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Gabor Kusper, Sorin Stratulat

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AiRobo: A EU Project on Artificial Intelligence and Robotics for Higher Education

Isabela Dramnesc
Computer Science Department,
West University of Timisoara, Romania
isabela.dramnesc@e-uvt.ro

Erika Abraham
Computer Science Department,
RWTH Aachen University, Germany
abraham@cs.rwth-aachen.de

Nikolaos Fachantidis
LIREs,
University of Macedonia, Thessaloniki, Greece
nfachantidis@uom.edu.gr

Tudor Jebelean
ICAM
West University of Timisoara, Romania
tudor.jebelean@e-uvt.ro

Gabor Kusper
Computer Science Department,
Eszterhazy Karoly Catholic University, Eger, Hungary
kusper.gabor@uni-eszterhazy.hu

Sorin Stratulat
Université de Lorraine
CNRS, LORIA, F-57000 Metz, France
sorin.stratulat@univ-lorraine.fr

Abstract: The project Artificial Intelligence based Robotics (AiRobo 2023-2026) is a partnership of universities from Romania, Greece, Germany, Hungary, and France, with the aim of enhancing both the quality and appeal of partner universities' departments by significantly elevating the expertise and skills of academic staff in Artificial Intelligence (AI) and Robotics. Furthermore, it addresses the European priority of promoting inclusion in higher education—supporting social inclusion and improving outreach to individuals with fewer opportunities, including those with disabilities or migrant backgrounds. Within the project four trainings were organised for the partners' academic staff on AI, Robotics and effective teaching methodologies. The partners will collaboratively develop a comprehensive book on AI, robotics and AI-based robotic applications, and scientific publications. These materials are intended to serve for both academic staff and students as engaging teaching materials on these related subjects, and provide practical applications for theoretical courses that students often find challenging to understand. For disseminating the results, the partners will organise an international summer school for students and an international conference for people outside the partnership (academic staff, researchers, and industry professionals).

1. Introduction

This paper presents the ongoing project Artificial Intelligence based Robotics (AiRobo 2023-2026), an innovative project for higher education that intersects three important domains: robotics, artificial intelligence, and formal verification. The primary motivation for this project is that higher education in Computer Science must continually adapt to rapidly evolving technologies. Robotics and Artificial Intelligence are rapidly expanding fields that are vital to both research and industry, with a significant future impact on the labor market. By integrating AI,

robotic systems become more efficient across diverse sectors—such as education, agriculture, healthcare, and manufacturing—transforming automation through advanced capabilities. AI-driven robots can execute complex tasks with precision, adapt to changing conditions, and learn from experience. In education, they have the potential to redefine teaching and learning, boosting academic performance and preparing students for future careers. However, the powerful capabilities of AI robotics also carry substantial risks. Flaws in robot design can lead to severe outcomes, including fatalities when direct human interaction is involved. Consequently, formal verification methods are essential to ensure correct design and safeguard human safety.

Our target groups are: *academic staff* (teachers of courses in robotics, teachers of topics that have applications in robotics, researchers in the field of robotics, AI and formal methods, researchers in fields that have applications in robotics) and higher education *students of all levels* (Bachelor, Master, PhD).

The purpose of this presentation is to introduce this project to the scientific community and foster interaction and international cooperation. The project outputs will be publicly shared on the project's homepage (AiRobo 2023-2026) as soon as they are finalised. For disseminating the final results of the project, the partners will organize an international summer school for higher education students of all levels and an international conference worldwide open to academic staff, researchers, and industrial professionals.

The project's main objective is to enhance both the quality and appeal of the partners' university departments by substantially increasing the expertise of academic staff in AI, robotics and formal verification. Furthermore, it aims to foster inclusivity for students with disabilities and those with migrant backgrounds by ensuring accessibility, promoting diversity, equipping learners with valuable technical skills, boosting confidence and self-esteem, and emphasizing ethical considerations in the development and use of these technologies. For specialisation of academic teachers in the field of robotics (in particular based on Artificial Intelligence, Robotics and Formal Methods), the partners organised four trainings for academic staff and trainings after trainings. Within the project implementation period, the partners will jointly develop: a book as a comprehensive teaching material for the three related subjects, tools and video tutorials; seven AI-based robotic applications, including design and simulation, testing and verification, and practical experiments with applications in different domains, like education (including students with disabilities and migrant background), agriculture, industry, and health; as well as joint scientific papers for international conferences.

