COURSE DESCRIPTION CARD - SYLLABUS

Course name
AUTONOMOUS DRIVING: AI AND ROBOTICS PERSPECTIVE [S5AEEITK>ASPWAIR]

Course

Proposed by Discipline
–

Year/Semester
3/5

Level of study
Doctoral School

Course offered in
English

Form of study
full-time

Requirements
elective

Number of hours

Lecture
4

Laboratory classes
0

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

1,00

Coordinators

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Lecturers

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Prerequisites

Knowledge: PhD student starting this course should have extended knowledge of programming practice, architectures of computer systems and operating systems, robotics and artificial intelligence. Skills: PhD student should have the ability to obtain information from indicated sources. Social competences: the student should be aware of the need for a professional approach to technical issues, meticulous familiarization with the documentation and environmental conditions in which devices and their components can function.

Course objective

The aim of this course is to explore the operation and application of autonomous vehicles, focusing on navigation systems, sensor integration, artificial intelligence, and algorithm development for self-localisation and mapping.

Course-related learning outcomes

Knowledge
1) P8S_WG / SzD_W01 – Advanced theoretical knowledge in the discipline
Understands advanced concepts in artificial intelligence, robotics, probabilistic modeling, perception, planning, and control that form the theoretical foundations of autonomous driving systems.
2) P8S_WG / SzD_W02, SzD_W03 – Knowledge of research trends and methodologies

Knows current global research directions in autonomous vehicles, including deep learning architectures, sensor fusion algorithms, SLAM, safety-critical systems, verification/validation, and knowledge of state-of-the-art methods.
3) P8S_WK / SzD_W05 – Understanding of interdisciplinary contexts
Understands how autonomous driving integrates knowledge from computer science, robotics, transportation engineering, ethics, human–machine interaction, and systems engineering.
4) P8S_WG / SzD_W03 – Understanding of methodological limitations
Knows the limitations, uncertainties, and assumptions behind AI and robotic systems used in autonomy (e.g., dataset bias, model explainability, reliability of perception under edge cases).

Skills
1) P8S_UW / SzD_U01 – Ability to formulate research problems
Can independently formulate advanced research questions in autonomous driving, e.g., designing perception-planning pipelines, improving robustness, or developing novel sensor fusion methods.
2) P8S_UW / SzD_U01 – Ability to design experiments
Is able to design and implement experiments for evaluating AI/robotics modules (simulation, datasets, hardware-in-the-loop), selecting appropriate metrics for safety, latency, or accuracy.
3) P8S_UK / SzD_U04 – Ability to communicate results effectively
Can clearly and precisely communicate research results on autonomous driving systems to both specialists (engineers, researchers) and non-experts (industry partners, policy makers).
4) P8S_UW / SzD_U02– Ability to critically analyze and evaluate algorithms
Can critically assess the performance, generalization, and safety of AI and robotic algorithms for autonomy, identifying sources of potential failure.

Social competences
1) P8S_KR / SzD_K07 – Responsibility for research reliability
Demonstrates awareness of the ethical and societal impact of autonomous driving, including safety, fairness, data protection, and accountability.
2) P8S_KO / SzD_K04 – Collaboration in interdisciplinary teams
Is ready to work collaboratively with experts in machine learning, robotics, automotive engineering, human–machine interaction, and regulatory bodies.

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Written report or essay on a topic related to the aims of the course.

Programme content

The program covers the architecture of autonomous vehicles navigation systems, addressing key aspects of autonomous navigation such as map building, localisation, and SLAM (Simultaneous Localization and Mapping), environment maping and motion planning methods. The program also includes the implementation issues of self-localisation and mapping algorithms for vehicles, and integrating deep learning methods to enhance navigation capabilities.

Course topics

Lecture 1: SLAM, Mapping, and Perception AI
Perception–planning–control pipeline
Role of localization and mapping in the autonomy stack
Foundations of Localization and Mapping
Absolute vs. relative localization
Probabilistic sensor fusion (IMU, GNSS, wheel odometry)
SLAM for Autonomous Vehicles
Grid, feature-based, and semantic maps
Classical SLAM (EKF, particle filters, graph-based SLAM)
Visual, LiDAR, and multi-sensor SLAM
Deep Learning–Enhanced Perception and SLAM
Semantic mapping for scene understanding
Challenges in Real-World Driving Environments

Lecture 2: Motion Planning, Decision-Making, Software Architectures
Motion Planning Fundamentals
Global vs. local planning
Sampling-based planners (RRT*, PRM) and optimization-based planners
Behavior and Decision-Making for Autonomous Vehicles
Interaction with other road users (prediction, intent modeling)
Map-based vs. map-less planning
Planning on semantic and HD maps
Software Architectures for Autonomous Driving
Modular vs. end-to-end design
ROS and real-time middleware

Teaching methods

Lecture: multimedia presentation, illustrated with examples and movie clips, own work of the student with recommended literature.

Bibliography

1. S. Thrun, W. Burgard, D. Fox, Probabilistic robotics, MIT Press , Cambridge, 2005
2. I. Nourbakhsh, R. Siegwart, D. Scaramuzza, Introduction to Autonomous Mobile Robots, The MIT Press, 2011
3. C. Stachniss, Robotic Mapping and Exploration, Springer, 2009
4. Będkowski, Large-Scale Simultaneous Localization and Mapping, Springer, 2023
5. R. Murphy, Introduction to AI Robotics, 2nd Edition, The MIT Press, 2019

Breakdown of average student's workload

	Hours	ECTS
Total workload	25	1,00
Classes requiring direct contact with the teacher	4	0,00
Doctoral student's own work (literature studies, preparation for laboratory classes/tutorials, preparation for tests/exam, project preparation)	21	1,00