WELCOME
from the MMAR 2026 Organizing Committee

It is my great pleasure to welcome you to Międzyzdroje, Poland, for the **30th International Conference on Methods and Models in Automation and Robotics (MMAR 2026)**, organized by the Faculty of Electrical Engineering of the West Pomeranian University of Technology in Szczecin in cooperation with the Polish Academy of Sciences.

The MMAR conference series was established in 1994 as an initiative of young scientists from the Institute of Control Engineering. Its primary objective was to create an international forum for researchers from Poland and abroad working in the fields of automation, control, and robotics to exchange knowledge, present their latest research results, and foster scientific collaboration in a truly international environment. Over the past three decades, this initiative has evolved into a well-established and internationally recognized scientific event. It is therefore particularly gratifying to celebrate the 30th edition of the conference this year.

For MMAR 2026, nearly 120 papers were submitted for consideration. Following a thorough peer-review process, the International Program Committee, chaired by Professor Andrzej Bartoszewicz, selected 102 papers for presentation. As in previous years, the conference is organized under the auspices of the IEEE Robotics & Automation Society and the IEEE Control Systems Society. It is also 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 opens on Tuesday afternoon, **18 August 2026**. The scientific program includes four plenary lectures delivered by distinguished invited speakers, parallel technical sessions featuring both on-site and online presentations, and three poster sessions during which 35 papers will be presented. All accepted papers will be submitted for publication in the IEEE Xplore Digital Library.

I trust that MMAR 2026 will provide an excellent opportunity to present recent research achievements, exchange ideas, and discuss current challenges and emerging directions in automation and robotics. I also hope that the conference's social programme will offer opportunities for informal networking and that your stay in Międzyzdroje will be both enjoyable and memorable.

On behalf of the Organizing Committee, I wish you a pleasant stay in Międzyzdroje, a successful conference, and many inspiring discussions and fruitful scientific collaborations.

Prof. Zbigniew Emirsajłow

Chairman of the MMAR 2026 Organizing Committee

Faculty of Electrical Engineering

West Pomeranian University of Technology, Szczecin

Contents

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West Pomeranian University of
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CONFERENCE SECRETARIAT

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During the Conference

Amber Baltic Hotel

Promenada Gwiazd 1

PL-72-500 Międzyzdroje, Poland

Phone: (+48 91) 328 1000

WWW SITE

The Final Program

of the MMAR 2026 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 2026 and their efforts in coordinating the review process.

We would also like to express our gratitude to all reviewers for their valuable efforts in the MMAR 2026 review process.

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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 30th in a series which started in 1994.

VENUE AND DATES

The Conference will be held at the Amber Baltic Hotel in Międzyzdroje, from Tuesday, 18th August and Friday, 21st August 2026.

The Conference registration desk in Amber Baltic Hotel will be open on Tuesday morning, 18 August and during each day of the Conference.

The Conference will start on Tuesday, 18 August at 3:00 p.m. CET.

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 is English.

TIME TABLE

Tuesday, 18th August, 2026

	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 **Neuro-inspired Dynamics for Fast, Flexible, and Frugal Multiagent Decision-Making and Control** Speaker: **Naomi Ehrich Leonard**	
16.40 – 18.00	A1L-A **Control & System Theory I** Chair: Jacek Kabziński 3040, 3051, 3055, 3090	A1L-B **Intelligent Systems & Methods I** Chair: Michał Grochowski 3005, 3007, 3039, 3045
19.00	**Welcome Party** (Barbecue, On Deck Restaurant, Amber Baltic Hotel)	

Wednesday, 19th August, 2026

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gama**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: Andrzej Bartoszewicz **Recent Advances on Disturbance Rejection Control for Mechatronic and Robotic Systems** Speaker: **Shihua Li**	
10.10 – 11.10	B1L-A **Modelling & Simulation I** Chair: Andreas Rauh 3021, 3024, 3072	B1L-B **Robotics I** Chair: Maciej Michałek 3077, 3100, 3022
11.00 – 13.00	B2P-C **Poster Session I** (Poster area) Chair: Krzysztof Okarma 3008, 3032, 3041, 3042, 3047, 3050, 3060, 3081, 3084, 3101, 3110, 3115	
11.10 – 11.40	Coffee break	
11.40 – 13.00	B3L-A **Control Applications I** Chair: Zdzisław Kowalczuk 3014, 3017, 3067, 3071, 3117	B3L-B **Intelligent Systems & Methods II** Chair: Marcin Witczak 3020, 3033, 3035, 3037
13.00 – 15.00	Lunch	
15.00 – 16.40	B4L-A **Modelling & Simulation II** Chair: Eero Immonen 3095, 3097, 3109, 3113, 3119	B4L-B **Robotics II** Chair: Dariusz Pazderski 3082, 3083, 3093, 3089, 3025
15.00 – 16.40	B5P-C **Poster Session II** (Poster area) Chair: Łukasz Sajewski 3018, 3023, 3026, 3054, 3029, 3031, 3038, 3052, 3062, 3065, 3085, 3107	
19.30	**Conference Banquet** (Columbus Hall, Amber Baltic Hotel)	

Thursday, 20th August, 2026

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gama**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: Harald Aschemann **Learning Control and Its Application in Rehabilitation Robotics** Speaker: **Ying Tan**	
10.10 – 11.10	C1L-A **Intelligent Systems & Methods III** Chair: Michał Bartyś 3059, 3061, 3076	C1L-B **Control & System Theory II** Chair: Krzysztof Oprzędkiewicz 3009, 3057, 3058
11.00 – 13.00	C2P-C **Poster Session III** (Poster area) Chair: Ewa Pawłuszewicz 3069, 3078, 3086, 3087, 3088, 3102, 3103, 3104, 3112, 3114, 3118	
11.10 – 11.40	Coffee break	
11.40 – 13.00	C3L-A **Intelligent Systems & Methods IV** Chair: Adam Krzyżak 3073, 3092, 3099, 3048	C3L-B **Control & System Theory III** Chair: Witold Respondek 3063, 3094, 3096, 3015
13.00 – 15.00	Lunch (Amber hotel)	
15.00 – 16.20	C4L-A **Robotics III** Chair: Przemysław Herman 3046, 3019, 3070, 3105	C4L-B **Control Applications II** Chair: Edyta Kucharska 3003, 3053, 3075
17.00	**Social event** Trip to Kamień Pomorski - visit to the Cathedral and Kleist House, organ concert, dinner	

Friday, 21st August, 2026

	Room 1 **Marco Polo**	**Room 2** **Vasco da Gama**
9.00 – 10.00	Plenary Lecture (Marco Polo), Chair: Józef Korbicz **Electronic Personal Navigation Systems for Blind People** Speaker: **Paweł Strumiłło**	
10.10 – 11.10	D0L-A **Intelligent Systems & Methods V** Chair: Bartłomiej Sulikowski 3079, 3080, 3108	D0L-B **Signal & Image Processing** Chair: Krzysztof Okarma 3027, 3064, 3030
11.10 – 11.40	Coffee break	
11.40 – 13.00	D1L-A **Modelling & Simulation III** Chair: Wojciech Hunek 3001, 3002, 3116, 3028	D1L-B **Control Applications III** Chair: Ewa Pawłuszewicz 3044, 3111, 3121
13.00 – 13.15	Conference Program Committee Meeting (Young Author Prize Contest)	
13.15	**Award Ceremony of the Young Author Best Paper Contest** and Farewell Lunch – Columbus Hall, Amber Baltic Hotel	

TECHNICAL PROGRAM

Tuesday

August 18, 2026

Conference Opening

Day: **Tuesday, August 18th, 2026**

Time: **15:00 – 15:30**

Room: **Marco Polo**

Plenary 1, A0L-A

Day: **Tuesday, August 18th, 2026**

Time: **15:30 – 16:30**

Room: **Marco Polo**

Chair: **Tadeusz Kaczorek**

Author: **Naomi Ehrich Leonard (Princeton University, USA)**

Paper: **Neuro-inspired Dynamics for Fast, Flexible, and Frugal Multiagent Decision-Making and Control**

Day: **Tuesday, August 18th, 2026**

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

Room: **Marco Polo**

Chair: **Jacek Kabziński**

Paper: **3040** **A1L-A**

Descriptor Continuous-Time Linear Systems with State and its Derivatives Feedbacks

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Descriptor continuous-time linear systems with state and its derivatives feedbacks are analyzed. A method for the choice of the feedback matrices so that the closed loop system is controllable is proposed. The method is illustrated by numerical example.

Paper: **3051** **A1L-A**

Strong Tracking Iterative Learning Control for Linear Parameter-Varying Systems

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This paper presents an advanced predictive Iterative Learning Control (ILC) methodology tailored for discrete-time Linear Parameter-Varying (LPV) systems subject to strict input and state constraints, as well as bounded process and measurement disturbances. The proposed framework operates through a dual-phase architecture. First, a receding-horizon ILC scheme generates an optimal feedforward control sequence for a virtual, deterministic reference model. Second, the actual perturbed system tracks this learned trajectory using a robust feedback controller designed via the Lyapunov-Metzler (L-M) approach and Parallel Distributed Compensation (PDC). To strictly enforce physical hardware limits despite system uncertainties, the state and input constraints are systematically tightened leveraging Quadratic Boundedness (QB) theory. Consequently, the closed-loop system achieves guaranteed global stability and strong tracking performance, effectively decoupling the learning process from real-time noise. The efficacy and

practical applicability of the proposed methodology are comprehensively demonstrated through the simulation of a multi-mode two-tank liquid level control system.

Paper: **3055** **A1L-A**

A Comparison of Static and Dynamic Sliding Manifolds with the Reaching Law Approach

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This paper presents a comparison of reaching law based sliding mode control for static and dynamic sliding manifolds. In spite of multiple advantages of sliding mode control, its significant drawback is the so called chattering phenomenon, when in the sliding phase the system states oscillate in the vicinity of the switching hyperplane. This effect is further amplified by the presence of sample and hold devices in the control chain. To counteract this, dynamic sliding manifolds are designed specifically to suppress oscillations caused by unmodeled actuator dynamics. This study takes into account reaching law based sliding mode design for both static and dynamic sliding manifolds. The manuscript not only presents the control synthesis with different reaching functions, but also compares the system's performance in terms of the control effort and the oscillations amplitudes.

Paper: **3090** **A1L-A**

Respiration Estimation Using Non-Linear Adaptive Luenberger-Like Observer in WWTP Bioreactor

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The article addresses data collection for managing dissolved oxygen concentration in a bioreactor at a wastewater treatment plant. In detail, it examines the problem of obtaining stable, bounded estimates of respiration using a developed non-linear adaptive Luenberger-like observer. The designed observer is based on a developed model derived from a balance model of dissolved oxygen concentration dynamics. The model's observability analysis is provided in detail. The exponential convergence of the estimates generated by the developed observer is established using the Lyapunov stability theory. The entire solution has been implemented in the MATLAB/Simulink environment and verified via simulation. The obtained results are discussed and compared with previous results, demonstrating the high effectiveness of the developed observer.

Day: **Tuesday, August 18th, 2026**

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

Room: **Vasco da Gama**

Chair: **Michał Grochowski**

Paper: **3005** **A1L-B**

Test of Usefulness of Two Different Control Schemes for Planar Manipulator with First Passive Joint

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In the paper a simulation comparison test of two control strategies for a three-degree-of-freedom (3 DOF) planar manipulator with passive first link is demonstrated. The first strategy serves for trajectory tracking and achieving the target point, whereas the second to move the end effector from any initial position to any target point. Although the selected control methods address different issues, their common goal is to achieve a target point when one of the links is passive. Furthermore, the effectiveness of each method was confirmed using simulations on a single manipulator model. Therefore, in this article, tests were performed for two other models and other operating conditions to check the universality of the selected control schemes. A procedure is also proposed that allows for comparison of methods in terms of their usefulness for control purposes. Numerical simulations were performed to determine, even within a narrow range, whether the strategies were effective. The results were analyzed and discussed.