2. The Outcomes of the AiRobo project

One of the most significant achievements of the project is the development of the comprehensive resource package, which includes the book “AiRobo”, a suite of custom-designed educational tools, video tutorials, and practical robotic applications. These materials are co-created through close collaboration between academic staff and researchers from the partner universities, combining expertise from multiple disciplines and institutional contexts. The primary objective of these resources is to provide high-quality, practice-oriented support for teaching and learning in areas such as Artificial Intelligence, Robotics, and Formal Verification. Designed to facilitate both theoretical understanding and hands-on experimentation, the resources are intended to enhance the delivery of both foundational and advanced courses in these fields and to promote active learning approaches. Once finalized, all project outcomes will be made freely available on the official website (AiRobo 2023-2026), enabling academic staff and researchers worldwide to access, utilize, and adapt them for their own teaching objectives, curricula, and research purposes. This open-access approach aims to foster wider dissemination, reuse, and long-term sustainability of the project's contributions to higher education.

3.1. The Book and tools

The book “AiRobo” (approx. 500 pages, in English), is a comprehensive educational resource on Artificial Intelligence, Robotics, and Formal Methods. Guided by the motto “From Zero to Expert,” it targets a broad audience from beginners to professionals. Structured into five progressively advanced chapters, it combines theory, practical examples, and hands-on exercises to build both understanding and skills. It is suitable for undergraduate and postgraduate courses, as well as professional development.

Chapter 1 introduces robotics by providing historical context and foundational technical knowledge. It explores the evolution of robots, their applications, and the multidisciplinary aspects of robotic system design. The chapter highlights robotics' role in STEM education and its impact on industry, from traditional manufacturing to Industry 4.0. Technical topics include manipulation, locomotion, sensors, control systems, actuators, servo motors, and robotic kinematics. To connect theory with practice, hands-on exercises guide readers in assembling and programming a basic robot using Arduino (<https://www.arduino.cc>), sensors, motors, 3D modeling, and printing - reinforcing key concepts and technical skills.

The second chapter focuses on the programming and simulation of robotic systems, providing a thorough overview of the methodologies, tools, and technologies that underpin modern robot development environments. It begins by introducing fundamental principles of robot programming, including both low-level control and high-level behavior design, followed by an exploration of various simulation approaches used to model, test, and optimize robotic behavior in virtual environments before physical implementation. A significant emphasis is placed on the use of digital twins, which are virtual representations of physical robotic systems that enable real-time monitoring, testing, and predictive analysis. The chapter illustrates how digital twin technology can be leveraged for robotic simulation, performance evaluation, and design iteration in a risk-free setting. Additionally, the chapter covers the Robot Operating System (ROS) (<https://www.ros.org>), a widely adopted middleware framework in robotics, detailing how ROS can be utilized for both simulated and real-world robotic applications. Readers are guided through examples of ROS-based simulation workflows, demonstrating how software packages, communication protocols, and sensor integrations are managed in a modular architecture. The chapter also introduces tools for computer vision and image annotation, with particular focus on Computer Vision Annotation Tool (CVAT). It explains the role of annotated datasets in training vision models for robotic applications, and provides guidance on generating and managing training sets for tasks such as object detection, classification, and scene understanding. The chapter concludes with practical tutorials and guided applications that allow learners to apply the covered topics in realistic scenarios, such as simulating robotic perception, programming navigation algorithms, and deploying computer vision models in robotics.

The third chapter is dedicated to exploring the intersection of Artificial Intelligence (AI) and Robotics, with a particular emphasis on how intelligent algorithms enhance the perception, decision-making, and autonomy of robotic systems. It begins with an accessible introduction to core AI concepts, including machine learning, computer vision, reinforcement learning, neural networks, and data-driven decision-making, providing readers with the foundational knowledge necessary to understand how AI technologies are transforming robotics. A central focus of this chapter is the integration of AI into robotic systems, illustrating how intelligent algorithms can be embedded to support tasks such as object recognition, path planning, motion control, and adaptive behavior in dynamic environments. This includes practical guidance on incorporating AI modules into robotic architectures and examples of real-world applications where AI significantly enhances robotic capabilities. This chapter also introduces the use of Unity (<https://unity.com>), a popular game engine and simulation platform for building interactive AI-powered robotic environments. It demonstrates how Unity can be used in combination with AI frameworks to create realistic 3D simulations where robots can learn, interact, and be tested in controlled virtual spaces. In addition to technical topics, the chapter addresses the increasingly important area of ethics in robotics and AI, encouraging critical reflection on issues such as algorithmic bias, transparency, accountability, and the societal impacts of AI-driven robotic systems. Discussions include real-life case studies and guidelines for responsible AI development and deployment in robotic applications. Through this multifaceted approach, the chapter aims to equip readers with both the technical skills and ethical awareness necessary to design and implement AI-driven robotic systems that are not only effective, but also aligned with broader social and human values.

