COURSE DESCRIPTION CARD - SYLLABUS

Course name
Controlling of mobile robots and commercial vehicles [S1Elmob1>PO8-SRMiPA]

Course

Field of study
Electromobility

Year/Semester
3/6

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
Polish

Form of study
full-time

Requirements
elective

Number of hours

Lecture
30

Laboratory classes
15

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

3,00

Coordinators

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Lecturers

Prerequisites

A student starting the course should have a basic knowledge on kinematics and dynamics, control of electric servodrives, fundamental knowledge on control and systems theory. Moreover, the student should be able to to implement programs in the Matlab language, and should have skills in implementing and simulating block schemes in the Simulink environment, should be able to interpret and present the simulation and experimental result by using selected information-communication techniques, and should be able to acquire information from selected sources. The student should also be ready to cooperate with others in a team.

Course objective

Objectives of the course are the following: presentation of selected topics on wheeled mobile robotics and autonomous vehicles; drawing a state of the art in the field of modelling and motion control of wheeled mobile robots and highly automated ground vehicles; analysis of practical problems in the context of designning and implementing motion control systems for autonomous vehicles, and discussing examples of their solutions; shaping the skills in implementing, testing, and control performance assessing for selected motion control laws devised for highly automated vehicles in the context of selected motion tasks; shaping the skills for cooperation in small working teams.

Course-related learning outcomes

Knowledge:
1. Basic knowledge on modelling of wheeled vehicles on the kinematic and dynamic levels; knowledge of classification and properties of generic kinematics of wheeled and wheeled-tracked single-body and articulated vehicles; ordered basic knowledge in the area of designing of control systems for highly automated vehicles and mobile robots (especially of (3,0), (2,0), and (1,1) class) in the context of selected control tasks; knowledge on underlying structures of cascaded controllers for automated vehicles and mobile robots, and knowledge of functions played by particular blocks of these control systems; consciousness of fundamental limitations characteristic to designing and realizing control laws for restricted-mobility wheeled vehicles; knowledge on selected control techniques and algorithms of autonomous vehicles and mobile robots and their properties; knowledge on practical issues, benefits and limitations related to applications of control methods in practice; knowledge of selected quality criteria being applied to assess performance of control systems.
2. Basic knowledge in the area of contemporary development trends in wheeled mobile robotics and automated commercial vehicles, and motion/control tasks being defined for wheeled mobile robots and autonomous vehicles; knowledge on examples of practical applications of wheeled robots and automated vehicles; basic knowledge on groups of connected automated vehicles (CAV) and automated highway systems (AHS); basic knowledge on sensors and actuators used in automated wheeled vehicles; basic information and examples in the area of (advanced) driver assistance systems (DAS/ADAS).

Skills:
1. Skills for implementing and testing of wheeled vehicle models and selected functional blocks of control systems in a simulation environment on a fast-prototyping testbed using a physical laboratory vehicle.
2. Skills needed for performing a basic analysis of a resultant control performance obtained during classes, and for comparing of selected control laws by applying known quality criteria.
3. Skills for a synthesis of control systems paying attention to environmental and economic issues.

Social competences:
1. Competences for cooperation in a team with responsibility of commonly realized tasks.
2. Consciousness of a necessity for professional approach to technical problems and permanent updating the skills and knowledge in the area of autonomous vehicles.

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

A) In terms of lectures, the established learning outcomes are verified by assessing the student's knowledge during the completion of lecture content in the form of a choice test. The test contains 20 questions, each question has four answers (A, B, C, D), two of which are correct and two incorrect. Marking two correct answers results in a score of 1 point for the question; marking one correct answer and no second answer results in a score of 0.5 points for the question; marking one correct and one incorrect answer (or marking two incorrect or not marking any answer) results in 0 points for a given question. A passing grade from the test requires a total score > 10 points.
B) In terms of laboratory classes, the verification of the established learning outcomes is realized by evaluating the results of the tasks performed by student teams during laboratory classes. The quality of operation of the implemented control systems and answers to factual questions related to the performed tasks are checked and evaluated.