Paper: **3007** **A1L-B**

The Impact of Hybrid Optimizers on Policy Approximation in Deep Reinforcement Learning

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This paper investigates the impact of hybrid optimization algorithms that combine classical first-order methods with the Muon gradient moment orthogonalization mechanism on the effectiveness of agent learning in deep reinforcement learning (DRL) tasks. The study was conducted in the Isaac

Lab simulation environment using three diverse benchmark scenarios of increasing difficulty. All experiments employed the same neural network architecture, and the quality of the learned policies was evaluated in terms of the average cumulative reward computed over 100 evaluation episodes. The results were subjected to statistical analysis using permutation tests and Cliff's δ. The findings indicate that, in most of the analyzed cases, the incorporation of Muon yields a statistically significant improvement in performance over the corresponding baseline optimizers, with the magnitude of this effect depending on the characteristics of the environment and the selected baseline algorithm. Overall, the results confirm that a hybrid optimization approach can constitute an effective means of improving efficiency of the learning process in DRL tasks.

Paper: **3039** **A1L-B**

Design and Validation of a Sun-Glare-Aware Dataset for Robust Traffic-Light Colour Recognition

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Traffic-light color recognition is a key perception task for intelligent transportation systems and autonomous driving, yet its reliability degrades under real-world illumination challenges such as sun glare, reflections, and exposure saturation. These photometric distortions introduce color ambiguity that is insufficiently addressed by existing datasets. This paper presents the design and validation of a sun-glare-aware traffic-light dataset for robust color recognition. The dataset is constructed through a unified multi-source pipeline combining custom driving videos and public benchmarks and is enhanced with controlled glare augmentation to realistically model optical distortions while preserving color semantics. A dedicated Dataset Quality Assessment framework is further employed to ensure annotation integrity, class balance, and photometric consistency. The resulting dataset provides a balanced and illumination-diverse benchmark that supports reliable training and evaluation of traffic-light color recognition methods across glare-prone driving conditions.

Paper: **3045** **A1L-B**

Decentralizing Reputation Scoring Using Blockchain Behavioral Data and Machine Learning

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This paper proposes a decentralized behavioral reputation frame- work that leverages blockchain transaction behavior and machine learning (ML) to estimate user reliability in decentralized finance

(DeFi) ecosystems. Transaction-level data from the Aave lending protocol on Ethereum (V2 and V3) are utilized to derive indicators of borrower activity. Because direct financial health metrics are often obscured on-chain without full state reconstruction, this framework treats protocol interaction complexity and gas consumption as proxies for user engagement and reliability. Ensemble learning models, including Random Forest, LightGBM, and AdaBoost, are evaluated alongside linear and tree baselines using grouped cross-validation to strictly prevent entity-level data leakage. Experiments conducted on 1.10 million transaction records demonstrate that Random Forest achieves the most robust predictive performance with an $R2 = 0.953$ and the lowest Root Mean Square Error (RMSE).

TECHNICAL PROGRAM

Wednesday

August 19, 2026

Day: **Wednesday, August 19th, 2026**

Time: **9:00 – 10:00**

Room: **Marco Polo**

Plenary 2, B0L-A

Day: **Wednesday, August 19th, 2026**

Time: **9:00 – 10:00**

Room: **Marco Polo**

Chair: **Andrzej Bartoszewicz**

Author: **Shihua Li (Southeast University, China)**

Paper: **Recent Advances on Disturbance Rejection Control for Mechatronic and Robotic Systems**

Day: **Wednesday, August 19th, 2026**

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

Room: **Marco Polo**

Chair: **Andreas Rauh**

Paper: **3021** **B1L-A**

Computational Fluid Dynamics (CFD)-Based Modeling and Optimal Flow Control of a Bioprinter

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Extrusion-based bioprinting requires precise control of bioink flow to ensure consistent filament formation and structural fidelity. Conventional systems typically regulate extrusion pressure rather than the actual volumetric flow rate, making the process sensitive to rheological variations and material inhomogeneities. This study proposes a computational framework for flow-based control in pneumatic bioprinting by integrating Computational Fluid Dynamics (CFD) modeling with an optimal Linear Quadratic Gaussian (LQG) tracking controller. A CFD model of a tapered nozzle and shear-thinning alginate hydrogel was used to generate pressure–flow datasets for system identification. The LQG controller computes optimal pressure commands to track a target flow rate while compensating for disturbances. Simulation results demonstrate accurate tracking of dynamic flow references and robustness to viscosity variations. The approach enables reliable flow regulation without additional sensors, improving printing stability and construct quality.

Paper: **3024** **B1L-A**

Validation-Oriented Optimization of a Nonlinear Parametric Model for an Abs Isolation Valve

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This paper presents a validation-oriented optimization of a nonlinear parametric model of an ABS isolation valve used in an electro-hydraulic braking (EHB) system. The valve is modeled as a coupled electro-hydraulic-mechanical system including nonlinear magnetic force characteristics, hydraulic flow through multiple restrictions with Reynolds-number corrections, and armature–spool dynamics. Experimental measurements were performed on a hydraulic testbench over a grid

of pressure differences and flow rates to obtain reference coil current data. Initial simulations showed systematic deviations from measurements. To reduce these errors, a two-dimensional look-up table (LUT) was introduced to locally scale the magnetic force using an iterative proportional update law. The proposed optimization reduced the global modeling error to about 5% of its initial value, corresponding to roughly 95% error reduction and significantly improved agreement between simulations and experiments. The method was also successfully applied to other valve models, simplifying parametrization while preserving model structure and computational efficiency.

Paper: **3072** **B1L-A**

The Superiority of the Generalized Minimum Variance Control Procedure Over the Minimum Variance Control-Based Algorithm Under the Blurred Real-Life Servomechanism System

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In this paper, the physical implementation of the Generalized Minimum Variance Control (GMVC) algorithm onto the blurred real-life Servomechanism system has been performed. In contrast to the former Minimum Variance Control (MVC)-derived practical explorations covering the state-space-oriented framework supported by the state observer, the novel ARMAX-based solution clearly exhibits the advantages of the input-output-originated approach, particularly in the context of speed and robustification of the closed-loop control system. In this way, the previous LQG-related technique has already been outperformed by the superior structurally stable (robust) GMVC methodology in common disturbance-related engineering issues.

Day: **Wednesday, August 19th, 2026**

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

Room: **Vasco da Gama**

Chair: **Maciej Michałek**

Paper: **3077** **B1L-B**

Kinematic Modelling of Five-Bar Bipedal Locomotion: an Analytical Approach

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This paper presents an analytical framework for the kinematic modeling of a five-bar bipedal robot, which is a home-made experimental prototype. The five-bar linkage introduces complex holonomic constraints and closed-loop dependencies that require precise mathematical formulation. We derive the forward and inverse kinematic equations using an analytical approach, providing a deterministic solution for the foot trajectory relative to the hip base. The study further establishes a closed-form mapping between joint space and task space, this research provides as a first approach for path tracking and control a Kalman filter for straight trajectories. The proposed model is validated through numerical simulations and laboratory experiments, characterizing the workspace and motion primitives of five-bar bipedal locomotion.

Paper: **3100** **B1L-B**

RL-Inspired Pairwise Path Selection for Multi-Agent Navigation

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This paper presents an RL (Reinforcement Learning) inspired pairwise path selection framework for multi-agent navigation in an offline setting. Path performance is quantified using interaction metrics derived from artificial potential field (APF)-based collision avoidance, together with overall task completion time. These metrics are incorporated into a reward formulation that captures both safety and efficiency. A neural network model is trained using pairwise comparisons of path executions, enabling the system to learn relative preferences among candidate path. This formulation eliminates the need for continuous environment interaction during training while preserving key characteristics of reward-driven optimization. The framework is validated through simulations implemented in ROS~2 (Robot Operating System) using TurtleBot4 platforms in a

warehouse environment. Multiple path combinations are evaluated under varying interaction conditions. Results demonstrate stable training convergence, high ranking accuracy, and clear discrimination between efficient and conflict-prone paths.

Paper: **3022** **B1L-B**

From Soil Sensing to Agronomic Decisions: an Explainable IoT Framework for Crop Suitability and Nutrient Recommendation

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Precision agriculture improves sustainability by matching crop and fertilizer choices with soil conditions, but many farms still rely on uniform practices based on experience, which can lead to nutrient imbalances. This paper introduces an IoT-based smart farming system that provides clear crop selection and fertilizer recommendations using real-time soil data and rule-based agronomic models. A crop suitability score for different soil samples was generated using normalized agronomic thresholds utilizing a RS485 sensor data implemented on an ESP32 and cloud visualization. The calculated scenario-based crop suitability score of 0.35 or above can be used to correctly identify the suitable crops for a specific soil. In addition, we generated a fertilizer recommendation scheme through a nutrient deficit model that includes unit conversion, manure contribution, fertilizer-use efficiency correction and pH adjustments. The system achieved approximately 13 to 16% reduction in chemical fertilizer use compared to a baseline approach that considers only nutrient deficits.

Poster Session I, B2P-C

Day: **Wednesday, August 19th, 2026**

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

Room: **Poster Area**

Chair: **Krzysztof Okarma**

Paper: **3008** **B2P-C**

Fractional-Order Modeling of Pneumatic Transmission Dynamics in Soft Robotic Actuation

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Pneumatic actuation is fundamental to soft robotic systems, yet modelling airflow dynamics is challenging when thin, elongated pipelines introduce transport delays, boundary-dependent transients, and long-memory effects. Classical integer-order (IO) models often fail to capture slow relaxation, non-exponential transients, and distributed damping from compressibility, friction, and wave propagation. This paper presents an experimental comparison of IO and fractional-order (FO) time-domain models for pneumatic pipeline dynamics in a closed-end configuration, identified from step-response measurements on a 13.2 m nylon pipeline. FO models are implemented using the Grünwald--Letnikov (GL) discretisation. A unified identification framework estimates an effective time delay, identifies dynamic parameters by minimising a weighted RMSE emphasising early-time transients, and computes the static gain via least squares. FO models consistently achieve lower fitting errors than IO counterparts, offering a more compact representation of long-memory relaxation and distributed damping. Simulink validation confirms RMSE improvements of 32.64% to 69.80% across model comparisons.

Paper: **3032** **B2P-C**

Comparative Study of Neural State-Space Models for Nonlinear Pendulum Identification

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This paper compares two reinforcement learning (RL) approaches for controlling nonlinear multiple-input multiple-output (MIMO) systems: direct control, where the RL agent outputs

control signals applied directly to system actuators, and adaptive feedback control, where the RL agent adjusts parameters of a feedback controller based on measured outputs. The theoretical principles and practical implications of both approaches are analyzed. Direct control offers high flexibility and the ability to capture complex nonlinear dynamics, but raises challenges related to stability guarantees, interpretability, and real-time computational requirements. Adaptive feedback control improves interpretability and can support stability through integration with classical control structures, although its performance depends on the chosen controller architecture. The study highlights the trade-offs between flexibility, stability, and practical implementation in RL-based control of nonlinear MIMO systems.

Paper: **3041** **B2P-C**

Zeroing of the Transfer Matrices of Fractional Linear Continuous-Time Systems

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It is shown that if the fractional continuous-time linear system is uncontrollable and unobservable, and the product CB of the matrices is zero, then the transfer matrix of the system is the zero matrix. The results is illustrated by simple numerical example.

Paper: **3042** **B2P-C**

A Method for Generating a Fuzzy Model from Data

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This paper presents a fast and computationally efficient method for generating fuzzy models directly from data. The method is conceptually inspired by the classical Wang-Mendel rule generation framework, but introduces a fundamentally different mechanism for rule construction and model output generation. The approach is based on a histogram-based representation of empirical output distributions associated with combinations of input partitions, which enables robust rule generation and improves resistance to outliers. The resulting model allows extremely fast output evaluation, making it particularly suitable for real-time applications implemented in embedded industrial devices. The effectiveness of the proposed approach is demonstrated using selected modeling examples based on industrial process data. The obtained results show that the statistical properties of the modeling error are comparable to those obtained using the Wang-Mendel method, while significantly reducing computational complexity.

Nonlinear Optimisation of the Reference Dissolved Oxygen Concentration Trajectory in Biological Sequencing Batch Reactor

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This paper proposes the optimisation of the reference dissolved oxygen (DO) concentration in a biological sequencing batch reactor (SBR). A dynamic, nonlinear process model was developed using a model with a three-layer structure and variable volume, based on the activated sludge model no.3 with a bio-p module, calibrated with measurements from the Swarzewo WWTP (Northern Poland). The main objective was to treat wastewater in accordance with the water law permit and reduce energy consumption for aeration. The Particle Swarm Optimisation (PSO) algorithm was applied. A nonlinear model predictive controller was designed to track the optimised DO reference trajectory. The relative reduction index for chemical oxygen demand, nitrogen and phosphorus reached values of99.5%, 69.6% and 81.8%, respectively. The energy cost was 0.321kWh for the baseline, while the optimisation achieved a lower value of 0.294 kWh, which means an energy reduction of 8.4%.