The fourth chapter is dedicated to the formal verification of robotic algorithms, a crucial area for ensuring that intelligent robotic systems behave as intended, especially in safety-critical or real-time environments. It begins with a detailed examination of hybrid systems (Alur et al. 1993), which combine discrete and continuous behaviors - a common characteristic in robotic systems where digital control interacts with physical environments. This section introduces the concept of hybrid automata as a formal modeling framework and discusses key techniques used in the verification of hybrid systems, including general reachability analysis algorithms, flowpipe construction methods, and operations on state set representations. Techniques such as clustering and aggregation are also explored as strategies for managing system complexity during verification. This section presents a range of established benchmark scenarios and tools that support hybrid system verification, enabling readers to apply these methods in both theoretical and practical contexts. The chapter then transitions to the topic of algorithmic certification, with a particular emphasis on the role of sorting algorithms in robotics and artificial intelligence. Sorting is often foundational in robotic decision-making, data organization, and task prioritization. To ensure the correctness of such algorithms, the chapter introduces the Coq proof assistant (Coq 2022), a powerful tool for formal specification and certification. Through detailed examples, it demonstrates how several sorting algorithms can be certified in Coq (Drămnesc et al. 2024c). Readers are guided through the formalization and proof of several sorting algorithms, gaining insight into how formal correctness guarantees can be achieved through interactive theorem proving. In parallel, the chapter explores the Theorema system (Buchberger et al. 2016), (Windsteiger 2014), a system for computer supported mathematical theorem proving and theory exploration. Readers are guided through the process of implementing and verifying sorting algorithms in Theorema, highlighting its strengths in expressing mathematical

properties, generating automated proofs in natural style (similar to human proving), and enabling the development of provers for algorithm synthesis (Drămnesc & Jebelean 2021) and verification (Drămnesc et al. 2024a), (Drămnesc et al. 2024b) for different domains. A dedicated section presents a comparative analysis of the Coq and Theorema systems, evaluating aspects such as usability, expressiveness, proof automation, and suitability for teaching and research purposes. This comparative insight provides valuable guidance for academic staff and researchers seeking to choose appropriate tools for formal methods education and algorithm verification. The chapter concludes with a discussion on algorithmic complexity and running time analysis, offering theoretical and practical tools for evaluating the performance of robotic algorithms under resource constraints. This final section reinforces the importance of balancing correctness with efficiency, both critical in real-time robotic applications.

Chapter five presents real-world applications of robotics across diverse societal and industrial domains, structured into seven dedicated subchapters. Each subchapter focuses on a specific thematic area where robotics plays a transformative role, offering both theoretical insights and practical implementations. The first subchapter addresses robotics in support of individuals with disabilities and special educational needs, showcasing how assistive technologies and adaptive robotic systems can enhance accessibility, autonomy, and learning experiences for students with physical or cognitive challenges. The second subchapter focuses on robotics for vulnerable populations, including foreign-language speakers, refugees, and elderly people. It examines how socially assistive robots and human-robot interaction (HRI) technologies can foster communication, provide companionship, and support the social integration and well-being of marginalized groups. The third subchapter explores the domain of intelligent agricultural robotics, presenting applications where robots are used for precision farming, crop monitoring, harvesting, and sustainable resource management. This section highlights the role of AI and sensor integration in optimizing productivity and minimizing environmental impact. The fourth subchapter discusses the implementation of collaborative robots (cobots) in industrial settings, where humans and robots work side by side. The fifth subchapter is dedicated to robotics in healthcare and therapeutic contexts, where robots assist in surgery, rehabilitation, elderly care, and mental health support. The sixth subchapter explores the use of telepresence robots, which enable remote interaction and presence through mobile robotic platforms. These systems are particularly valuable in contexts such as remote education, healthcare, international collaboration, and during travel restrictions or mobility limitations. The final section introduces soft robotics using flexible, bio-inspired materials. Each subchapter includes links to the source code implementations of the developed robotic applications. These resources, presented in the next section, are designed to facilitate replication, adaptation, and further exploration by students, academic staff, and researchers interested in hands-on development and interdisciplinary learning.

Together, the chapters of this book along with the accompanying tools provide a comprehensive, hands-on progression from basic concepts to advanced applications in robotics and artificial intelligence, connecting theory with real-world practice to support education, research, and innovation in higher education.

3.2. Robotic applications and video demonstrations

Seven AI-based robotic applications will be developed, addressing diverse domains such as academic environments, agriculture, brain-computer interfaces, and human-robot interaction. These applications are designed with a dual purpose: (i) to serve as research platforms for evaluating and benchmarking artificial intelligence algorithms, and (ii) to be integrated into educational activities, specifically within AI-focused robotics courses and related theoretical disciplines at our partner universities. Three of these applications will be dedicated to addressing the needs of socially vulnerable groups, including individuals with disabilities or special educational needs, as well as foreign-language speakers, and refugees. These robotic systems will focus on assistive functionality, accessibility, and inclusive design, reflecting the project's broader commitment to equity and human-centered innovation. These applications are built on theoretical foundations from the partner universities' curricula. Key topics include graph theory, search algorithms, pathfinding, heuristics, motion planning, computer vision, and social robots in education—guiding both the algorithms and practical use of the systems.

