COURSE DESCRIPTION CARD - SYLLABUS

Course name
Robotics II [S1SI1E>ROB2]

Course

Field of study
Artificial Intelligence

Year/Semester
3/6

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
english

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
30

Laboratory classes
30

Other (e.g. online)
0

Tutorials
0

Projects/seminars
0

Number of credit points

4,00

Coordinators

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Lecturers

Prerequisites

Basics of structured and object-oriented programming, In particular. Foundations of computer vision and machine learning. Knowledge and skills related to robotics, as well as basic tools and methods of programming robots acquired at the Robotics I course.

Course objective

The course aims at extending the knowledge and skills related to robotics acquired by the Artificial Intelligence students at the Robotics I course towards more advanced problems in robotics and perception. Robotics II focuses on robot autonomy - methods and algorithms that allow the embodied agents to process the gathered information in the physical world and take informed decisions. devise plans and undertake actions with minimal human intervention.

Course-related learning outcomes

Knowledge:
K1st_W4: knows and understands the basic techniques, methods, algorithms, and tools used for solving computer problems as well as problems in applied artificial intelligence, including clustering, classification, optimization, and decision support in embodied agents

K1st_W5: has a basic knowledge of key directions and the most important successes of artificial intelligence understood as an essential sub-domain of computer science, making use of the achievements of other scientific disciplines, including robotics, and providing solutions with a high practical impact; knows the history and recent trends in Artificial Intelligence and robotics
K1st_W6: has a basic, ordered, and well-grounded knowledge of computer architecture and robotics, which is useful for modeling, designing, and controlling the computer and robotic systems
K1st_W9: knows cybersecurity and ethical issues related to the creation and use of computers, robots, and, in particular, AI-based systems

Skills:
K1st_U3: can formulate and solve complex perception, optimization, and decision problems within the scope of computer science and, in particular, artificial intelligence and robotics, by applying appropriately selected methods such as clustering algorithms, classification techniques, optimization approaches, graph search methods, or decision analysis tools
K1st_U7: can carry out a critical analysis and an assessment of the functioning of computer systems, AI and robotic methods
K1st_U9: can adapt the existing algorithms as well as formulate and implement the novel algorithms, including the algorithms typical for different streams of AI such as robotics, machine learning, artificial neural networks, multiple criteria decision analysis, and optimization
K1st_U11: can adapt and make use of the models of intelligent behavior (e.g., genetic algorithms, artificial neural networks, or decision support methods) as well as computer tools simulating such a behavior for embodied agents
K1st_U12: can model, design, and control simple robotic systems

Social competences:
K1st_K1: understands that knowledge and skills quickly become outdated in AI, and perceives the need for constant additional training and raising one's qualifications
K1st_K2: is aware of the importance of scientific knowledge and research related to AI in solving practical problems which are essential for the functioning of individuals, firms, organizations as well as the entire society within such example application fields as transport, healthcare, education, home/service robots, public safety, and entertainment
K1st_K3: knows the examples of poorly functioning AI systems, which led to the economic, social, or environmental losses
K1st_K5: can think and act in an enterprising way, finding the commercial application for the created AI-based systems, having in mind the economic benefits as well as legal and social issues

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Lecture: Assessment test (written or on-line in eKursy) is conducted at the last lecture. The student can acquire up to 30 points answering questions that are drawn from the database of questions created from the topics introduced during the lecture. The points are summed up and a standard scale is used to derive the final marks: <50% - 2.0, [50% , 60%) - 3.0, [60% , 70%) - 3.5, [70% , 80%) - 4.0, [80% , 90%) - 4.5, and [90% , 100%] - 5.0.
Laboratory classes: Small groups of students (two persons by default) prepare programming assignments related to the topics of lectures. The evaluation is determined on the basis of the current progress in the assignment, the introduction of each subsequent functionality designated for a given task results in obtaining a higher grade.