Robustness Analysis of Backstepping Control for Magnetic Levitation Systems

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This paper presents a tuning framework for a robust Backstepping controller applied to a magnetic levitating disk system. A high-fidelity nonlinear model is first identified from experimental data using Particle Swarm Optimization (PSO). Subsequently, a Backstepping law is synthesized, with gains optimized via an ensemble-based PSO strategy within analytically constrained domains. This approach minimizes trajectory dispersion across uncertain model realizations. Finally, a sensitivity analysis quantifies the impact of parametric uncertainties on the optimized closed-loop performance.

Opportunistic Repeat-Pass Interferometric Observation in a Repeating Sun-Synchronous Orbit

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This paper presents a probabilistic framework for assessing opportunistic repeat-pass interferometric observation in a repeating Sun-synchronous orbit under periodic station keeping. High-fidelity deputy trajectories relative to a nominal chief orbit are generated in MATLAB Aerospace Toolbox with perturbations including high-order gravity, drag, solar radiation pressure, and third-body effects. The resulting relative motion in the RIC frame is reduced to a hybrid stochastic free-drift model composed of an empirical mean template and a CW-anchored Gaussian fluctuation model with calibrated acceleration-level noise. Station keeping is represented as a stochastic reset applied at prescribed epochs. Interferometric feasibility is evaluated from the difference between two states of the same stochastic trajectory separated by one or more repeat-ground-track cycles, using radial and ground-track error proxy differences as admissibility metrics. The method yields pairwise and eventual opportunity probabilities, linking orbit-maintenance design to observation availability.

On Output Trajectory-Based Functionals of Control Systems on Time Scales

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A trajectory-based functional approach to determining an unknown parameter, such that the corresponding linear control system in time scale minimizes the discrepancy measure between an output trajectory determined from measured output and an output trajectory generated by the model is consider. This approach is inspired by the idea of the global accumulation in parameter space, known from Hough-type methods. Considering a parameterized family of linear time-scale control systems, two types of functionals are defined: a functional as the difference between the measured output values of the system and the trajectories generated by potential realizations, and a functional as the difference in the rates of change of the output trajectory obtained from measurements and from the model. For linear systems, explicit forms of such functionals are presented, and their basic properties are discussed.

Implementation of a Multidimensional Predictive Control System with PLC Load Scheduling

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This article presents the implementation of an adaptive Multiple-Input Multiple-Output (MIMO) Model Predictive Control (aMPC) algorithm on a standard Programmable Logic Controller (PLC). This algorithm utilizes a custom Scheduler that controls the PLC load by dividing the necessary calculations of a single algorithm step across multiple controller cycles. The load factor is specified by the user, representing a compromise between the PLC processor load in a single cycle and the execution step length of the aMPC algorithm. The proposed solution is validated using a model of a real laboratory setup characterized by nonlinear dynamics. The experimental results demonstrate that the PLC successfully executes the advanced MIMO aMPC, achieving precise reference trajectory tracking and robust unmeasured disturbance rejection. The successful implementation of this advanced algorithm with long prediction horizons demonstrates the high utility and versatility of the Scheduler mechanism. Ultimately, this study proves that resource-constrained, real-time control environments such as PLCs can serve as effective hardware platforms for hosting advanced predictive control and estimation algorithms.

Multiresonance RF Energy Harvesters

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RF Energy Harvesting emerges as a crucial power source for Internet of Things (IoT) sensors, wearables and even medical devices. Currently, RF energy harvesters are often powered using dedicated transmitters, which is a non-optimal approach. To be able to harvest ambient energy from the civil infrastructure such as telecommunication base stations, WiFi routers or other RF emitting sources, it is crucial to provide design that is capable to harvest energy from a wideband.

Hybrid Speed Controller with Constrained Radial Basis Function Neural Network Applied to BLDC Motor

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This paper presents a concept of a hybrid controller merging a PI controller with a Radial Basis Function Neural Network (RBFNN) applied to Brushless DC (BLDC) motor control. The strategy is implemented to achieve a better response when parametric uncertainty is introduced. Signal constraints seem to be one of the key issues in adaptive systems. The issue is particularly important in relation to real systems where current limits need to be applied. For this purpose, the RBFNN is enhanced with an output-constraining function to prevent unwanted behavior and breaching the controller limit. Proposed solution leads to stable operation of the electric drive. The theoretical description of the algorithm, the laboratory stand equipped with a BLDC motor, and the experimental confirmation are all presented.

Experimental Platform for Car-Driven Inverted Pendulum

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This paper presents a low-cost, mobile cart–pole platform for control education and experimentation. It is implemented on a JetRacer Ackerman type robotic base with onboard computation unit and a mobile application interface. A nonlinear dynamic model of the system is derived and linearized around the unstable equilibrium to obtain a state-space representation. To address actuator nonlinearities, a dead-zone model is identified using experimental data. Based on the identified model, a discrete-time Linear Quadratic Regulator (LQR) with Kalman filter state estimation is designed. Experimental results demonstrate effective stabilization despite hardware limitations and disturbances.

Day: **Wednesday, August 19th, 2026**

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

Room: **Marco Polo**

Chairs: **Zdzisław Kowalczuk**

Paper: **3014** **B3L-A**

Experimental Characterization and Static Thrust Modeling of a Swashplateless Rotor System for Unmanned Aerial Vehicles with Phase-Lag Compensation

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This paper presents an experimental and theoretical study of a swashplateless tilting-blade drive for small Unmanned Aerial Vehicles (UAVs). In steady-state, the motor–rotor with electronic speed controller (ESC) produces thrust orthogonal to the motor plane; sinusoidal blade-pitch modulation allows control of thrust magnitude and direction. Using a custom test rig with a six-axis force sensor, high-speed imaging, and MATLAB analysis, a physics-based model capturing rotor speed, modulation amplitude, thrust loss, and ESC tracking dynamics is developed and validated. The dynamic phase lag between actuator input and thrust azimuth is characterized, and a synchronization strategy is proposed to compensate for it, enabling precise real-time thrust-vector control. Experiments confirm model accuracy and show significant improvements in thrust-vector precision, allowing agile UAV flight-controller design.

Paper: **3017** **B3L-A**

Structural Reduction of DMC Matrices via Window Horizon Extension: A Preliminary Study

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This paper presents a preliminary study on a structural reduction approach for the Dynamic Matrix Control (DMC) algorithm based on a window horizon extension. The primary objective of the proposed modification is to reduce computational complexity, which remains a significant barrier

to the implementation of advanced control algorithms on industrial hardware, such as Programmable Logic Controllers (PLCs). The practical potential of the concept was verified through simulations on benchmark plants, with the results compared to the SC-KM reference tuning strategy. It was demonstrated that the proposed approach allows for a reduction in the dimensions of the matrices processed within the algorithm by over 96 %, resulting in a substantial reduction in memory usage. This was achieved while maintaining nearly identical control quality. The results suggest that this structural simplification has a strong potential to facilitate the deployment of the DMC algorithm in systems with limited hardware resources, establishing a foundation for future development of heuristic tuning rules.

Paper: **3067** **B3L-A**

Nonlinear Tracking Control with EKF for a DC Motor Supplied by a Boost Converter

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This paper deals with angular velocity tracking control for a DC motor that is supplied by a boost DC--DC power converter. Here, robustness regarding model uncertainty and unknown load disturbance torques is important. The cascaded nonlinear control design for the electromechanical systemis is based on a time-averaged nonlinear model. The proposed tracking control has a cascade structure reflecting the subsystems boost converter and DC motor, which is combined with a central extended Kalman filter for state and disturbance estimation. In the inner control loop, a nonlinear tracking control based on extended linearization techniques is designed for the output voltage of the boost converter, whereas the outer loop involves a super-twisting sliding mode control for the angular velocity of the DC motor addressing an unknown load disturbance torque and model uncertainty. The benefits of the proposed control structure are evaluated by simulations using a validated model from the literature.

Paper: **3071** **B3L-A**

Robust Safety-Critical Control of Planar Robotic Manipulators Under Disturbances

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We present a safety-critical control framework based on Disturbance Observer-Parameterized Control Barrier Functions (DOP-CBF) for general n-DOF planar robotic manipulators. The framework enforces joint angle and joint angular velocity limits as key safety constraints. It integrates a proportional-derivative (PD)-like nominal controller, a momentum-based disturbance observer, and an adaptive safety filter in a unified design. Using online estimates of lumped disturbances and their cross-joint effects, the method adaptively adjusts safety margins in real time,

removing the need for prior knowledge of uncertainty bounds while accounting for disturbance-induced coupling effects commonly encountered in robotic manipulators. Our theoretical analysis establishes Input-to-State Stability of the closed-loop system. The proposed approach is validated through simulations on a 2-DOF planar manipulator under multiple scenarios. Compared with an Explicit Reference Governor (ERG), it suppresses transient overshoot and oscillations in disturbance-free conditions and maintains robust performance under Gaussian white noise, while mitigating the severe oscillations observed in the baseline.

Paper: **3117** **C4L-B**

Physics-Based Derivation of Scrap Probabilities in the Stacking Stage of Battery Manufacturing

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The reliability of production systems can be assessed with the help of discrete-event simulations. For that purpose, it is necessary that failure probabilities of each individual production stage are quantified. As an example, we consider the stacking stage of battery manufacturing. On the one hand, failures are due to defects in manufacturing equipment caused by component wear. On the other hand, also defective products themselves represent a reason for a decrease of the efficiency of a production chain. Many defective products result from the fact that certain manufacturing tolerances are exceeded. An optimization of the process control loops then has to be performed to reduce the likelihood of such kind of defects. To systematically analyze the probabilities of defective products, it is necessary to interface system-level discrete-event simulations with information obtained from physics-based process simulations.

Day: **Wednesday, August 19th, 2026**

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

Room: **Vasco da Gama**

Chair: **Marcin Witczak**

Paper: **3020** **B3L-B**

Autonomous Retail Systems with Vision-Based Tracking and Customer Behavior Modeling

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We establish formal geometric relationships between tracking and identification camera systems, derive error bounds for spatial localization, and implement a finite state machine model for customer behavior analysis. Experimental validation in a prototype environment demonstrates the system's effectiveness across various operational conditions. The work contributes both theoretical foundations and practical implementation guidelines for scalable autonomous retail deployment.

Paper: **3033** **B3L-B**

Supervised vs. Self-Supervised Learning for Corrosion Detection

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This paper investigates supervised and self-supervised deep learning approaches for corrosion detection in robotic inspection systems. A lightweight SE-ResNet classifier with mixup and label smoothing is compared with a SimCLR-based self-supervised representation learning method followed by fine-tuning. Experiments on the Rust-Iron dataset (1,455 images) show that SE-ResNet achieves 93.96% accuracy and 0.975 ROC-AUC, while the SimCLR approach achieves 92.31% accuracy. Cross-dataset evaluation on a pipeline corrosion dataset demonstrates good generalization, highlighting the potential of deep learning for vision-based robotic inspection.

Edge Deployment of Cross-Sensor Bearing Fault Diagnosis: Accuracy–Cost Trade-Offs in Signal Representation

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This paper investigates the deployment of vibration-based bearing fault diagnosis under a cross-sensor setting using the Case Western Reserve University dataset. Models are trained on the drive-end (DE) sensor and evaluated on the fan-end (FE) sensor to introduce a realistic domain shift. The study compares three commonly used signal representations: raw time-domain input with a 1DCNN, frequency-domain input using an FFT frontend, and time–frequency input using an STFT frontend with a 2D CNN. Experimental results show that spectral and time–frequency representations improve cross-sensor diagnostic performance, with STFT achieving the highest balanced accuracy. However, deployment experiments on an NVIDIA Jetson platform reveal practical constraints: raw CNN models can be exported directly to ONNX/TensorRT, while FFT and STFT require external preprocessing due to limited runtime support for spectral operators. The results highlight a trade-off between diagnostic accuracy and deployment efficiency, demonstrating that representation choices for edge-based condition monitoring must be evaluated at the system level rather than by model accuracy.

