an inversionbased pure feedforward control. Synchronous reference values are derived from the desired motor angular velocity as system output, in compliance with a suitable transmission ratio. The swash-plate angle of the hydraulic pump represents the control input for an SMC approach using a linear tracking differentiator (LTD) providing estimates of the error signal derivatives. The proposed control structure has been investigated by means of simulations and validated by experiments on a dedicated test rig at the Chair of Mechatronics, University of Rostock.

Day: **Wednesday, August 25th, 2021**

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

Room: **Marco Polo**

Chairs: **Rafał Łangowski**

Paper: **8024** **C4L-A**

Evolutionary Algorithm for Scheduling Battery Charging Jobs with Decreasing Power Demands to Minimize the Makespan

Rafał Różycki, Grzegorz Waligóra, Tomasz Lemański

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In this work we consider a problem from the field of green computing. The problem is to schedule nonpreemptable and independent jobs to minimize the schedule length, where each job requires some amount of power and consumes a certain amount of energy during its processing. We assume that the power demand of each job linearly decreases with time. For the assumed job model we show some properties of the considered problem. We also propose an Evolutionary Algorithm to solve the problem, and we evaluate its efficiency on a basis of a computational experiment involving a few priority rules.

Paper: **8026** **C4L-A**

Aggregation Algorithms for Graph Coloring

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Many practical applications in production systems can be formulated in terms of graph coloring, for example task scheduling or planning a robot moves. In the paper a class of heuristic algorithms for graph coloring is considered which use the technique of aggregation of vertices. It is shown that some well known constructive heuristics like GIS and RLF belong to the class of vertex aggregation algorithms. In fact, they only differ in the rule that is used to select a pair of vertices to aggregate in the successive steps of the algorithm. In the paper various variants of the aggregation algorithm have been examined and some new rules have been developed that result in better coloring than RLF with the same computational complexity.

Game Against Nature Based Control of an Intelligent Wheelchair with Adaptation to Pedestrians' Behaviour

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This paper addresses the problem of synthesis of the control law for intelligent wheelchair navigation assistant, intended to support the navigation in dynamic and populated areas. The method presented in this paper uses a deterministic, model-based prediction strategy to generate the wheelchair motion. The motion has the feature that is acceptable by the patient being transported on the wheelchair. Using the long-term pedestrians motion prediction the minimal collision risk control strategy is applied. While concerning the wheelchair navigation and its environmental interactions, an issue arises which is related to the pedestrians' empathy towards a disabled person being carried by the wheelchair. In this work we propose to use this phenomena for designing adaptive, driving strategy of the intelligent wheelchair. An intelligent motion controller proposed in this paper, generates collision free trajectory based on safe distance policy and evaluation of the environmental response. By comparing the predicted pedestrians behaviour to the real one, the system adapts control strategy coming from game against nature formalism and Hurwicz criterion based solution. The method performance was evaluated in a simulated environment. Relevant simulation scenarios are presented and discussed.

Research on Effective Analysis and Forecasting of Demand in ERP Systems - Case Studies

Katarzyna Grobler-Dębska*,, Bartłomiej Żak**, Jerzy Baranowski*, Edyta Kucharska*, Adam Domagała *****

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Supply chain planning, and especially demand forecasting in companies, is a difficult task for organizations and both crucial for their profits and for market penetration. The main difficulty is that there is a lack of analysts in manufacturing companies and the lack of an adequate forecasting method. Although science provides many methods for forecasting, business cannot apply them. The main software supporting management in companies are ERP systems. ERP support decision-making at the strategic, tactical and operational level. It must also have an intuitive forecasting tool. The paper presents the results of the InfoConsulting research and development project related to the adaptation of the forecasting tool based on IFS Application so that it meets the requirements of Polish companies from mass customization and pharmacy industry and the development of a quick implementation method.

Heuristic Workload Scheduling Algorithms for Rolling Stocks with Mixed Preventive Maintenance Policies

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Railway vehicles must to undergo inspections and preventive maintenances following from the practical and safety reasons. They are carried out in a periodic manner that involves time-based and distance-based maintenance cycles classified into various levels of complexity. A vehicle needs to get maintained when its time or accumulated running mileage reaches a predefined threshold related with a certain level. On the other hand, the fleet of rolling stocks have to perform cyclic jobs characterized by different workloads, which can shortened interval between succeeding maintenances and increase the operating cost. Therefore, it is economically justified to minimize the unavailability of railway vehicles caused by preventive maintenances by a proper assignment of jobs in particular months of the optimization horizon taking into account preventive maintenances. In this paper, we propose efficient heuristic algorithms providing solutions that are satisfying from the perspective of an industrial practice.