Programme content

1. Introduction - agents and robots. Definitions, examples of autonomous robots, brief history of relations between robotics and AI research.
2. Autonomous robots - software architectures. Basic paradigms of software design in robotics focusing on mobile and autonomous robots. The Subsumption Architecture example. The Motor Schemas architecture example. Modern multi-tier architectures and the role of middleware.
3. Autonomous vehicles - software architectures. Software architectures in self-driving cars and the SAE levels of autonomy. Multi-stage architectures vs. end-to-end leaned systems. Basic modules and functions. Safety in autonomous vehicles.
4. Localization - dead reckoning and landmarks. Basic techniques of localizing robots and AGVs. Artificial

and natural landmarks. Triangulation and trilateration methods. Dead reckoning and odometry.
5. Localization - filter-based SLAM I (EKF). Introduction to probabilistic models of motion and localization. Kalman Filter and Extended Kalman Filter for agent localization. Limitations of the framework - linearization and matching of features. Examples of EKF SLAM.
6. Localization - filter-based SLAM II (PF). SLAM as Bayesian filtering. Introduction to Particle filtering methods and the structure of PF for agent localization in a 2D environment. Implementation and limitations of the framework. FastSLAM as a practical solution.
7. Localization - advanced & visual SLAM. Introduction to visual navigation: SLAM and Visual Odometry. Feature-based methods in visual navigation. Direct-based methods in visual navigation. SLAM using factor graphs and optimization frameworks.
8. Mapping - grid-based maps. Introduction to the problem of environment representation in robotics. Types of maps and their application areas. Grid mapping frameworks. Bayesian framework as an implementation example. Limitations of the Bayesian approach.
9. Mapping - feature-based and topological maps. Feature-based maps in 2D and 3D. Using feature-based maps for localization. Topological and semantic maps as representation of high-level knowledge in robotics.
10. Motion planning - search-based planning. Introduction to motion and path planning in robotics. Classification of the planning approaches. Visibility graph planner. Voronoi graph planner. Exact and approaximate cell decomposition for path planning. Potential-based methods in motion planning.
11. Motion planning - sampling-based planning. Limitations of the classic planning algorithms in robotics. Introduction to the concept of randomized motion planning. Probabilistic Road Maps (PRM) planner. The concept of Rapidly exploring Random Trees (RRT) planner. Analysis of the RRT-Connect algorithm and its implementation. Extensions of the RRT concept.
12. Manipulation and grasping. Basic concepts in robotic manipulation. Definition of contacts and grasps. Classic and underactuated grippers. Transfer of contact points and representations of objects for manipulation. Application examples.
13. Learning in robot perception. A review of using machine learning techniques in robot perception focusing on features extraction, mapping, and semantic segmentation.
14. Learning in robot navigation. . A review of using machine learning techniques in robot navigation, focusing on machine learning in motion planning and decision making fro vehicle autonomy.

Teaching methods

Lecture: slide show presentations illustrated with examples of practical applications.
Laboratory classes: solving illustrative examples implemented using open-source software, experiments in simulations and on pre-recorded data, discussion on the chosen methods and tools, teamwork.

Bibliography

Basic:
1. S. Thrun, D. Fox, W. Burgard, Probabilistic Robotics, MIT Press, Cambridge, 2005.
2. I. Nourbakhsh, R. Siegwart, D. Scaramuzza, Introduction to Autonomous Mobile Robots, MIT Press, Cambridge, 2011.
3. R. Murphy, Introduction to AI Robotics, 2nd Edition, MIT Press, Cambridge, 2019.

Additional:
1. J. Cacace, Mastering ROS for Robotics Programming, Packt Publ., 2018
2. R. Arkin, Behavior-Based Robotics, MIT Press, 1998
3. M. J. Mataric, The Robotics Primer, MIT Press, 2007

Breakdown of average student's workload

	Hours	ECTS
Total workload	100	4,00
Classes requiring direct contact with the teacher	60	2,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	40	2,00