Condition-Invariant Feature Selection for Operating-Condition-Robust Fault Diagnosis

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Fault-diagnosis models often degrade under changed operating conditions. This work investigates whether cross-condition fault classification can be improved using a simple and interpretable source-only feature-selection strategy based on vibration features. To identify features that remain informative under changing regimes, a ranking score was proposed that combines fault discriminability, measured by the ANOVA F-score, with a penalty for operating-condition sensitivity computed across source regimes. Based on this score, reduced subsets containing the top 25%, 50%, and 75% of ranked features were used to train machine-learning classifiers and evaluated on a previously unseen operating condition following a leave-one-condition-out protocol. The results show that selecting condition-invariant features can substantially improve generalization under domain shift. The best performance was obtained by XGBoost using the top 50% feature subset, achieving an accuracy of 0.861, compared with 0.684 on all features. The proposed approach preserves interpretability, reduces dimensionality, and offers a computationally efficient alternative to more complex adaptation-based solutions.

Day: **Wednesday, August 19th, 2026**

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

Room: **Marco Polo**

Chairs: **Eero Immonen**

Paper: **3095** **B4L-A**

Modelling Dynamic and Time-Dependent Power Consumption Using a Black-Box Approach

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The growing energy demand in the industrial sector necessitates improved methods for modelling and optimising power consumption. However, modelling industrial machines remains challenging due to limited access to their internal functionality, requiring black-box approaches. This paper presents a non-invasive approach for modelling the power consumption based solely on observable input/output signals and electrical measurements. It combines a behavioural model and a power state machine, both of which are specified as extended finite state machines and enhanced with timed automata concepts to incorporate characteristic values for the dynamic system behaviour and environmental parameters. The approach is evaluated on an industrial robotic arm using real measurement data. The results show that power consumption can be systematically assigned to functional states and represented as parameterised, time-dependent power profiles with low variance across repeated runs, demonstrating the robustness and accuracy of the approach.

Paper: **3097** **B4L-A**

Enhancement of Localization Accuracy for Double Simultaneous Leaks via an Equivalent Pipeline Model

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This study examines the localization of double concurrent leaks in liquid transmission pipelines utilizing the standard gradient-based procedure. Typically, the procedure relies on a simplified pipeline model that accounts for global frictional resistance effects (linear pressure losses) while often neglecting local resistance effects (local pressure losses). In this work, the performance of the leak localization procedure is evaluated using two different models of the investigated pipeline.

In addition to the aforementioned simplified model, an enhanced model is considered that incorporates both global and local pressure losses by transforming all pipeline components into an equivalent model composed of straight pipe sections with equivalent lengths. The input data for both models consist of pressure values obtained from a computational flow model based on the geometry and flow parameters of a laboratory scale water pipeline. The analysis considers double simultaneous leaks occurring at various locations along the pipeline, and combined leak rates. Another important aspect of the examined variants of this procedure is the resolution of the input pressure data.

Paper: **3109** **B4L-A**

Parameter Estimation of Fractional-Order Hammerstein Systems with Colored Noise

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This work considers the identification problem of fractional-order Hammerstein systems with colored noise starting from filtered input and output data. The system consists of a nonlinear block followed by a fractional-order linear subsystem. A novel identification approach based on the recursive least squares algorithm of optimization is developed to estimate all model parameters including the parameters of the noise model. During the estimation process, the principle of auxiliary models is used to overcome the issue of unknown parameters and unmeasured intermediate signals. To demonstrate the efficiency of the proposed method in offering consistent parameter estimates, simulation results and comparison with existing methods are presented.

Paper: **3113** **B4L-A**

On the Limitations of Residual Gaussian Processes for Multi-Aeration Dynamics in SBRs

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Sequencing batch reactors (SBRs) operating with multiple aerated intervals exhibit dissolved oxygen (DO) dynamics with regime-dependent behaviour and transition-induced variability. While residual Gaussian process (GP) models provide stable multi-step prediction under stationary conditions, their applicability to multi-phase operation remains unclear. This work investigates whether an increment-based residual GP formulation can be extended from single- to multi-aeration regimes. The react phase is represented as a finite-memory nonlinear system, and a unified model is constructed via regressor augmentation with phase information without explicit switching. Empirical evaluation shows that the baseline SISO model achieves the lowest error (RMSE 0.2798) and preserves bounded behaviour, while additional variables degrade performance (up to 0.4366 RMSE). The largest mismatch occurs near regime transitions, where bias and uncertainty accumulate. The results indicate that residual GP modelling is feasible in multi-phase settings but limited by transition representation, motivating transition-aware hybrid extensions.

Quality Score: A Behavioural Metric for Deliberation Quality in LLM-MAS Systems

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Large Language Models (LLMs) are increasingly used as a deliberative layer when classical machine learning faces out-of-distribution situations. In multi-agent settings (LLM-MAS), multiple models can mutually verify responses and reduce single-model bias. This paper introduces \textbf{Quality Score~(Q)}, a behavioural post-hoc metric for assessing deliberation quality from observable dialogue patterns. Q combines four components: Position Evolution~(PE), Argument Diversity~(AD), Consensus Timing~(CT), and Mutual Acknowledgment~(MA). The metric was evaluated on 303 dialogues under three conditions differing in the use of Dialogue Service Level Objectives~(DSLO). Q differentiated the resulting deliberation regimes: unconstrained dialogues achieved an average Q of 0.795, while the two DSLO conditions reached 0.702 and 0.747. With sufficiently large samples, Q can help identify configurations that systematically produce more thorough deliberation.

Day: **Wednesday, August 19th, 2026**

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

Room: **Vasco da Gama**

Chair: **Dariusz Pazderski**

Paper: **3082** **B4L-B**

Nonholonomic Omnidirectional Mobile Robot with Dual Steerable Drive Modules — Part I: Modeling

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This paper addresses the modeling of an omnidirectional mobile robot equipped with dual steerable drive modules that are subject to nonholonomic rolling constraints. This class of mobile robots with steerable driving units is nowadays attractive for tasks that demand locomotion versatility and steering reorientation capability. However, their motion is constrained by rolling conditions that explicitly depend on the steering configuration, which increases the complexity of the modeling problem compared to conventional fixed-wheel platforms. The proposed formulation includes planar kinematics, rigid-body dynamics under rolling constraints, and a reduced virtual-velocity parameterization that characterizes admissible motions in the null space of the constraints. The resulting model offers a compact and physically consistent basis for simulation and subsequent control design.

Paper: **3083** **B4L-B**

Nonholonomic Omnidirectional Mobile Robot with Dual Steerable Drive Modules — Part II: Tracking Control

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This paper addresses the tracking control problem for a dual-steering omnidirectional robot subject to rolling constraints, where the control action is applied along the admissible direction of motion. To this end, a cascade controller is developed from the reduced-order model in virtual-velocity coordinates [1]. The outer loop regulates the admissible component of the tracking error, while the

inner loop regulates the forward velocities of the drive modules. The resulting formulation is consistent with the constrained model and is defined on a singularity-free domain. Based on the reduced-order dynamics, the closed-loop design guarantees exponential convergence of the inner velocity error and local convergence of the admissible tracking error.

Paper: **3093** **B4L-B**

Nonholonomic Omnidirectional Mobile Robot with Dual Steerable Drive Modules — Part III: Steering Control

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This paper addresses the steering control layer of a dual-steering omnidirectional mobile robot, where motion control alone is not sufficient to regulate the direction of motion because the steering configuration determines the admissible motion of the platform. The objective is to regulate the steering behavior of the drive modules to support direction control and direction correction, which are instrumental for compensating for path deviations and recovering the desired motion orientation while remaining consistent with the constrained equation of motion of the robot [1]. The resulting formulation complements the admissible tracking controller developed in the companion paper [2] and provides the direction-related components required for precise and robust robot locomotion.

Paper: **3089** **B4L-B**

Adjustable Stiffness of a Robot Formation Under Set-Point Control with Collision Avoidance Based on Artificial Potential Functions

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Artificial Potential Functions (APFs) enable effective real-time collision avoidance in robotics but degrade formation integrity in dense multi-robot environments by displacing converged robots via repulsive fields from moving agents. This paper proposes a set-point controller augmented with APF-based collision avoidance, in which the repulsive field is spatially modulated to progressively stiffen the formation response as each agent approaches its target. The stiffness profile is governed by tunable design parameters that provide independent control over two key properties: the degree of disturbance rejection applied to settled agents, and the spatial extent of the neighborhood around each set-point within which that rejection is active. The stability of the closed-loop system is established through a Lyapunov analysis. The proposed approach is evaluated by comparing its ability to keep each robot in its desired position in the presence of disturbance-generating neighbors with that of a conventional APF controller.

Autonomous Mobile Robot Navigation Using Adaptive Particle Filter

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The paper describes an adaptive particle filter for estimating the state in autonomous mobile robot navigation. The standard particle filter (PF) is suffering from degeneracy issues. A novel Adaptive Particle Filter based on Resampling (APFR) is presented using fuzzy logic. It replaces a rigid resampling threshold with a fuzzy decision process that regulates resampling intensity using particle diversity parameters such as effective sample weight and size variance. The proposal (APFR) is com- pared to the Adaptive Particle Filter based on Adjusting Noise (APFN) and PF. The APFN uses fuzzy logic for monitoring the degree of divergence in innovation stats and dynamically changes process and measurement noise variances. Both strategies intend to preserve particle diversity while avoiding sample reduction and degeneracy. The proposed filter (APFR) is built into a mobile robot tracking system and verified through simulated studies. The results show that the APFR adaptive technique achieves higher state estimate accuracy than the APFN and PF.

Day: **Wednesday, August 19th, 2026**

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

Room: **Poster Area**

Chair: **Łukasz Sajewski**

Paper: **3018** **B5P-C**

GyroStep: A Portable IMU-Based System for Knee Flexion Measurement and Real-Time Analysis

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This paper presents GyroStep, a wearable inertial-measurement-based system for real-time estimation of knee flexion angle. The system integrates two MPU6050 sensors mounted on the thigh and shank with an ESP32 microcontroller responsible for synchronized data acquisition, signal processing, and wireless transmission. A Kalman-filter-based orientation estimation scheme is applied for roll and pitch angles. The knee flexion angle is computed as the relative angular displacement between limb segments in the sagittal plane. Experimental validation includes static accuracy assessment and repeatability analysis performed using a dedicated laboratory test rig. The results demonstrate stable operation, consistent angle estimation, and reliable performance under wearable conditions. The proposed architecture constitutes a low-cost and portable solution for motion monitoring and rehabilitationoriented movement analysis.

Paper: **3023** **B5P-C**

Experimental Analysis of Sensor Calibration Effects on Multi-Sensor Fusion for IMU-Based Attitude Estimation

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Accurate attitude estimation using low-cost microelectromechanical systems (MEMS) inertial measurement units (IMUs) is challenging due to bias, scale-factor errors, axis misalignment, magnetic distortions, and stochastic noise. This paper experimentally investigates the combined effects of sensor calibration and sensor fusion on orientation estimation performance using the IMU-9250 with a tri-axial accelerometer, gyroscope, and magnetometer. Calibration procedures for the accelerometer and magnetometer compensate deterministic errors including bias, non-orthogonality, and hard- and soft-iron distortions. Calibration effectiveness is evaluated by comparing raw and corrected measurements. Three sensor fusion methods are implemented: a complementary filter, a two-dimensional Kalman filter for roll and pitch estimation, and a three-

dimensional Extended Kalman Filter (EKF) for full roll–pitch–yaw estimation. Results show that sensor fusion reduces noise and gyroscope drift, while calibration significantly improves estimation accuracy and stability. The EKF with calibrated data provides the most robust orientation estimation.

Paper: **3026** **B5P-C**

A Simple Regression Approach for Estimating the Health State of a Milling Cutter

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This paper proposes a lightweight method for estimating the normalized health state of a milling cutter using ridge regression. The approach was evaluated on a public dataset containing 968 milling cycles from 14 tools tracked from new condition to breakage. A new engineered feature combining cycle number and radial depth of cut was introduced, and automatic univariate feature selection was used to keep only the most informative predictors. To avoid information leakage and overly optimistic results, model tuning and assessment were performed with nested grouped cross-validation, where all samples from the same tool were kept together. In addition to standard regression metrics, the study used an asymmetric score to penalize late predictions more strongly, reflecting their higher practical cost. The best model, using clipping and a square-root transformation of the target, achieved $R^2 = 0.780$, MSE = 0.019, MAE = 0.107, and AS = 0.905, outperforming previously reported results while relying on fewer features.