Day: **Wednesday, August 25th, 2021**

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

Room: **Vasco da Gamma**

Chairs: **Ewa Pawluszewicz**

Paper: **8036** **C4L-B**

Virtual Urban Space Simulator – Gliwice, Poland City Centre Example in the Context of COVID-19 Pandemic

Adam Gałuszka*, Marcin Pacholczyk*, Damian Bereska*, Eryka Probierz*,**, Ewa Bajer****, Jarosław Śmieja***, Kamil Skowroński*, Aleksandra Szydłowka*, Piotr Solarz*, Łukasz Kania*, Maciej Cholewa*, Paweł Woronow***

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Virtual environments (VE) are commonly used in learning or training in many different areas. We are focused on the problem when a group of artificial agents are simulated at the same time; their behavior is easily recognized as ‘artificial’. To avoid this undesired property presented work was aimed at creating a virtual world with agents equipped with psychosomatic elements that occur in the real world. It has been chosen the implementation of basic needs based on Maslow’s hierarchy of needs (MHN), since they are one of necessary elements for the development of simulation of the real world. It is shown that the VE design based on artificial intelligence (AI) planning algorithms and the theory of MHN can be efficiently applied to generate semi-realistic behavior of agents population. Models of coronavirus spread have been introduced into the simulated environment. It allowed to build cases related to the number of infected people and the rate of infection depending on the level of avatar activity associated with basic needs.

Numerical Modeling of the Possibility of Scale Power Growth of the Internal Combustion Engine in Real Time

Igor Korobiichuk*, Viktorij Mel'nick, Volodimir Karachun**, Vladyslav Shybetskyi**, Sergii Kostyk****

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A technical solution is proposed to improve the operational properties of the internal combustion engine in the process of operational use. The means for this is the formation of an additional blowing of the air mixture in the working volume, thanks to the artificially formed caustic surface. It is shown that low-frequency, below the cutoff frequency, oscillations artificially formed in cylindrical glasses of the engine under certain conditions, namely, with wave coincidence, as well as with a significant wave size of the glass surface, are formed coaxially to the glass of the caustic surface in the form of a cylindrical, increased energy activity of liquidphase component of the engine, radically enriched with cavitation bubbles of various sizes. The presence of a wave coincidence, which forms a resonant environment in the combustion chamber, makes it possible to practically use the energy of sound irradiation practically without losses for automatic or semi-automatic regulation of the formation of a caustic surface of a given size.

Cost-Effective Control of Roll-On/Roll-Off Emission-Free Ships

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This paper investigates the energy management of a roll-on/roll-off emission-free ship (RoRoEF-ship) that can carry passengers and vehicles. Fuel cells (FCs), energy storage systems (ESS), and cold-ironing (CI) are considered to be the energy resources of the ship. Moreover, the charging and discharging abilities of the electric vehicles (EVs) carried by the ship are used as an auxiliary source for managing the energy flow in the ship. In this paper we propose three cost-effective strategies to use EVs as a backup in the ship energy system based on the agreements between the ship operator and EV owners. A mixed-integer linear programming (MILP) approach is proposed to a highly efficient and cost-effective control for the energy management of the integrated solution (ship resources and EVs). The proposed model considers the non-linearity in the efficiency of FCs, power ramp-rate constraints of FCs and ESSs, and preferences of the EV owners. The proposed control model is applied to a test system and the simulation results are discussed. GAMS software is used to achieve the optimization process.

Predicting System Degradation Using Bayesian Time Series Models

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Efficient maintenance of industrial equipment requires degradation monitoring and prediction. Currently used prediction models are mostly deterministic and cannot consider uncertainty inherent to degradation measurements.

In this paper we propose using time series models obtained using Facebook Prophet algorithm to predict the evolution of degradation of turbomachinery. We illustrate our considerations with data from large scale industrial centrifugal compressors. Our predictions are promising and confidence intervals cover the predictions well.

TECHNICAL PROGRAM

Thursday

August 26, 2021

Day: **Thursday, August 26th, 2021**

Time: **9:00 – 10:00**

Room: **Marco Polo**

Plenary Sesion, P-4

Day: **Thursday, August 26th, 2021**

Time: **9:00 – 10:00**

Room: **Marco Polo**

Chair: **Z. Emirsajłow**

Author: **Karl H. Johansson (Royal Institute of Technology, Sweden)**

Paper: **Traffic Control Using Automated Truck Platoons: Distributed Sensing, Actuation, and Learning.**

Day: **Thursday, August 26th, 2021**

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

Room: **Marco Polo**

Chairs: **Artur Babiarz**

Paper: **8002** **D2L-A**

Accuracy Analysis of the Fractional Order, Positive, State Space Model of Heat Transfer Process

Krzysztof Oprzędkiewicz, Klaudia Dziedzic, Wojciech Mitkowski

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In the paper the accuracy estimation for fractional, positive state space model of heat transfer process is presented. The new criterion of the external positivity for this model is presented. Next the parameters of the model are estimated via numerical minimization of the Mean Square Error (MSE) and FIT cost functions. Finally, the externally positive models are compared to non-positive. Results of simulations show that the positive model is more accurate in the sense of considered cost functions than non positive.

