COURSE DESCRIPTION

- Course name: ROS in Embedded Design for Mobile Robots

Form of course	***Lecture***	***Tutorial***	***Laboratory***	***Project***	***Seminar***
Total number of hours	*14*		*12*	*24*	
Form of completion	*Credit*		*Credit*	*Credit*	

- Initial requirements:
  - Understanding of software development principles and practical programming skills in C, C++ or Python.
- Name/s, surname and title of the teacher:
  - Dr. Eng. Janusz Jakubiak
  - Sérgio Duarte Correia, PhD, Portalegre Polytechnic University
  - Jorge Barreiros, PhD, Polytechnic University of Coimbra
  - Fernanda Coutinho, PhD, Polytechnic University of Coimbra
  - Thomas Herpoel, HELHa — Haute École Louvain en Hainaut
- Aims of course and educational outcomes:
  After completing the course, the student:
  - Explains the principles of designing and implementing embedded systems in the context of mobile robotics.
  - Describes the architecture of the ROS framework and the principles of software development within it.
  - Designs and integrates a robotic system.
  - Develops microcontroller-based control software for a mobile robot.
  - Collaborates effectively within a team on a project task.
- Form of teaching (on-site/ e-learning/ hybrid):
  - Hybrid (lecture: e-learning; laboratory and project: on-site)
- Number of ECTS (if applicable):
  - 3 ECTS
- Short description of the course's content
  The course provides students with hands-on experience in designing and implementing embedded systems for mobile robotics.
  Participants will learn how to design embedded components integrated with the ROS 2 (Robot Operating System) ecosystem and acquire practical skills in microcontroller programming and hardware component integration through the development of a localization application.
  (Detailed contents of the course are presented in the descriptions of individual teaching forms.)
- Lecture – content:

Form of classes - lecture		Number of hours
Lec1	Introduction to ROS 2 and microROS: system architecture, communication mechanisms, and development of custom components.	2
Lec2	Simulation environments for robotic system design and validation.	2
Lec3	Design of multitasking control architectures for mobile robots.	3
Lec4	Sensors and localization algorithms in mobile robotics.	4
Lec5	Fundamentals of embedded system programming.	3
	Total hours	**14**

Lectures are supplemented with a set of problems and study questions for independent work, aimed at verifying students' understanding of the lecture material.

- Laboratory – content:
    - Mobile robot localization task: development and verification of a localization algorithm in a simulation environment – 4h.
    - Integration of an embedded system with ROS 2 using microROS – 4h.
    - Implementation and testing of robotic sensors and actuators in real-world conditions – 4h.
- Project – content:
    - Group-based practical project applying the knowledge and skills gained in lectures and laboratories. Students will design, implement, and test on a real mobile robot a localization and navigation algorithm with collision avoidance capabilities. The project will conclude with a demonstration of the developed system and a presentation of the implemented solutions – 24h.
- Core literature:
    - Quigley, M., Gerkey, B., & Smart, W. D. (2015). Programming Robots with ROS: A Practical Introduction to the Robot Operating System. Sebastopol, CA: O'Reilly Media. ISBN 978-1-4493-2389-9
    - Lynch, K. M., & Park, F. C. (2017). Modern Robotics: Mechanics, Planning, and Control. Cambridge University Press. ISBN 978-1107156302
    - Joseph, L., & Cacace, J. (2021). Mastering ROS for Robotics Programming: Best Practices and Troubleshooting Solutions When Working with ROS. Packt Publishing. ISBN 978-18-010-7946-4
- Supplementary literature:
    - Li, Q., & Yao, C. (2003). Real-Time Concepts for Embedded Systems. CRC Press. ISBN 9780429181597

- ROS 2 Documentation & Tutorials – https://docs.ros.org/en/
- microROS Documentation – https://micro.ros.org/

- Completion rules:
  - Preparation and verification of solutions to lecture-related problems and questions.
  - Active participation in laboratory sessions and completion of assigned tasks.
  - Achievement of project objectives and presentation of applied methods.