Paper: **3054** **D1L-A**

Fractional Discrete-Time Systems with Alternating Memory Structure for Grünwald-Letnikov Operator of Convolution Type

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This paper investigates fractional discrete-time systems defined by Grünwald-Letnikov type operators with variable and alternating orders. Using the Z-transform, we derive explicit expressions for the operator symbol and establish a connection between the system dynamics and its spectral properties. Within this framework, we derive stability conditions in terms of the image of the unit disk under the associated characteristic mapping. It is shown that the presence of integer-order terms can be interpreted as local reductions of memory, which significantly influence the stability region of the system.

Robot-Assisted Measurement of Knee Joint Mechanical Response in Six Degrees of Freedom

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This paper presents a robotic system for the measurement of knee joint mechanical response in six degrees of freedom. The proposed experimental setup uses an ABB industrial robot equipped with a six-axis force and torque sensor to apply controlled displacements and rotations to the joint and to record the resulting load response. The methodology enables evaluation of joint stiffness and range of motion for intact and damaged ligament conditions. Measurements performed for flexion angles of 0° and 30° confirm that posterior cruciate ligament deficiency has a limited effect in full extension, whereas it significantly alters the mechanical response of the joint in flexion. The developed approach demonstrates the potential of robotic systems as repeatable and precise tools for biomechanical diagnostics and experimental orthopaedic research.

Interactivity of a Mobile Robot: A Case Study of the Autonomous Airport Assistant CarryBot

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The paper presents CarryBot, an autonomous mobile robot improving the efficiency of logistics and the level of service for passengers at airport terminals. The system is based on a Split-Brain architecture to separate high-level decision-making from low-level security protocols. CarryBot uses the standard path planning algorithm A*, based on squared Euclidean heuristics and a 0.2m grid, and Python-implemented with a computation time of 34ms. The robot safely gives way to pedestrians, using the YOLOv8 vision model set to a confidence threshold of 0.75. At the same time, independent C++ firmware running on the Arduino Mega 2560 supports safety reflexes via a 15cm radius ultrasonic buffer. Mission integrity is enforced using a two-step authentication gateway combining RFID with simulated biometrics, while the Flask-SocketIO platform manages real-time telemetry. System validation was performed using a Software-in-the-Loop approach, synchronizing high-fidelity Webots physics simulations with Proteus electrical models. Experimental results demonstrate a 98% mission success rate and control latency of 48ms, enabling reliable system operation in dynamic aviation environments.

Real-Time Multi-Camera Map Tracking with Adaptive Allocation, Caching and Filtering

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This study extends a prior multi-camera, multi-robot visual localization algorithm by introducing four optimizations to enable real-time operation. The proposed enhancements include: (1) heuristic-based image stitching for efficient multi-source fusion with native support for more than 2 cameras; (2) adaptive buffer allocation using exponential smoothing and hysteresis to minimize memory overhead; (3) homography caching with heuristic invalidation to reduce redundant geometric calculations; and (4) filtered marker visibility employing an exponentially weighted moving average (EWMA) and dual-threshold hysteresis to mitigate transient detection failures. The optimized pipeline is evaluated across five tracking scenarios and eight configuration variants. Results demonstrate a statistically significant reduction in computational latency, achieving processing rates of 24.5 ± 5.8 FPS with 30 FPS input FPS input. Crucially, statistical analysis confirms that these efficiency gains cause no significant degradation in tracking precision, validating the system's suitability for real-time, resource-constrained robotic applications.

Virtual Orchard Simulation Environment for Development and Testing of Autonomous Fruit-Harvesting Robots

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This paper presents a high-fidelity virtual orchard simulation in Gazebo and ROS 2 to bridge the sim-to-real gap in autonomous harvesting. We introduce custom plugins for dynamic environmental effects (active headlights, rainfall) and a compliant-joint physics model for fruit detachment evaluation. The framework supports quantitative benchmarking, demonstrating that a tightly-coupled LIO-SAM approach significantly reduces trajectory RMSE compared to a standard Dual EKF in repetitive orchard corridors. Furthermore, a YOLOv8-based perception pipeline, trained on a highly randomized synthetic dataset, achieved reliable apple detection under degraded visual conditions. To validate sim-to-real transfer, a four-fingered soft gripper prototype was designed in simulation and successfully tested in laboratory conditions. Results show that this framework effectively accelerates agricultural system development, while the physical gripper prepares the system for full hardware integration.

End-to-End Control of a Quadruped Robot Using Deep Reinforcement Learning

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This paper presents an end-to-end control framework for a quadruped robot using deep reinforcement learning (DRL) to autonomously generate locomotion strategies. A mathematical model was developed in Simscape Multibody to provide a physics-based simulation environment for training and evaluation. The control approach utilizes a DRL agent trained with the Twin Delayed Deep Deterministic Policy Gradient (TD3) algorithm. By interacting directly with the simulation, the agent learns locomotion behaviors without relying on predefined gait trajectories or manually designed control laws. Through iterative training, the agent optimizes its policy against a predefined reward function to discover efficient, stable movement patterns. Experimental results demonstrate the efficacy of this TD3-based approach for continuous control tasks involving complex nonlinear dynamics. The agent successfully learned advanced locomotion strategies, including dynamic gaits with flight phases, highlighting the capability of DRL methods to manage naturally unstable behaviours that are difficult to design using classical control techniques.

Section-Based Dynamic Model of a Concentric-Tube Heat Exchanger Validated by Laboratory Experiments

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The paper presents a section-based dynamic model of a concentric-tube heat exchanger. The governing PDE model is adopted from existing literature and describes the spatio-temporal temperature distribution. Using the method of lines, the PDEs are discretized into four sections, yielding a system of ODEs suitable for simulation. The model is implemented in MATLAB/Simulink and validated against experimental data from a laboratory setup (Edibon TITCA). Comparisons show that the model captures the main trends of transient responses and steady-state temperature distributions, although some discrepancies occur due to constant model parameters. Analysis confirms expected thermal behavior: parallel flow exhibits decreasing temperature difference along the exchanger, while counter-flow provides higher efficiency. Static characteristics reveal a nonlinear relationship between outlet temperature and flow rate. The model offers a good compromise between accuracy and computational efficiency, making it suitable for control and optimization applications.

Camera-Based Synthetic Completion of Point Clouds Captured with Quadruped Robot

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LiDAR-based perception systems commonly used in mobile robots often struggle to accurately capture transparent or reflective surfaces such as glass, leading to incomplete point clouds and degraded understanding of the scene. This paper presents a camera-based synthetic point cloud completion method designed to address these limitations. The proposed approach integrates RGB images with LiDAR measurements using a quadruped robot equipped with synchronized sensors. A deep learning model based on YOLOv26 is trained to detect and segment window regions in camera images. The resulting semantic information is projected onto corresponding LiDAR data to identify areas with missing geometry. For each detected region, planar surfaces are estimated and synthetic points are generated within these boundaries to reconstruct the missing structures. Experimental evaluation conducted on a real-world dataset demonstrates that the method significantly improves the completeness and consistency of point clouds, particularly in areas containing glass surfaces. The enhanced maps provide more accurate 3D representations, which can improve navigation, obstacle avoidance, and path planning in robotics.

A Simulation-Based Framework to Design a Fixed-Wing UAV for Inspecting Large Industrial Zones

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We presents the design of a fixed-wing UAV intended for inspection of large industrial zones. The design methodology encompasses parametric sizing, configuration selection, geometric modeling, and software-based evaluation. The post-design analysis includes aerodynamic assessment, stability evaluation, and UAV performance characterization. A software-in-the-loop simulation framework has been developed in Simulink. The model includes aerodynamic modeling, propulsion modeling, and nonlinear 6-DoF flight dynamics. The flight control model is based on the ArduPilot architecture. It includes inner-loop controllers for roll, pitch, and yaw stabilization, as well as outer-loop controllers such as L1 guidance and Total Energy Control System (TECS) for trajectory and speed management. The latter generate demands for the inner loop controllers, which directly command the actuators to achieve the desired attitude. The integrated framework is tailored to coordinate inspection tasks of multiple autonomous UAVs and AGVs in an open-pit mine. The proposed approach provides an efficient platform for design, control verification, mission evaluation, as well as risk assessment and mitigation measures

TECHNICAL PROGRAM

Thursday

August 20, 2026

Day: **Thursday, August 20th, 2026**

Time: **9:00 – 10:00**

Room: **Marco Polo**

Plenary 3, C0L-A

Day: **Thursday, August 20th, 2026**

Time: **9:00 – 10:00**

Room: **Marco Polo**

Chair: **Harald Aschemann**

Author: **Ying Tan (University of Melbourne, Australia)**

Paper: **Learning Control and Its Application in Rehabilitation Robotics**

Day: **Thursday, August 20th, 2026**

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

Room: **Marco Polo**

Chair: **Michał Bartyś**

Paper: **3059** **C1L-A**

Assembly-Accelerated Sub-Byte Inference on Edge AI Device: GA Feature Selection with Integer Precision Sweep for Agricultural Machinery Diagnostics

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This paper presents a precision-sweep analysis across integer quantization for a genetic-algorithm-evolved MLP classifier deployed on the ESP32-S3 microcontroller for real-time fault detection in a P12 rotary tedder. The classifier operates on a 28-element diagnostic feature vector extracted from five-channel vibration data and targets 13 fault classes of the rotary tedder. Assembly-level SIMD kernels for INT8 and INT4 dot-products achieve up to 4.34× latency reduction over native C scalar floating-point (32 µs for INT8, 47 µs for INT4), with accuracy losses of <1% and 2–3% respectively relative to FP32. A key architectural finding is that Xtensa LX7 lacks hardware bit-count instructions, limiting the practical latency benefit of sub-INT4 precision on MCU-class platforms. The GA jointly evolves a feature selection mask and arithmetic precision as a single chromosome, autonomously identifying the optimal accuracy–latency trade-off point. INT4 is identified as the recommended configuration, offering 4.8 KB model size at 47 µs inference latency. These results provide practical design guidelines for ultra-low-cost embedded diagnostics in agricultural machinery.

Lossy Compression of HyperHeight LiDAR Forested Landscapes Data

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Light detection and ranging (LiDAR) systems are characterized by numerous applications including forest and relief control. They are able to produce 3D models and 2D maps for forested territories retrieved from hyper-height data cubes (HHDCs). Since the amount of acquired data can be quite large, it is often needed to perform compression. This paper considers an opportunity of applying the Better Portable Graphics (BPG) coder to compress noisy HHDCs. Algorithms for preprocessing noisy HHDCs to adapt their properties to the coder's input requirements are proposed. Its characteristics for different values of parameter that controls compression (PCC) are obtained. It is shown that an optimal operation point exists for both component-wise compression and compression of data in three-component groups. Both approaches are studied and shown to provide approximately the same results, offering a reasonable trade-off between noise suppression and edge/detail preservation. The possibility of achieving a compression ratio (CR) in the range of 4-15 depending on the PCC and data complexity is demonstrated.

Optimization of Predictive Maintenance Schedules Under Uncertainty: A Scenario-Based Theoretical Framework

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This paper proposes a scenario-based framework for predictive maintenance scheduling under uncertainty in a finite planning horizon. The considered setting involves multiple assets for which maintenance decisions are informed by three heterogeneous sources of information: calendar-based overhaul intervals, usage-based limits driven by uncertain future operating cycles, and condition-monitoring outputs represented through remaining useful life (RUL) estimates with uncertainty. While these elements have been studied extensively in the maintenance literature, they are often treated separately or only partially integrated. In contrast, the proposed formulation evaluates complete maintenance schedules under simulated future scenarios and compares them using expected-cost and tail-risk criteria. The contribution is primarily conceptual and methodological. A small synthetic computational example is used as a proof of concept. The results show that integrated scenario-based policies can substantially outperform simpler single-trigger rules, while the difference between risk-neutral and risk-aware integrated policies remains modest under the present calibration.

Day: **Thursday, August 20th, 2026**

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

Room: **Vasco da Gama**

Chair: **Krzysztof Oprzędkiewicz**

Paper: **3009** **C1L-B**

Start-Up Control for Reliable Closed-Loop Commissioning and Structured PID Handover

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This work addresses the start-up phase of control loops as a distinct control problem. A variable-structure start-up controller (SUC) is proposed to enable reliable closed-loop activation without requiring prior plant models. During commissioning, error-dependent switching shapes the transient response while a set of process models is evaluated in parallel for internal model control (IMC)-based initialization of an operational PID (OPID) controller. Once validated parameters are available, control authority is transferred smoothly to the OPID without interrupting closed-loop operation. In contrast to classical auto-tuning methods that rely on excitation to optimize performance, the proposed approach prioritizes safe, controlled loop activation under uncertainty. Simulation results demonstrate bounded manipulated variables, reliable controller handover, and robust commissioning behavior even in the presence of significant model mismatch and limited process knowledge.