Paper: **8023** **D2L-A**

Controllability of Fractional Linear Systems with Delays

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The main purpose of this paper is to study controllability of linear continuous-time fractional dynamical systems containing both lumped constant delay in state variables and distributed delays in admissible controls. Necessary and sufficient conditions for relative controllability in finite time interval are formulated and proved using theory of linear bounded operators, solution properties of fractional differential equations and results taken directly from linear matrix algebra. The main result of the paper is to show, that global relative controllability of fractional linear systems with different types of delays is equivalent to non-singularity of suitably defined relative controllability matrix.

Application of the Shuffle Algorithm to Analysis of the Fractional Descriptor Continuous-Time Linear Systems

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The shuffle algorithm is applied to analysis of the fractional descriptor continuous-time linear systems. Using the shuffle algorithm the solution to the fractional descriptor linear system is derived and the system is decomposed into dynamic and static parts. Procedures for computation of the solution and dynamic and static parts of the system are proposed. Sufficient conditions for the positivity of the fractional descriptor continuous-time linear systems are given.

Day: **Thursday, August 26th, 2021**

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

Room: **Vasco da Gamma**

Chairs: **Aleksandra Kawala-Sterniuk**

Paper: **8008** **D2L-B**

Incremental 3D Maps Server Based on Feature Matching for Multi-Robot Systems

Michał Drwięga

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Wroclaw University of Science and Technology

This paper describes an incremental 3D maps server based on the point feature matching, which is dedicated to multi-robot systems. The idea behind the presented map server is that it maintains the 3D map by subsequent merging of received partial maps. The solution can be applied to distributed systems where each robot have its own map server instance and maintains a separate map instance. On the other side, in centralized robots systems, it can be one map server instance which integrates partial maps from robots, creates the common map and propagates it to the robots. The process of adding incoming maps consists of few steps. The first one is called a global alignment and is based on the feature extraction, description and matching with the assumption that the maps have an overlapping area. Then, the solution from the first step is used as the initial solution in the next step and it is corrected with a local alignment method. The last step is the data merging to obtain one, globally consistent model in the octree based representation. The presented solution was verified in the experiment with a group of wheeled robots - Turtlebots.

Paper: **8015** **D2L-B**

Programming of a Lightweight Robot Using Function Blocks and Sequential Function Charts

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This paper presents an approach to realize a universal robot programming language. Currently, numerous programming languages for industrial robots exit, depending on the manufacturer of the robot. Attempts to create a standardized language have failed in the past. The presence of several new providers of robots on the market increases the number of different programming languages

and concepts. For this reason, it would be desirable to have a unified procedure as can be found in the field of programmable logic controllers. Here, a specification is valid, which defines certain types of programming languages. In this contribution, a lightweight robot was connected to a programmable logic controller, where the programming of the robot should be performed. For this purpose, the communication between these two partner devices was achieved using precast data structures. Concerning the programmable logic controller, function blocks were developed to operate the robot and its periphery. They include robot-based functionality, known from common robot programming languages. With regard to the robot, a client program, which interprets and executes the commands from the programmable logic controller, was implemented. Some small robot tasks were performed to show the simplicity of our approach to robot programming based on the languages of programmable logic controllers.

Paper: **8019** **D2L-B**

Mu-Synthesis Based Cascaded Robust Controller Design for Exact Linearizable Dynamical Systems

Barnabás Finta, Bálint Kiss

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Model-based controllers for nonlinear systems require the adequate knowledge of plant parameters in order to produce nominal performance and stability. Moreover, external disturbances can also interfere with reference tracking performance. The paper presents a robust controller synthesis method for a class of nonlinear systems. It merges two state-ofthe-art approaches, namely exact linearization by state feedback, and mu-synthesis which is known from linear robust control theory. The resulting architecture is cascaded, where the outer loop contains the robust, linear two-degrees-of-freedom (2DoF) controller, which has better disturbance rejection properties compared to its serial compensator counterpart. Two examples (the second being a 2DoF robotic arm) are used to illustrate the control design procedure, which is then validated by simulations.

