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Preface to the Issue on Recent Developments in AI-Based Robotics: A Polish Perspective

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This volume of the *Foundations of Computing and Decision Sciences* (FCDS) is devoted to recent advances in AI-driven robotic systems, with a focus on contributions from the Polish research community. The papers collected here originate from the Robotics and Autonomous Systems (RAS) Track of the **5th Polish Conference on Artificial Intelligence (PP-RAI 2024)**, which took place from the 18th to 20th of April 2024 in Warsaw, Poland. The conference was organised by Warsaw University of Technology, in cooperation with the Polish Alliance for the Development of Artificial Intelligence (PP-RAI).

The RAS Track featured 24 accepted papers, making it one of the largest thematic tracks at the event. The presented works covered a wide spectrum of topics in AI-based robotics and autonomy, including robotic perception, motion planning, human-robot interaction, embedded optimisation, autonomous exploration, and the application of large language models in robotic systems. The strong representation of learning-based methods and optimisation-driven solutions across these papers reflects a growing trend in Polish robotics research towards integrating artificial intelligence techniques to handle complexity and uncertainty in real-world deployment of autonomous systems.

This trend follows global developments in robotics, where combining deep learning, transfer learning, reinforcement learning, and foundation models has created new opportunities, but also introduced specific challenges. Deep learning in robotics faces challenges related to working with physical systems, ensuring safety, and adapting to new situations—issues that are less common in general AI. This often requires combining learning from data with knowledge-based methods [5]. Transfer learning has emerged as a promising framework for enabling adaptability across tasks and environments, however, it brings its own demands for measuring transfer quality and mitigating negative effects [2]. Reinforcement learning, especially in its deep form, has shown strong results in training robotic behaviours, but still struggles with data

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efficiency, long-term planning, and reliable performance in the real world [6]. A growing area of interest is the use of large pretrained foundation models, which show promising generalisation capabilities and may enhance robot perception, reasoning, and control [1]. The contributions in this special issue reflect some of these themes, showing how Polish researchers are engaging with these emerging approaches while addressing practical requirements in robotic systems. The collected papers explore sim-to-real generalisation, the combination of synthetic and real data, or lightweight learning-based control in safety-critical contexts—demonstrating how foundational AI methods are being adapted and applied to robotics by the Polish research community in both principled and pragmatic ways.

Although robotics is not among the core thematic pillars of FCDS, the journal has, in the past, accommodated high-quality research in this domain, not only through the 2017 special issue on 3-D visual perception in robotics [4], but also via selected individual contributions in the years that followed. This reflects the journal's continuing openness to contributions grounded in computing and decision sciences that address challenges arising in robotics and related areas. Moreover, broader reflections on the state and development of the Polish AI research community have also been published in FCDS, most notably in the 2020 editorial paper by Nalepa and Stefanowski [3], which highlighted the foundations of the Polish Alliance for the Development of Artificial Intelligence and the role of joint national conferences. The current issue builds upon that tradition, emphasising interdisciplinary links between artificial intelligence, optimisation, machine learning, and robotics, that increasingly intersect in modern autonomous systems.

All papers included in this issue underwent the standard FCDS rigorous peer-review process. In relation to their conference versions, they are the outcome of substantial revision and extension, with authors incorporating new results, additional experimentation, and in many cases, broader contextualisation of their approaches within the state of the art.

This special issue comprises five contributions that together illustrate important contemporary trends in AI-based robotics in Poland. Among these, the growing emphasis on optimisation techniques and data-efficient learning, as well as the integration of advanced machine learning models into core robotic capabilities, are particularly noteworthy.

The issue begins with *"Genetic Algorithm Approach to a Concurrent Real-Time Optimization Problem in the Embedded System Design Process"* by Adam M. Górski and Maciej Ogorzałek. This contribution addresses the challenge of concurrent real-time optimisation in embedded robotic platforms. The authors propose a genetic algorithm that manages interdependent decision phases in real-time, optimising and validating system parameters dynamically. This work exemplifies the expanding role of evolutionary algorithms in autonomous robotics, particularly under uncertain and changing operating conditions.

Continuing the theme of optimisation in constrained robotic environments, Wojciech Burzyński and Mariusz Kaleta, in their paper *"A Mixed Integer Programming Approach to the Rechargeable Rover Routing Problem on Mars"*, introduce a novel formulation of the vehicle routing problem tailored for planetary exploration by

energy-constrained autonomous rovers. By leveraging mixed-integer linear programming techniques, the authors offer a framework suitable for small-scale planetary missions, while also outlining directions for future heuristic solutions in large-scale multi-rover deployments.

From offline planning and design optimisation, the focus shifts toward the operational intelligence of robotic systems, particularly those driven by machine learning. Bartłomiej Kulecki and Dominik Belter, in their work *"Improving Machine Learning-Based Robot Self-Collision Checking with Input Positional Encoding"*, propose enhancements to lightweight neural network models, specifically multilayer perceptrons (MLPs), for self-collision detection. The neural network is trained to classify robot configurations as either safe or in collision, and the incorporation of positional encoding helps it capture fine-grained spatial patterns. This significantly improves the accuracy and efficiency of MLPs, demonstrating how learning-based methods can replace traditional geometry-based techniques in real-time motion safety tasks.

Machine learning also plays a key role in *"Overlapping Box Suppression and Merging Algorithms for Window-Based Object Detection"* by Aleksandra Kos. The author introduces two algorithms: Overlapping Box Suppression and Overlapping Box Merging, to improve object detection by addressing the fragmentation of detection windows. These techniques are particularly effective for small and partially occluded objects, and their evaluation on the SeaDronesSee dataset demonstrates their superiority over standard non-maximum suppression. This contribution underscores the continuing refinement of perception systems through task-specific AI components.

The final paper takes aim at one of the bottlenecks in AI model development for robotics: training data. In *"Annotation-free Generation of Training Data Using Mixed Domains for Segmentation of 3D LiDAR Point Clouds"*, Konrad Cop, Bartosz Sułek, and Tomasz Trzciński propose a pipeline that automatically generates rich training datasets by combining real-world LiDAR scans with synthetically placed navigation-relevant obstacles. Their approach eliminates the need for manual annotation and is validated in an underground parking scenario. Notably, the method performs well even in comparison to annotated datasets and demonstrates that synthetic data generation can be a practical alternative in robotic perception tasks.

These five papers reflect key tendencies in contemporary Polish robotics research: the increasing use of AI and machine learning to enhance traditional robotics functions, the pursuit of optimisation under real-world constraints, and the development of data-efficient techniques suitable for deployment in both structured and unstructured environments. Collectively, they demonstrate not only technical excellence but also a strategic alignment with the broader goals of autonomy, robustness, and adaptability in robotic systems.

We extend our sincere gratitude to the reviewers, whose expert insights have strengthened the quality and clarity of the contributions. We also thank the organisers of PP-RAI 2024 for creating a research forum that supports such high-quality work, and the editorial team of FCDS for once again welcoming robotics-related research into its pages.

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