Paper: **3057** **C1L-B**

Minimum Average Dwell-Time Computations via Continuous Piecewise Quadratic Lyapunov Functions

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Recently, continuous, piecewise linear Lyapunov functions were used to compute the minimum average-dwell time needed to assert global exponential stability for switched linear systems. Here, we use continuous, piecewise quadratic Lyapunov functions to do the same and compare the efficiency of the two methods. As in the case for piecewise linear Lyapunov functions, we use linear programming to parameterize our Lyapunov functions on a conical subdivision of the state-space.

XT-Based Decomposition of a PLC Controller Program in Distributed Control Application Using Petri Nets for Implementation Employing SFC Language

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The proposed article introduces an approach to automatic decomposition of a full control program in the context of implementation on a Programmable Logic Controller (PLC) using Petri nets and hypergraphs. The proposed decomposition algorithm involves utilizing hypergraphs and linear algebra techniques to obtain the smallest number of State Machine Components (SMCs) covering the original network. The obtained results, along with a comparative analysis, confirms the usefulness and potential of the proposed method. The proposed algorithm significantly minimizes the time required to obtain correct results. Automatically obtained State Machine Components can be directly implemented using programming languages compliant with the IEC 61131-3 standard, particularly utilizing the SFC language, as demonstrated in the smart home example.

Day: **Thursday, August 20th, 2026**

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

Room: **Poster Area**

Chair: **Ewa Pawłuszewicz**

Paper: **3069** **C2P-C**

Control-Oriented Modelling and Quantitative Evaluation of Maintenance Strategies in Data-Constrained Urban Public Transport Fleets

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Urban public transport fleets face fluctuating demand, limited maintenance capacity, and incomplete condition data. This paper examines fleet maintenance under partial observation through a discrete-time state-space model of stochastic deterioration. Each vehicle is modeled with a latent deterioration state shaped by infrastructure severity and unit-level heterogeneity, while noisy, intermittent observations are incorporated through recursive state estimation. Three policies are evaluated under identical workshop constraints: corrective maintenance, periodic preventive maintenance, and condition-based maintenance triggered by an estimated deterioration threshold that changes with system load. Monte Carlo simulation over a 365-day horizon assesses fleet availability, service level, and lifecycle cost. In the simulated cases, condition-based maintenance performs best overall, yielding availability gains of up to 12.34 percentage points and lifecycle cost reductions of about 9 percent relative to periodic maintenance under severe deterioration and long repair times. Its benefit falls as observation intervals widen and rises with infrastructure severity and repair duration.

Paper: **3078** **C2P-C**

Quantum Computing-Driven Optimization of Machine Learning Algorithms for Embedded Systems

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We report the experimental use of quantum computing for training machine learning (ML) algorithms and models designed to be then deployed for inference on embedded systems. Due to

small size of resource-efficient models for embedded systems, this application of quantum computing is an excellent candidate for verification of this technology. We develop an approach based on transforming classical supervised learning problems into a discrete form, enabling their solution using quantum annealing (QA) methods. Three models are presented, i.e., a binary XNOR-Net network, a support vector machine (SVM) with a discrete representation of dual coefficients and a convolutional neural network. All experiments are performed on the MNIST dataset, using classical optimisation methods, simulated annealing and QA on the D-Wave Advantage system. While classical gradient-based methods maintain superior absolute accuracy (up to 95.97% for SVM), the D-Wave system demonstrates a significant reduction in core optimization time, achieving speedups of up to 15.6x compared to the classical optimization on central processing unit when excluding system overhead.

Paper: **3086** **C2P-C**

Comparing ISO 19848 Sensor Naming Conventions: Interoperability Barriers and Tool-Assisted Standardization

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Effective maritime sensor data automation depends on consistent, machine-interpretable sensor identification. ISO 19848 establishes a common framework for shipboard sensor data exchange, but allows multiple co-existing naming conventions, meaning that standards compliance alone does not guarantee semantic interoperability. This paper compares two prominent ISO 19848-compliant implementations: the service-oriented JSMEA naming convention and the DNV Vessel Information Structure (VIS)-based convention. We analyze each convention's design philosophy, structural characteristics, semantic depth, and tool requirements, and assess their implications for automated sensor data pipeline integration. The analysis shows that the two conventions differ fundamentally in scope and structure, creating interoperability barriers requiring explicit translation mechanisms beyond standards compliance. We also characterize ML-assisted standardization approaches (supervised classification for legacy tag mapping, NLP-based identifier resolution, and semantic embedding for cross-convention translation) as practical support tools, and discuss their limitations in safety-critical maritime contexts.

Paper: **3087** **C2P-C**

Fast Detection of Cataract Based on Fundus Image

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Cataract is one of the leading causes of blindness worldwide, accounting for 39.6\% of global blindness according to the World Health Organization (WHO). The standard diagnostic procedure relies on an examination by an ophthalmologist, who determines the type and severity of the cataract. The article analyzes the possibility of effectively using fast machine learning techniques to detect cataracts based on the fundus images. An analysis of histogram characteristics was conducted, with a particular emphasis on the red channel, alongside an analysis of Local Binary Patterns (LBP). The proposed feature selection was evaluated to establish a rapid classification

method, enabling a significant reduction in inference time compared to standard deep neural networks. Experiments conducted on the ODIR-5K and EDC datasets demonstrated that the extracted features allow for the effective training of lightweight, fast classifiers. Evaluation on the ODIR-5K and EDC dataset showed that the proposed solution utilized the combined features achieved an accuracy of 93.97% and 95%, respectively. The inference time is significantly faster, than typically used deep neural networks.

Paper: **3088** **C2P-C**

ADRC Based on Fuzzy State Observer with Varying Dynamics Applied for Two-Mass System

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Due to the constant improvement of technological processes in today's industry, there is a visible struggle to improve a deployment process of new scientific solutions. As the complexity of industrial machinery increases, it becomes more difficult to conduct a whole implementation quickly and successfully during the first attempt. One of the most challenging issues is the dependency of the designed control systems on the plant parameters, they are meant to control. The paper proposes a novel solution, which allows to control a two-mass electric drive unit, considering a significant uncertainty in flexible shaft parameterization. The described solution is based on the Active Disturbance Rejection Controller (ADRC) with Fuzzy Extended State Observer (FESO), which increases the dynamics of the estimated disturbance regarding the actual torque demand. The experimental verification proves that the elaborated solution provides the possibility to operate the drive with roughly known shaft parameters, including efficient damping capabilities of torsional vibrations and remarkable overshoot minimization.

Paper: **3102** **C2P-C**

using Thevenin Equivalent Circuit to Identify LFP Cell Parameters: A Case Study for 1RC, 2RC, and 3RC

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This work presents the use of Thevenin equivalent electrical circuits, consisting of 1RC and 2RC resistive-capacitive elements, respectively. The adopted equivalent electrical circuits were used to identify the LFP cell's parameters during the charge/discharge cycle with a relaxation phase. The HPPC methodology was used to determine the open-circuit voltage. The Levenberg-Marquardt algorithm was used to identify the parameters of the 1RC, 2RC, and 3RC models. The identified parameters of the 1RC, 2RC, and 3RC models in the charge/discharge cycle, for state-of-charge values from 0 (complete discharge) to 1 (full charge), were described by a polynomial function,

subject to the condition that all elements of the parameter vector are nonnegative. The coefficient of determination was used to assess the fit of the approximating functions qualitatively. The results obtained were analyzed, and their scalability to a module and a battery was assessed, with potential for small electric vehicles and passenger cars.

Paper: **3103** **C2P-C**

ERP-Integrated Decision Support for Heavy-Equipment Allocation in Multi-Project Environment Using Cost-Minimization Criterion

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The paper addresses planning the use of heavy equipment in a construction company running multiple projects in parallel that share limited and costly resources. The main challenge is to assign machines to tasks while considering task time windows, resource availability, the possibility of relocating equipment between sites, and the alternative of renting. In some cases, the combined transportation costs and the operating cost rate of the company's own equipment may be higher than local rental, so decisions require ongoing cost analysis. The aim is to design a decision-support tool integrated with the IFS ERP system and to propose a solution based on the RCMPSP mathematical model that minimizes the total cost of executing a project portfolio. The work defines parameters, decision variables, and constraints covering machine-to-task assignments, the choice of resource source (owned vs. rented), and relocation decisions. An additional component is a decision workflow that uses ERP data to recommend the most cost-effective equipment allocations.

Paper: **3104** **C2P-C**

Zero-Knowledge-Proofs for the Internet of Things Communication

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This paper proposes a hybrid Zero Knowledge Proofs Subnets design: non-interactive ZKPs for broadcast discovery beacons and interactive ZKPs for pairwise session setup. The variants of ZKPs (including elliptic-based proofs) were imple- mented in MicroPython on ESP32 and ESP8266 boards, repre- sentative examples of constrained IoT devices. Performance was measured in terms of execution time and energy consumption. The results show that verification dominates the cost (especially at higher security levels), elliptic-curve ZKPs provide favourable security-performance trade-offs, and more compact keys. The ESP32 system significantly outperforms ESP8266 (typically 2- 5 times), highlighting the practicality of ZKPs as authentication mechanisms for decentralised IoT mesh networks.

Multi-Criteria Index Structure for a Dynamic Product Placement Algorithm with a Relocation Function Optimized by Swarm Intelligence in Automated Warehouses

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This article discusses the optimization of product placement in automated storage systems with dynamic relocation. A model for selecting and quantifying key performance indicators that directly impact order fulfillment time, which is the most important economic factor in warehouse operations, has been proposed. These indicators have been selected based on their availability in real warehouse systems, which is intended to facilitate the implementation of the system. In the multicriteria decision model, we integrated the static indicators, annual and seasonal demand levels and product weights. We modeled the operational constraints associated with the pickup and return of individual storage containers. The main focus of this article is to formulate operational factors in the form of a set of measurable indicators, which are intended to serve as a fitness function for nature-inspired swarm intelligence algorithms, such as Particle Swarm Optimization and Ant Colony Optimization. The article presents the theoretical foundations and mathematical formulations of the proposed indicators, as well as a simulation-based analysis demonstrating their influence on order completion efficiency.

Preliminary Evaluation of Background Inpainting Quality in the Context of Visual Slam Accuracy

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This work presents a preliminary experiment in which dynamic objects are removed from an image sequence to assess their impact on algorithms estimating a mobile agent's ego-motion from camera data (visual odometry, VO). The study is restricted to a baseline stereo visual-odometry approach based on point features and local descriptors (SIFT/ORB). Dynamic objects are identified via instance segmentation (YOLO11-seg), then removed and the background is reconstructed using image inpainting (LaMa). Ego-motion estimation performance is evaluated by comparing the resulting trajectories against the reference trajectory provided with the dataset, using the evo toolkit and the Absolute Trajectory Error (ATE) metric. In addition, the relationship between ATE and selected image quality assessment (IQA) metrics is investigated to preliminarily assess whether inpainting quality correlates with trajectory accuracy.

XGBoost Regression Model for Remaining Useful Life Prediction - Case Study of Turbofan Engines

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This paper focuses on the prediction of Remaining Useful Life (RUL) for turbofan engines in the context of Predictive Maintenance (PdM) in Industry 4.0. The study is based on the NASA C-MAPSS dataset and focuses on the development of a predictive stage, including data preprocessing, feature engineering, normalisation, and sensor selection. An XGBoost regression model was evaluated on four benchmark subsets of increasing operational complexity. The obtained results show that prediction accuracy strongly depends on operating conditions, with RMSE values ranging from 20.97 to 29.64 cycles. The analysis indicates that operational variability has a greater impact on model performance than the number of fault modes alone. Additional investigation of sensor degradation trends, data distributions, and outliers provided insight into the factors affecting prediction quality. The results confirm that carefully designed machine learning pipelines can effectively support condition monitoring and maintenance planning in complex engineering systems.