Programme content

The course program includes the following content:
- introduction to the problems of mobile robotics and autonomous vehicles,
- mathematical models of vehicles used for control purposes,
- definition and features of selected control tasks of mobile robots and autonomous vehicles,
- blocks and functional subsystems of mobile robot control systems,
- selected control algorithms for mobile robots and autonomous vehicles.

Course topics

The lecture program covers the following topics:

- basic concepts: mobility, limited mobility, wheeled vehicle (mobile robot) autonomous / intelligent / semi-autonomous / teleoperated, automated vehicle;
- degrees of autonomy of mobile robots and degrees of automation of commercial vehicles according to SAE J3016 standard (with emphasis on levels 3-5);
- contemporary applications and examples of mobile robots and automated vehicles; examples of commercial vehicle robotization; practical motivations for vehicle automation;
- features of wheeled and wheel-sliding locomotion; types of vehicle wheels and mobile robots;
- mathematical description of movement models of motor vehicles, wheeled mobile robots (five basic kinematic classes: (3,0), (2,0), (1,1), (2,1), (1,2)) and selected articulated vehicles for control purposes; vehicle degrees of freedom in flat motion and indices of kinematics (degrees of mobility, steerability and maneuverability), kinematic ties and their fulfillment under practical conditions (nonholonomic models vs. models without constraints);
- modes of transmission and realization of motion, differential mechanism, Ackermann mechanism, omni-directional motion vs. constrained mobility;
- vehicle platform posture and configuration vector, platform orientation representations, instantaneous vehicle platform center of rotation;
- basic sensors/sensors of automated vehicles;
- general functional diagram of the motion control system of an autonomous vehicle (mobile robot);
- motion task vs. control task; definition of basic motion tasks and control tasks for automated vehicles, especially autonomous vehicles, and examples of their practical implementation; obstacle collision avoidance problem;
- mathematical formulation of the traffic task (reference signal generator - ways to implement calculations);
- structures and design of basic cascade control systems used in autonomous vehicles and mobile robots; description of control algorithms for selected control tasks;
- qualitative comparative criteria of control algorithms;
- practical aspects of the implementation of control systems for mobile robots and automated vehicles: quality of control under practical conditions, limitations of control signals and speed scaling block, the problem of measuring feedback signals,
- basic hardware blocks of control systems of mobile robots and automated vehicles;
- selected examples of practical and experimental control systems of wheeled mobile robots and automated commercial and articulated vehicles;

Laboratory classes are conducted in the form of eight 2-hour exercises held in the laboratory. The exercises are carried out by teams of two or more students. The laboratory program includes the following issues (implementation of tasks in the Matlab-Simulink environment),
- implementation and testing of selected wheeled vehicle models, speed scaling block and reference signal generators,
- implementation and testing of selected motion control algorithms for a model of a mobile robot of class (2,0) or (1,1).

Teaching methods

(A) Lectures: multimedia presentations (slides, animations, video, simulations) additionally illustrated by selected examples and derivations provided on a blackboard.
(B) Laboratory classes: programming-simulation tasks concering the implementation and verification of mobile robot control system in the simulation environment.

Bibliography

Basic:
1. Sterowanie robotów mobilnych. Laboratorium, M. Michałek, D. Pazderski, WPP, Poznań, 2012
2. Vehicle dynamics and control. Second edition, R. Rajamani, Springer, 2012

Additional:
1. Wheeled mobile robotics. From fundamentals towards autonomous systems, G. Klancar, A. Zdesar, S. Blazic, I. Skrjanc, 2017
2. Handbook of intelligent vehicles, A. Eskandarian (ed.), Springer, 2012
3. Autonomous intelligent vehicles. Theory, algorithms, and implementation, H. Cheng, Spinger, 2011
4. Principles of robot motion. Theory, algorithms, and implementations, H. Choset, K. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. Kavraki, S. Thrun, The MIT Press, Cambridge, 2005

5. Motion control of wheeled mobile robots, P. Morin, C. Samson, Springer Handbook of Robotics, 2008

Breakdown of average student's workload

	Hours	ECTS
Total workload	85	3,00
Classes requiring direct contact with the teacher	47	1,50
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	38	1,50