Day: **Thursday, August 26th, 2021**

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

Room: **Marco Polo**

Chairs: **Michał Niezabitowski**

Paper: **8011** **D3L-A**

Internal Model-Based Lateral and Longitudinal Control for Autonomous Electric Vehicles

Adorjan Kovacs, Istvan Vajk

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In this paper, a novel lateral and longitudinal control algorithm is presented for autonomous vehicles. The proposed cascade structure has two loops: the inner loop is a force and moment-based internal model controller (IMC), and the outer loop is an optimization-based yaw-rate reference planner. IMC provides robustness against parameter changes and external disturbances, and the problem formulation of the optimization minimizes the intuitively tuned parameters of the controller. The proposed controller was tested and evaluated in simulation and real-time measurements on ThyssenKrupp's Lotus Evora test vehicle.

Paper: **8055** **D3L-A**

Continuous-Time Model Predictive Control with Disturbances Compensation for a Glass Forehearth

Michał Drapała, Witold Byrski

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Model Predictive Control (MPC) is an advanced method of process control. Despite its usefulness, it is applied mostly for large industrial processes. In the paper, a model predictive algorithm for a glass forehearth is presented. The problem of molten glass temperature stabilisation under external disturbances is especially important during the glass conditioning, so the use of an adaptive predictive controller seems to be reasonable. The controller tuning utilizes linear models of the process, that can be obtained on-line. Modifications of the known continuous-time MPC approach are described. The most important difference is the original method of measurable disturbances

compensation and its implementation in the algorithm. The developed controller was tested using the process model with distributed parameters (Partial Differential Equation). The experimental results are presented in the paper.

Paper: **8075** **D3L-A**

Hardware Implementation of Neural Shaft Torque Estimator Using Low-Cost Microcontroller Board

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This article presents the design process of control structure applied for electrical drive with flexible shaft. Problems, that may occur while implementation of standard methods of synthesis, are indicated. Application of bio-inspired optimization algorithm (Flower Pollination Algorithm) for tuning the controller is also described. However, the main point of work deals with the first stage of real tests –calculations of neural estimator performed using low-cost programmable device. For this purpose the SIPEED Maix Bit development board with the RISC-V K210 Kendryte CPU was used. The details of code implementations and concept of prepared calculations are presented in following sections. Finally test results and conclusions are given.

Day: **Thursday, August 26th, 2021**

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

Room: **Vasco da Gamma**

Chairs: **Marek Długosz**

Paper: **8025** **D3L-B**

A Selection of PID Type Controller Settings via LQR Approach for Two-Wheeled Balancing Robot

Krzysztof Laddach, Mateusz Czyżniewski, Rafał Łangowski

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The problem of PID type controller tuning has been addressed in this paper. In particular, a method of selection of PD settings based on the solution of linear–quadratic optimization problem using the energy criterion has been investigated. Thus, the possibility of transforming optimal settings of the linear–quadratic regulator into the settings of the controller in the classical control system has been given. The presented methodology has been used during synthesis of control system for a two–wheeled balancing robot. Finally, the performance of the proposed control system has been validated by simulation in Matlab/Simulink environment with the use of a two–wheeled balancing robot model.

Paper: **8052** **D3L-B**

Speech Interface for a Lightweight Industrial Robot

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This paper presents an interface used to control a lightweight industrial robot via speech. Many examples of speech control can be found in everyday life, and there may also be a useful application in industrial automation devices, e.g., robots. Because of their intuitive teach-in concept for hand guidance, lightweight robots are particularly convenient. Furthermore, they include special safety functions in the form of speed and force limitations, which makes the combination of speech recognition and industrial robots in the first instance uncritically.

In this study, speech control was firstly compared with other approaches to intuitive and novel robot programming. Here, it is important to distinguish between experts and non-experts. A suitable speech-recognition system was chosen for implementation of a robot speech-control interface. For this purpose, we compared various aspects of currently available speech software. Speech-recognition functionality was then fitted to the robot, and program flow-charts for speech control were developed. Speechcontrolled teach-in and speech-controlled robot motion were both integrated into the robot system, and the algorithms were successfully verified by practical experiments. Finally, speech teach-in was compared to teach-in using the teach pendant, and to teach-in of a conventional industrial robot, in terms of duration and usability.

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On Control of a Capsubot Robot

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This paper has presented a model and motion simulation of one-dimensional planar legless internal force static friction capsubot. The control strategy has been developed to manage the accurate capsubot trajectory tracking using the closed-loop system with a proportional–integral–derivative controller. The controller has been tuned by a particle swarm optimization algorithm. The simulation confirmed the correctness of the proposed four-step motion profile by demonstrating the mobility of the capsubot in the periodic pattern, manifested in fast and slow modes.

Index of Authors

SESSIONS

NOTES

WHAT TO SEE AT MIĘDZYZDROJE?

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

Places particularly worth visiting:

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

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

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

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

The fishing harbour in the eastern part of the town.

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

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

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

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

settlement.

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

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