Day: **Thursday, August 20th, 2026**

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

Room: **Marco Polo**

Chair: **Adam Krzyżak**

Paper: **3073** **C3L-A**

A Cross-Domain Deep Learning Prediction System for Ki-67 Proliferative Status in Breast Cancer via Domain-Invariant Feature Fusion

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Ki-67 proliferative status is a clinically significant prognostic biomarker in breast cancer, frequently used to guide decisions regarding adjuvant chemotherapy. Assessment is currently performed via immunohistochemical analysis of biopsy specimens, a procedure poorly suited to longitudinal monitoring. Non-invasive estimation from full-field digital mammography is proposed as a compelling alternative, yet is hindered by systematic domain shift introduced by vendor-specific post-processing pipelines. The patient-level framework integrates shape-constrained radiomic features with attention-pooled multi-view deep representations from an EfficientNet-B0 backbone augmented with MixStyle and Variance Risk Extrapolation. These are aggregated across four mammographic views via gated attention pooling. The framework is evaluated under a leave-one-domain-out protocol across three scanner manufacturers on 2,410 patients. It is evident that feature fusion achieves an Area Under the Curve of 0.976 on the Hologic held-out set, 0.776 on the Siemens set, and 0.576 on the GE set. Feature design is identified as the primary factor in determining cross-vendor generalisation.

Weakly Supervised Detection of Satellite Streak Signatures in SST Imagery Using Multiple Instance Learning

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The number of objects launched into space increases significantly every year. In combination with vast amounts of data produced by imaging instruments each day, the need for automated processing remains one of urgent tasks at hand. Manual annotation process, despite being time-consuming, is still common. This study proposes the application of multiple instance learning, coupled with domain-specific preprocessing, as a weakly supervised classification pipeline to support and accelerate the manual annotation process in SST imagery analysis. Two feature extraction backbones are evaluated: a pretrained ResNet-18 and a custom convolutional masked autoencoder. Three aggregation methods are compared: max pooling operator as a baseline, attention-based pooling, and CLAM, which involves an additional instance-level classification branch. Heatmap-based interpretability analysis is also conducted to provide insight into the decision-making process. The results show that the proposed MIL-based pipeline, supported by interpretability methods, effectively addresses key challenges in automated SST image processing, including weak supervision and limited annotated images availability.

Expert Advisor System for QoS-Aware Energy Management of Outdoor Underground Heating Systems

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Outdoor underground heating systems typically rely on linear controllers and manual overrides, leading to excessive energy use. This paper presents an online Expert Advisor system providing QoS-aware decision support for underground heating operations. The system integrates live weather forecasts, dynamic electricity pricing, and facility usage data with a dynamic internal thermal model. An EKF-LQG control strategy estimates temperature evolution and computes optimal heating recommendations that minimize energy costs while satisfying operational constraints. The unified decision-support interface renders the energy-quality trade-off explicit for non-specialist operators. Evaluated at Veritas Stadion in Turku, Finland, retrospective analysis demonstrates a 35% reduction potential in heating energy consumption over one full heating season. The work establishes a reproducible pathway toward human-in-the-loop optimization for large-scale hydronic heating infrastructures.

Quantum-Enhanced Fine-Grained Hematologic Cell Classification: A Hybrid ResNet18 Architecture with Adjoint-Differentiable Variational Quantum Heads

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we use a hybrid classical–quantum architec- ture comprising a pretrained ResNet18 convolutional backbone with a PennyLane adjoint-differentiable variational quantum head for fine (16-class) classification of hematologic cells. We begin by benchmarking several classical deep learning archi- tectures to obtain a competitive backbone, including VGG19, InceptionV3, EfficientNetB0, DenseNet121, and YOLO26-cls. We then attach a quantum head consisting of angle embedding, strongly entangled variational layers, and joint Z/ZZ expec- tation measurements to the chosen ResNet18 model, followed by a classical classifier. Experimental results showcase that the classical ResNet18 achieves 79% test accuracy with macro-F1 and weighted-F1 scores of 0.77 each, while the hybrid ResNet18 + PennyLane model improves performance to 85% test accuracy with macro-F1 and weighted-F1 scores of 0.83.

Day: **Thursday, August 20th, 2026**

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

Room: **Vasco da Gama**

Chair: **Witold Respondek**

Paper: **3063** **C3L-B**

Robust, Nonlinear Motion Control Under Piecewise-Defined Tracking Error Constraints

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A position and velocity tracking problem is addressed. The control objective is defined by piecewise exponential constraints imposed on the position tracking error. This error is controlled indirectly through the so called extended tracking error, which is a linear combination of position and velocity with time varying coefficients. The use of time varying design parameters and independently specified constraints for successive control stages provides additional flexibility in designing a simple and robust motion controller with bounded control action. The proposed approach is demonstrated by controlling a modified, chaotic Van der Pol oscillator.

Paper: **3094** **C3L-B**

Extremum Seeking Control of a Unicycle-Like Robot Using the Transverse Function Approach

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This paper addresses the problem of extremum seeking control for a planar mobile robot of unicycle type subject to nonholonomic constraints. The proposed approach is based on the transverse function framework, which enables the transformation of the nonholonomic system into a form suitable for control design. To ensure persistent excitation, an excitation component is injected directly into the transverse function, allowing for effective exploration of the objective function. The gradient information required for extremum seeking is obtained through a local parametric approximation computed over a sliding time window. The resulting control scheme enables the robot to converge toward the extremum of an unknown spatial field while respecting the system's kinematic constraints. Simulation results are provided to demonstrate the effectiveness of the proposed method.

Design of Iterative Learning Control Schemes Based on Model-Free Feedback Linearization for a Plant with Unknown Dynamics

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This paper presents a new iterative learning control (ILC) scheme for affine nonlinear systems of repetitive nature with unknown dynamics, combining model-free feedback linearization with a two-dimensional (2D) system framework. The method eliminates the need for prior model knowledge by employing model reference adaptive control (MRAC) together with Q-learning to achieve feedback linearization. After linearization, the control law is formulated within the 2D system setting, enabling the integrated design of both feedback and learning controllers to ensure stability and tracking error convergence. Numerical experiments on a thermoplastic injection molding process validate the effectiveness of the proposed approach, demonstrating accurate trajectory tracking across trials.

On LTI System Identification by CFD Solution Data

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A key bottleneck in modern engineering design is that the 3D design workflows, even those including high-fidelity physics simulations, seldom directly yield a dynamical plant model which supports controller synthesis. In this article, we describe an automated workflow for identifying Linear Time-Invariant (LTI) Reduced-Order Models (ROM) from high-fidelity 3D Computational Fluid Dynamics (CFD) simulation data, for advection-diffusion systems in complex domains. The LTI plant thus obtained can be directly used in controller synthesis. We study the RMSE accuracy of the approach as a function of training data size and ROM degree in two practical applications for which no analytical solution exists. The proposed methodology is based on statistical Design-of-Experiments (DOE) and the Dynamic Mode Decomposition with Control (DMDc) due to Proctor et al.

Day: **Thursday, August 20th, 2026**

Time: **15:00 - 16:20**

Room: **Marco Polo**

Chair: **Przemysław Herman**

Paper: **3046** **C4L-A**

Online Repulsion Scaling in Artificial Potential Fields via Gradient Matching at a Safety-Offset Point

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In this paper, a novel modification of the local path planner, the Artificial Potential Field algorithm, is proposed. The aim of the modification is to ensure that the required distance to the obstacle is not violated regardless of the gradient vectors orientation. Therefore, adaptation of the scaling factor of the repulsive potential is introduced. It is based on the calculation of the position of the safety-offset point and the matching of the gradients to achieve the required direction of the mobile robot motion. The proposed Gradient Matching Artificial Potential Field algorithm has been verified using \textsc{Matlab} software to generate a thousand random environments, and experimentally using a real mobile robot, Husarion ROSbot 2.0 PRO.

Paper: **3019** **C4L-A**

Visible Spectrum Fluorescence for Reliable Oil and Water Discrimination

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Liquid spills are common in industrial environments and pose significant safety and environmental hazards. Whereas large-scale oil spills are typically detected with satellite and airborne imagery, we consider local water and oil spills that can possibly be detected by autonomous mobile robots, for example, floor cleaning robots or AGVs. Numerous studies have utilized hyperspectral imaging for water and oil detection, but its high cost and complexity limit its use in robotic applications. Therefore, in this work, a novel method based on structured light projection is proposed. The method utilizes the fact that a visible-spectrum laser line projector interacts with oil, triggering fluorescence that can be captured by an RGB camera. The resulting image is then processed to extract features such as color and brightness distribution. The method's performance is evaluated on various surfaces without prior knowledge of their reflectance or other visual properties. The

implementation of the proposed method resulted in high classification accuracy (99.87%) and interpretability using a threshold-based classifier.

Paper: **3070** **C4L-A**

PostureAware: A Novel AI System for Pain Assessment Among Textile Workers

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This paper presents PostureAware, an innovative machine learning-based system that uses a wearable device, integrating Inertial Measurement Units (IMUs) and a Flex sensor to predict the intensity, location, and frequency of mechanical back pain among textile workers. This study reports findings based on 36,821 sensor readings collected from sixty-four textile workers during their regular working shifts. This research developed three distinct AI models to predict the pain metrics. The primary finding is that the SensorNet+ model has achieved remarkable performance by using only sensor data, with 98.46\% accuracy for pain frequency, 98.39\% accuracy for pain location, and a Mean Absolute Error (MAE) of 0.0795 for pain intensity. The key significance of this result is that the SensorNet+ model performed similarly to the FusionNet model that uses demographic and medical data. Therefore, an accurate pain assessment is achievable using only kinematic data, which is a practical and less intrusive tool for proactive occupational health monitoring and the prevention of back pain.

Paper: **3105** **C4L-A**

Off-Track Reduction for Non-Standard N-Trailers Along Backward-Followed Paths

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Motion of the long articulated vehicles is characterized by substantial off-tracking when following along a curved roads. An appropriate motion control strategy enables, however, reducing the off-track of the vehicle's units. We proposed such a control strategy for the task of backward path-following with the kinematics of non-Standard-N-Trailers (nSNT) equipped with an arbitrary number of trailers. The concept utilizes a cascade-like, highly scalable, control system developed in the literature for the N-trailers, while the outer-loop control function builds upon a positional feedback-linearization control law devoted to the unicycle model in a version specialized to the

path-following task. By an appropriate location of a guidance point of the last trailer, we show that one can reduce the maximal off-tracking distance of all the N-trailer's units when reversing along the reference paths of a varying curvature. Numerical simulations illustrate the influence of the guidance point location on the maximal off-track reduction in the case of nS3T kinematics.

Day: **Thursday, August 20th, 2026**

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

Room: **Vasco da Gama**

Chair: **Edyta Kucharska**

Paper: **3003** **C4L-B**

Closed-Form Design of High-Type Control Systems

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This paper presents a novel method for closed-form design of high-type feedback systems without the typical complications of traditional loop-shaping approach. Commonly, increasing system type improves disturbance rejection and reference tracking performance. However, this often requires complex compensator tuning to counteract the phase lag introduced by added integrators. This work bypasses that issue by directly embedding Tracking Error Reduction Algorithm (TERA) properties into the controller itself, rather than relying on a prefilter. The proposed approach constructs an inner controller equivalent to a higher order prefilter TERA, enabling superior performance in both reference tracking and disturbance rejection. This is particularly valuable in scenarios where a prefilter is inapplicable, such as those relying solely on tracking error measurements. The result is a significant increase in effective system type alongside provided stability robustness, offering a practical alternative to conventional control design approaches.

Paper: **3053** **C4L-B**

Disturbance-Reducing Inversion-Based Control for Heteropolar Active Magnetic Bearings with an Experimental Validation

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This paper presents an experimental validation of a disturbance-reducing inversion-based control approach for active magnetic bearings. Two voltage-controlled active magnetic bearing units are used to evaluate the designed controller. These units, however, are subject to a sinusoidal disturbance, caused by an unbalance of the rotor. Given the knowledge of the disturbance and its time-derivative using a Kalman filter (KF), a disturbance reducing control law is derived and implemented that counteracts the impact of the disturbance. Here, both the inverse dynamics as well as the state transformations, which are affected by the disturbance, need to be addressed

properly. The linear feedback stabilizes the equilibrium point despite periodic disturbances. Simulations as well as experimental results for the time responses due to initial position errors are presented and compared to each other. They clearly point out the benefits of the proposed solution, which manages to suppress large harmonic disturbance forces.