Each robotic application will include video demonstrations, detailed documentation, and step-by-step tutorials to support easy adoption in academic settings. Full source code implementations will also be provided and openly shared, ensuring that academic staff, students, and researchers can use, adapt, and extend the resources for teaching and further experimentation. The results obtained so far on generating 2D and 3D maps with the robots have been presented in (Grumeza et al. 2024a), (Grumeza et al. 2024b).

3. Dissemination activities

For the dissemination of the results of our project, beyond publishing collaborative scientific papers and presenting them at international conferences, we will organize at the end of the project two larger events.

3.1. The International Summer School

The International Summer School will be organized in Summer 2026 by academic staff from the partnership and will be held at the partner institution in Greece as 12 full days of activity. This Summer School is addressed to students of all levels (Bachelor, Master, and PhD) from partner universities. The application platform will be open from the beginning of 2026 and a number of 20 students will be selected based on their application to participate to the Summer School. Academic staff and researchers from partner universities who played an essential role in the development of the book, tools and robotic applications will be the instructors.

The International Summer School pursues two objectives: (1) to teach and involve the students in hands-on exercises based on problem-based learning principles, and (2) to evaluate the newly developed learning materials. In this way, the Summer School both disseminates the project's results among an international student audience and verifies the project's achievements. The results of the summer school will be that students will learn important notions from the book and they will acquire skills for using the developed tools and robotic applications in practical exercises based on problem-based learning principles. Participant students will receive an attendance certificate indicating the number of hours of courses (equivalent to ECTS credits).

3.2. International Conference

This conference is designed as a multiplier event and will be **worldwide open** to people outside the partnership (academic teachers and researchers as well as industry experts) interested in the results of our project. The conference will take place over two full days in Fall 2026, during the final month of the project, and will be held in a hybrid format at the partner institution in France. People interested in attending will be required to submit a motivation letter via the official submission platform, which will open several months prior to the event. A limited number of travel grants will be awarded to selected participants, based on the strength and relevance of their motivation letters.

The goal of the conference is (1) to disseminate the results of the AiRobo project, mainly to familiarize the participants with the book, the developed tools and robotic applications, and (2) to evaluate the results obtained, as the participants will be asked to give us feedback concerning the quality of the results of the AiRobo project.

4. Conclusions

The AiRobo project presents a unique opportunity to significantly enhance the teaching and learning of AI-based robotics within higher education. By fostering a collaborative environment among five leading European computer science departments, the project enables a rich exchange of expertise and best practices. This cross-fertilization approach is central to achieving the project's objectives:

- 1) Advancing the integration of artificial intelligence in robotics, both in theoretical and practical settings;
- 2) Promoting the usage of formal methods for the design, verification, and certification of robotic algorithms, including the application of powerful tools for algorithm synthesis and proof validation;
- 3) Developing and disseminating AI-powered robotic applications and video tutorials that support innovation across key sectors with a special focus on inclusion and accessibility for people with disabilities and migrant backgrounds;
- 4) Publishing a comprehensive book that introduces innovative educational materials covering a broad range of subjects, including AI, robotics, formal verification, automated reasoning, graph theory, and hybrid systems verification;
- 5) Providing professional development and training opportunities for academic staff;
- 6) Applying student-centered, problem-based pedagogical approaches, which depart from traditional teaching models to foster deeper engagement in courses related to the project's themes;
- 7) Disseminating research findings and methodologies through scientific publications;
- 8) Establishing a sustainable platform for international academic collaboration, facilitating the exchange of experiences and expertise in AI, robotics, and formal verification.

The project's impact goes beyond individual institutions. Its outputs including the book, tools, video tutorials, and robotic applications draw on interdisciplinary foundations already present in the partner universities' curricula. These materials encompass a wide array of subjects such as AI, robotics, formal verification, algorithm synthesis, theorem proving, hybrid systems, computer vision, and social robotics. The project also supports key areas in computer science like software engineering and programming, with a deliberate focus on connecting theory

to practical application. This helps make abstract topics more engaging, especially for students less inclined towards theoretical content. By incorporating real-world robotics examples into teaching, educators can offer more relatable and motivating experiences. Finally, the project's focus on accessibility, diversity, and ethical awareness ensures that the educational tools and robotic systems developed are not only technologically advanced, but also socially responsible. By offering inclusive learning materials and promoting equal access to cutting-edge skills, the AiRobo project contributes meaningfully to building a more equitable and innovative future in higher education.

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