

Syllabus

Advanced Autonomous Systems, 6hp

Issued by the WASP graduate school management group 2025-04-07.

Main Field of Study

AS, Software, AI/MLX, AI/math

Course Level

Advanced course for PhD students

- AI track: elective
- AS track: elective
- Joint curriculum: advanced

Course offered for

PhD Students in the WASP graduate school

Entry Requirements

The course requires

- A background in the basics of Autonomous Systems as covered by the WASP-course “Autonomous Systems”.
- A background in AI and deep learning corresponding to as a minimum the contents of the WASP-course “AI and Machine Learning”.
- A solid programming experience in a high-level language; the programming assignments will use Python and ROS2.

Intended Learning Outcomes

Autonomous systems are systems that are designed to work without, or with limited, human intervention. This course builds on the WASP “Autonomous Systems” course. The objective of this course is to cover the classical three-layer architecture of Autonomous systems: the Decision Layer, the Execution Layer and the Functional Layer.

On completion of the course, the student should be able to

- Understand fundamental low-level control architectures and their tuning.
- Understand how to design a Model Predictive Controller (MPC) for path tracking.
- Design and experimentally verify an MPC framework on a mobile robot.
- Understand the meaning, the creation and the selection of frontiers in autonomous exploration missions.
- Understand how to use and evaluate common learning-based methods for autonomous robots and vehicles.
- Explain the opportunities and challenges of different learning-based architectures as well as recent trends in large pre-trained models and embodied AI.
- Use hierarchical Finite State Machines and Behavior Trees for task modeling.
- Use PDDL and Planning for high-level planning.

Course Content

The WASP Autonomous Systems course covers the Sense-Reason-Action cycle of autonomous systems to some extent, incl. path planning, sensing and basic control. This WASP Advanced Autonomous Systems course will extend the previous course with more advanced concepts such as MPC-based path tracking, frontier-based exploration of unknown environments, learning-based approaches for action and perception, high-level planning, high-level decision-making, robot-behavior modeling with Robot Skills, Finite State Machine, Behavior Trees and Planning Domain Description Language (PDDL) abstractions. The course consists of three modules hosted at LTU, KTH and LU, respectively.

1. The first module at LTU will provide an understanding of different control level architectures with an emphasis on path following controllers and low-level control architectures in the area of MPC. We will also analyze the concept of frontiers for exploration missions in unknown and unstructured environments as well as their coupling to perception and control architectures for heading definition.
2. The second module hosted at KTH will focus on learning-based approaches commonly used in autonomous robots and vehicles, such as reinforcement learning for locomotion with legged robots, imitation learning for manipulation and navigation, learning for perception as well as recent trends in large pre-trained foundation models, world models and embodied AI.
3. In the third module at LU we will focus on high-level decision making, studying different deliberation techniques. For modeling task level behavior, we will discuss hierarchical Finite State Machines and Behavior Trees. For task planning, we will discuss modeling the domain using a PDDL-based abstraction such that a robot can achieve a given task goal through task planning.

Teaching and Working Method

The course will contain three teaching modules, each one with submodules, that will last two days each. The aim will be to provide knowledge and hands-on experience with state-of-the-art methods and architectures for advanced autonomy, complemented by advanced experimentations and realistic simulations in the form of assignments. The start of the course will be provided in the field of automatic control and for establishing proper path tracking capabilities. In the sequel, the course will focus on AI-based environmental awareness and motion planning. The course will conclude with topics for allowing higher levels of decision making and task planning which will be explored using a simulator.

Examination

The examination in the course consists of assignments to be completed individually and in groups. Some of the assignments or parts thereof will be carried out or examined during the in-person 2-day meetings to allow for more interaction and better support. A re-examination will be made available, upon request, about 6 months after the course covering completion of missing parts.

Grades

Fail or Pass