Paper: **3075** **C4L-B**

Nonlinear Model Predictive Control for Fast Charging of Vanadium Redox Flow Batteries

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This paper proposes a nonlinear model predictive control (NMPC) strategy for fast charging of a vanadium redox flow battery (VRFB). The method combines NMPC with a fast integral controller to track the reference stack voltage. To improve model accuracy, an online recursive least-squares (RLS) algorithm estimates the effective internal resistance, compensating for modeling errors and neglected concentration overpotential effects. Numerical results show that incorporating resistance estimation reduces charging time by approximately 23% compared to a standard NMPC approach without estimation.

TECHNICAL PROGRAM

Friday

August 21st, 2026

Day: **Friday, August 21st, 2026**
Time: **9:00 – 10:00**
Room: **Marco Polo**

Plenary 4, C5L-A

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Chair: **Józef Korbicz**

Author: **Paweł Strumiłło (Lodz University of Technology , Poland)**
Paper: **Electronic Personal Navigation Systems for Blind People**

Day: **Friday, August 21st, 2026**

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

Room: **Marco Polo**

Chair: **Bartłomiej Sulikowski**

Paper: **3079** **D0L-A**

Schedule-Based Urban Accessibility Relative to a Railway Node Using GTFS, OpenStreetMap, and Triangulated Travel-Time Isochrones

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This paper presents a workflow for schedule-based analysis of urban public transport accessibility relative to a railway node using only open data. The method integrates GTFS schedules, a walking network derived from OpenStreetMap, and a lightweight earliest-arrival scan over temporally ordered stop-to-stop connections. Spatial results are transferred from stop level to city space through walking-network intersections and visualized as georeferenced point maps and triangulated travel-time isolines. The workflow is demonstrated for Lodz, Poland, using Łódź Kaliska as the origin node and six departure times. The experiment used 10 131 active trips, 270 885 timetable connections and 92 964 destination intersections. More than 90,000 intersections were reachable in every tested time slice, which indicates broad but temporally differentiated coverage of the city. The resulting maps reveal a stable inner accessibility core around the railway node and increasing travel times toward the urban periphery, with a modest contraction of reachability in the late evening.

Paper: **3080** **D0L-A**

The Parallel Machine Scheduling Problem to Minimize the Makespan Under Deteriorating Effects with Maintenance and Travel Times

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In this paper, we present our preliminary results concerning the identical parallel machine scheduling problem to minimize the makespan, where jobs are spatially distributed and machine deterioration affects their processing times and travel times between locations. We include a service depot where full maintenance activities can be performed to restore machine condition. Due to the NP-hardness of the problem, we propose two algorithms based on simulated annealing. The first variant using a redundant schedule representation focuses solely on minimizing the makespan while also traversing through infeasible regions of the solution space. The second approach generates intermediate schedules without maintenance, and uses a dedicated decoding mechanism

converting them into feasible solutions, but it may overlook promising regions that contain the optimal solution. Their efficiency is evaluated during computational experiments.

Paper: **3108** **D0L-A**

BOinEA: A Unified Hybrid Approach Integrating Bayesian Optimization and Evolutionary Algorithms for Neural Network Hyperparameter Tuning

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Hyperparameter optimization (HPO) is a crucial yet computationally demanding task in modern neural network design, especially as model architectures and search spaces become more complex. Classical methods such as grid and random search are often inefficient in high-dimensional settings, while Bayesian optimization (BO) and evolutionary algorithms (EAs) offer complementary strengths but still face limitations in scalability, convergence, and exploration–exploitation balance. To address these challenges, we propose BOinEA, a novel hybrid HPO method that integrates BO-based surrogate modeling with the population-based search dynamics of EAs. Unlike existing hybrid approaches based on sequential switching or loosely coupled components, BOinEA maintains continuous coordination between global exploration and local exploitation. Evaluations on CIFAR-10, Fashion-MNIST, and NSL-KDD show that BOinEA achieves competitive or superior performance, with improved sample efficiency and faster convergence, particularly in high-dimensional spaces. These results indicate that BOinEA is a robust and scalable framework for neural network HPO.

Day: **Friday, August 21st, 2026**

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

Room: **Vasco da Gama**

Chair: **Krzysztof Okarma**

Paper: **3027** **D0L-B**

Automation Problems in Terahertz Image Processing

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The paper addresses typical problems thwarting the automation of processing of THz images such as low spatial resolution and small image size, intensive noise with possible presence of impulse component, extensive blurring with complicated blur kernel characteristics, and interference brightness changes with a priori unknown characteristics of the degrading signal. Some real-life examples illustrating the mentioned phenomena are shown and state-of-the-art in the corresponding image quality enhancement areas is considered marking possible ways to solving the raised problems.

Paper: **3064** **D0L-B**

A Benchmark Study of Input Design for Multiclass Broken Rotor Bar Diagnosis with a Fixed Convolutional Neural Network

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This paper presents a controlled benchmark of input design for multiclass broken rotor bar diagnosis with a fixed convolutional neural network. The aim is to identify which properties of the input representation most affect performance when the classifier architecture remains unchanged. The study uses an experimental database from a three-phase induction motor with five rotor conditions, eight load levels, and ten repetitions per condition. After preprocessing, the benchmark contains 400 synchronized multimodal samples built from three-phase currents, three-phase voltages, and three selected vibration channels. The protocol compares 44 predefined input

configurations, including single-family, pairwise-family, and three-family representations, each evaluated at four extracted vector lengths, giving 176 classification experiments. All inputs are converted to a common image-like tensor and assessed with the same CNN using accuracy and macro-F1. The results show that performance depends mainly on the information content of the signal family rather than on simply enlarging the input. Vibration-based inputs perform best, while longer vectors are often neutral or harmful.

Paper: **3030** **D0L-B**

Implementation of Multiple Objects Tracking Algorithm with Kalman Filters and JPDA Based on Three-Coordinate Radar Output for Highly-Dynamic Objects

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Tracking multiple maneuvering objects using radar measurements is a challenging problem due to measurement noise, false detections and missed observations. This paper presents an implementation and experimental evaluation of a multi-object tracking framework based on the Joint Probabilistic Data Association (JPDA) algorithm combined with an Interacting Multiple Model (IMM) estimator and Kalman filtering. The proposed system processes three-coordinate radar detections and performs probabilistic association of measurements with existing tracks while accounting for different motion dynamics of tracked objects. The algorithm was evaluated using both simulated trajectories and real radar measurements acquired during drone flight experiments. The obtained results demonstrate that the JPDA–IMM framework is capable of identifying object trajectories within dense radar measurement clouds and maintaining track continuity in the presence of measurement noise, trajectory crossings and temporary detection losses. The study confirms that the presented approach can be effectively applied in practical radar-based multi-object tracking systems operating in real measurement environments.

Day: **Friday, August 21st, 2026**

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Chair: **Wojciech Hunek**

Paper: **3001** **D1L-A**

Simulation Test of a Tracking Controller Using Evolution Algorithms for Planar Manipulator with Passive Last Joint

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—This paper presents a simulation test of a well- known trajectory tracking scheme for a three-degree-of-freedom (3 DOF) manipulator with a passive end link moving in the horizontal plane. The control strategy from the original work, adopted for simulation tests, consists of two evolutionary algo- rithms: trajectory planning and parameter optimization. The trajectory tracking task is implemented using sliding mode control (SMC). This paper investigates whether such a solution to the trajectory tracking problem can actually be effective, i.e., achieve acceptable target point accuracy. To this end, a specific procedure is proposed and then numerically verified. The results obtained are analyzed, and issues regarding the feasibility of this control strategy are discussed.

Paper: **3002** **D1L-A**

Numerical Analysis of an Initialized, Variable Parameters, Fractional Order Dynamic System Estimated by the FOBD Approximation

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In the paper the numerical analysis of the free,initialized, scalar, variable fractional order, time-varying dynamic system is presented. The initial condition for the fractional system approximated with the use of FOBD approximation can be given as a function, defined many steps before the initial one. The various initial functions as well as various orders and quasi time constants were examined. Results of simulations show that the decay of a free trajectory is determined by the shape of the initial function.

Model Predictive Control for MIMO Systems Integrated with Active Disturbance Rejection

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This paper presents a proposal for a novel predictive control scheme for uncertain and disturbed multi-input, multioutput (MIMO) systems. The proposed method is a fusion of a well-known and effective linear Model Predictive Control (MPC) and a modern concept, Active Disturbance Rejection Control (ADRC). The approach is to introduce a fictitious state that includes all possible uncertainties and disturbances originating from the plant that are unknown and not accounted for in the plant model and its estimation in real-time using an Extended State Observer (ESO). The estimated state is then used to generate control supporting the MPC controller with simplified model of the plant. This leads to an easily designed, robust predictive control structure like the well-known tubebased method. It seems that the proposed control approach has potentially great advantages, is simple to implement, and is easy to tune. Due to this, it can be used in many control systems of difficult and inaccurately identified objects.

Disturbance-Aware Signal Reconstruction for Autonomous Sodium and pH-Sensing Systems

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High-impedance ion-selective electrodes are susceptible to electromagnetic interference (EMI), degrading potentiometric sodium and pH monitoring. This study presents a disturbance-aware reconstruction pipeline for dual-channel 1 kHz recordings. A windowed sinusoidal regression subtracted 60 Hz interference using 0.5 s windows. Disturbances were detected per channel using robust scores and mask dilation; masked samples were replaced via interpolated quiet-state baselines from LOWESS. Events masking up to 33% of the record were reconstructed without altering the time axis. Results included a drift-preserving trace and a drift-removed trace anchored to a reference level. Six smoothing kernels and a zero-phase second-order sections (SOS) Butterworth low-pass filter (LPF) were benchmarked. The SOS-LPF outperformed alternatives in 22 of 24 test cases. Under optimal quiet segments, robust variability decreased by approximately 50 times after processing. Power spectral density values near -200 dB reflected a numerical reporting floor set by the safeguard.

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Chair: **Ewa Pawłuszewicz**

Paper: **3044** **D1L-B**

Low Cost & Memory-Safe Control BLE Implementation for Swarm Robots

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Building a large robotic swarm is a challenge from both a financial and communication perspective. Single-board computers, commonly used in mobile robotics, often proved to be too expensive, too heavy and too complex in the sowtware aspect. Using POSIX operating systems on multi-core proces- sors is convenient and fast to develop, but it's definitely not optimal approach for mass production. Additionally the power consumption of a single robot and it's energy balance is often far from expectted goal. In this article, we present our solution to this problem: a lightweight, open-source control framework implemented in Rust, utilizing Bluetooth Low Energy (BLE) technology for energy-efficient communication. By leveraging the ownership model and Rust's type system, memory safety is guaranteed at the compile stage, without the overhead of using a garbage collector or a full operating system.

Paper: **3111** **D1L-B**

Spatial Feedback Linearization for Tractor-Trailer Systems Using Active Disturbance Rejection for Bidirectional Path Tracking

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The autonomous tracking and reversing of tractor-trailer systems present severe control challenges due to nonlinear kinematics, nonholonomic constraints, and the inherent instability and the risk of jackknifing during backward motion. This paper proposes a robust spatial feedback linearization controller augmented with Active Disturbance Rejection Control (ADRC) framework. By parameterizing the system with respect to the tractor's displacement rather than time, the formulation yields a well-behaved spatial coupling. A third-order spatial Disturbance Observer (DOB) is designed to estimate and cancel translational and rotational disturbances, ensuring precise

tracking of a virtual output point. Simulation results are presented with a single-trailer vehicle with on-axle hitching to illustrate the effectiveness of the proposed method.

Paper: **3121** **D1L-B**

A Set-Based Predictive Control Procedure Under Consideration of Functional and Extra-Functional Constraints

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The control of interconnected systems is subject to numerous constraints concerning functionality, safety, and the actuation of the interacting components. In addition, modern interconnected systems also heavily rely on the exchange of information between the individual interacting components. Communication of measurements is, on the one hand, necessary to achieve the desired control goals. On the other hand, it also requires a non-negligible amount of energy, especially in scenarios with severe bandwidth limitations such as mobile or underwater robotics. Therefore, this paper proposes the formulation of a model-predictive control framework in which not only the functional properties of a distributed system are controlled but also the communication properties are dynamically adjusted so that a reasonable compromise between control accuracy and energy demand can be found. For that purpose, the concept of approximate communication is introduced, which allows for dynamically adjusting the resolution of the communicated data. A set-based error model then allows for handling the dynamically changing precision of the communicated quantities in a reliable manner.

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.