Autonomous Vehicles - Planning, Control, and Learning Systems

Programme course

6 credits

Autonoma farkoster - planering, reglering och lärande system

TSFS12

Valid from: 2020 Spring semester

Determined by
Board of Studies for Electrical Engineering, Physics and Mathematics

Date determined
2019-09-23

Main field of study
Computer Science and Engineering, Electrical Engineering

Course level
Second cycle

Advancement level
A1X

Course offered for
- Computer Science and Engineering, M Sc in Engineering
- Information Technology, M Sc in Engineering
- Industrial Engineering and Management - International, M Sc in Engineering
- Industrial Engineering and Management, M Sc in Engineering
- Computer Science and Software Engineering, M Sc in Engineering
- Applied Physics and Electrical Engineering - International, M Sc in Engineering
- Applied Physics and Electrical Engineering, M Sc in Engineering
- Mechanical Engineering, M Sc in Engineering

Entry requirements
Note: Admission requirements for non-programme students usually also include admission requirements for the programme and threshold requirements for progression within the programme, or corresponding.

Prerequisites
Automatic control, introductory courses in mechanics and programming

Intended learning outcomes

To give a theoretical, technological, and practical foundation for how planning and control for autonomous vehicles can be realized in complex scenarios. The overall aim is an understanding of how methods from different fields can be integrated and applied in autonomous vehicles.

After passing the course, the student should be able to:

- explain and identify possibilities and challenges with autonomous vehicles in the society.
- describe, use, and evaluate common system architectures for autonomous vehicles.
- choose necessary sensor equipment and explain how different components are used as well as explain how these are interacting within planning, control, simultaneous localization and mapping, perception, and other central parts of an autonomous vehicle.
- describe and compare modern algorithms for motion planning and control of vehicles with kinematic and dynamic motion constraints, and in addition motivate the choice of method in a specific scenario.
- describe and suggest strategies for how robustness in the systems can be achieved by using feedback control and in addition apply optimal control and model predictive control in autonomous vehicles.
- explain and evaluate the interaction between motion planning and control of an autonomous vehicle.
- identify how learning can be used for an autonomous vehicle.
- implement low-complexity controllers and planners for systems of cooperating autonomous vehicles.
- implement functions on existing hardware platforms using available software libraries to solve common problems for autonomous vehicles in laboratory environment.
- describe parts of the latest research within the field and in addition read and comprehend new methods presented in scientific literature.

Course content

- Introduction to autonomous systems and vehicles; identification of possibilities and challenges.
- Common system architectures in autonomous decision making, machine learning, planning, and control.
- Dynamic models for planning and control of autonomous vehicles.
- Fundamental planning algorithms in graphs and trees for motion of simple robots.
- Advanced algorithms for motion planning for non-holonomic vehicles described by dynamic motion equations with differential constraints.
- Introduction to and use of methods for simultaneous localization and mapping for autonomous vehicles.
- Control of autonomous vehicles; path following, model predictive control (MPC), and control of path velocity.
- Learning systems within autonomous vehicles: reinforcement learning, machine learning using deep neural networks, and Markov decision processes (MDP).
- Cooperating autonomous vehicles, including ground vehicles and flying vehicles, and the required communication.

Teaching and working methods

The course is organized in lectures, problem solving sessions, hand-ins and a concluding project.

Examination

UPG2	Hand in exercise for higher grade	0 credits	U, 3, 4, 5
PROJ	Project	2 credits	U, G
UPG1	Hand in exercises	4 credits	U, 3, 4, 5

To pass the course with grade 3, the student is required to:

- Complete the five compulsory hand-in exercises and present them in either oral or written format (examination form varies between exercises).
- Complete a final project, typically involving experiments on a hardware platform, and present it by an oral presentation and in a short written report.

To obtain grade 4 or 5, the student is in addition to the examination tasks for grade 3 required to:

- Complete additional smaller hand-in exercises, widening the scope of selected parts of the course or going deeper into selected theoretical aspects of the course.

Grades
Four-grade scale, LiU, U, 3, 4, 5

Other information

About teaching and examination language

The teaching language is presented in the Overview tab for each course. The examination language relates to the teaching language as follows:

- If teaching language is Swedish, the course as a whole or in large parts, is taught in Swedish. Please note that although teaching language is Swedish, parts of the course could be given in English. Examination language is Swedish.
- If teaching language is Swedish/English, the course as a whole will be taught in English if students without prior knowledge of the Swedish language participate. Examination language is Swedish or English (depending on teaching language).
- If teaching language is English, the course as a whole is taught in English. Examination language is English.

Other

The course is conducted in a manner where both men's and women's experience and knowledge are made visible and developed.

The planning and implementation of a course should correspond to the course syllabus. The course evaluation should therefore be conducted with the course syllabus as a starting point.

Department
Institutionen för systemteknik

Director of Studies or equivalent
Johan Löfberg

Examiner
Erik Frisk

Course website and other links
http://www.fs.isy.liu.se/Edu/Courses/TSFS12

Education components

Preliminary scheduled hours: 40 h
Recommended self-study hours: 120 h

Course literature

Books

LaValle, S.M., (2006) *Planning Algorithms,* Cambridge University Press.
Siciliano, Bruno, Khatib, Oussama, (2016) *Handbook of Robotics* Springer
ISBN: 9783319325507
Sutton, R. S., and Barto, A. G, (2018) *Reinforcement Learning: An Introduction,* 2nd Ed. Cambridge, MA: MIT Press.

Articles

Paden, B., Cap, M., Yong, S. Z., Yershov, D., and Frazzoli, E., A survey of motion planning and control techniques for self-driving urban vehicles, *IEEE Trans. Intell. Vehicles* 1:1 (2016) 33–55.

Other

The course literature will be based on book chapters, recent scientific articles from journals and conferences in the field, and course manuscripts. The following books and articles will be a subset of the literature that will be used. A complete literature list will be provided on the course homepage.