COURSE DESCRIPTION CARD - SYLLABUS

Course name
Control of mobile robots [S2AiR2-SSiR>SRMo]

Course

Field of study
Automatic Control and Robotics

Year/Semester
1/2

Area of study (specialization)
Control and Robotic Systems

Profile of study
general academic

Level of study
second-cycle

Course offered in
Polish

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

dr hab. inż. Maciej Michałek prof. PP
maciej.michalek@put.poznan.pl

Lecturers

Prerequisites

A student should know fundamentals on robotics (configuration space, task space, kinematics, dynamics, kinematic constraints, trajectory, path, tracking, stabilization, control of servodrives) and on theory of systems and control (state-space description, feedback control, feedforward control, linearization and linear approximation, controllability, Lie bracket, Lyapunov stability analysis, driftless dynamical systems and systems with a drift). Moreover, a student should have skills in Matlab programming, implementation and simulation of block schemes in the Simulink environment; should be able to present the simulation and experimental results by using selected information-communication tools, should have skills to acquire knowledge from indicated sources; should be ready to cooperate in a team.

Course objective

Course objectives are as follows: systematization of knowledge on mobile robotics and drawing a state of the art in the area of motion algorithmization for wheeled mobile robots; analysis of theoretical and practical problems and their solutions concerning modeling and control of autonomous wheeled vehicles; development of skills for practical implementation and testing of selected control algorithms for wheeled mobile robots, and their multicriterial assessment in the context of various motion tasks; development of skills for the purpose of cooperating in a small team.

Course-related learning outcomes

Knowledge

1. Extended knowledge in the area of modeling of wheeled mobile robots on the kinematic and dynamic levels; knowledge on classification and fundamental properties of basic kinematic structures of mobile robots; knowledge on properties of wheeled and wheeled-tracked locomotion; knowledge on fundamental properties of kinematic models of mobile robots and a universal chained-form model. [K2_W5]
2. Ordered, theoretically supported, detailed knowledge in the range of designing and analysing of control systems for mobile robots (especially of (2,0) kinematics) for basic motion tasks; knowledge on underlying cascaded structures of control systems for wheeled mobile robots (with an especial emphasis paid on the (2,0) class) and knowledge on functions of their particular blocks; knowledge on fundamental limitations in designing and implementing of control systems for mobile robots of a restricted mobility; knowledge on selected kinematic techniques and algorithms of mobile robot control and their properties; knowledge on practical issues and advantages and limitations concerning practical utilization of particular control methods; knowledge on selected quality criteria useful to assess performance of control algorithms. [K2_W7]
3. Extended knowledge in the field of mobile robotics, especially concerning wheeled mobile robots; knowledge on mobile robot examples and areas of their applications; knowledge on concepts such as: autonomous/semi-autonomous/teleoperated/intelligent mobile robot; knowledge on basic motion tasks defined for mobile robots and corresponding control tasks; knowledge on practical examples for particular motion tasks, and mathematical formulations of motion tasks for mobile robots of the (2,0) class (a reference signals generator). [K2_W10]

Skills

1. Implementing and testing of mobile robot models, generators of reference signals, and basic control algorithms in a simulation environment and in a fast-prototyping system (with utilization of a real mobile platofrm). [K2_U9],[K2_U10]
2. Analysis of control performance and comparison of selected control algorithms by using selected quality criteria. [K2_U19],[K2_U22]
3. Preparing and appropriate presenting of obtained laboratory results. [K2_U8]

Social competences

1. Ability to cooperate in a team with a responsibility for a common task. [K2_K3]
2. Consciousness of neccessity to professionally approch to technical tasks. [K2_K4]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Learning outcomes presented above are verified as follows:

A) For lectures: Verification of the teaching results during an exam in the form of an individual oral answers (possibly complemented by written schemes, equations, etc.) to three questions choosen from a set of about 30 questions provided to the students before the exam. Every answer is independently assessed and rated. A mean value from all three ratings determines the rating OW, which is positive if OW>=3.0. A final rating from the course, OK, is computed as follows: OK = OW*0.7 + OL*0.3, where OL is a rating obtained from laboratory classes. OK >= 3.0 implies a positive rating from the course.

B) For laboratory classes: Verification of the teaching results is performed during 'defending' by the students their final experimental results prepared in the second part of classes and presented both on-line and by a written report (assessment of: obtained results, quality of the written report, and answers to questions formulated by an instructor and related to the tested control algorithms).

Programme content

The program content is as follows:

- introduction to mobile robotics,
- modeling of wheeled mobile robots,
- selected properties of wheeled mobile robot models,
- motion and control tasks defined for mobile robots,
- structures of control systems for mobile robots,
- implementation issues concering the mobile robots' control systems,
- practical verification of selected control algorithms of mobile robots.

Course topics

The lectures cover the following topics:
- basic concepts: mobility, locomotion, autonomous/intelligent/semi-autonomous/teleoperated mobile robot; basic topics in mobile robotics,
- classification criteria for mobile robots, including wheeled robots; autonomy levels for mobile robots; applications and examples of mobile robots; levels of automation defined for commercial cars; robotization of commercial vehicles with examples,
- properties of wheeled and wheeled-tracked locomotion; types of wheels used in robotic vehicles, the types of drive transmission and motion realization, differential mechanism, Ackermann steering mechanism, omnidirectional motion vs. restricted mobility motion, necessary conditions of a non-degenerated structure of wheeled mobile robot,
- modeling of wheeled mobile robots: posture and configuration vectors, orientation representations for mobile platforms, instantaneous center of rotation, five basic kinematic models of wheeled mobile robots ((3,0), (2,0), (1,1), (1,2), (2,1)), kinematic constraints; dynamical (kinetic) model of a differentially driven robot, friction, rolling resistance, skid-slip effects; a normal form of mobile robot models,
- kinematic indexes: mobility index, steerability index, maneuverability index; degress of freedom; basic structures of single-body and multiple-body mobile robots (with trailers), two ways of hitching a trailer and their consequences for control, - controllability of mobile robot kinematics,
- canonical chained-form model and its role in the area of mobile robot control,
- properties of mobile robots models in the context of control (linearizability, differential flatness, controllability of a linear approximation of a model),
- fundamental limitations in mobile robots control: consequences of the Brockett's Theorem, nonholonomic constraints and their interpretation, the lack of a universal stabilizer,
- definitions of basic motion tasks and control problems, and practical examples of their utilization: trajectory tracking, path following, stabilization at a point, positional tasks, nonclassical tasks; the problem of collision avoidance with obstacles,
- mathematical formulation of a motion task (reference signals generator - the ways of computing); the concepts of a persistent excitation and an admissible trajectory,
- a general structure of a control system for mobile robots, structures and classification of cascaded control systems with respect to a control signal interpretation; synthesis of the velocity control loops,
- description, derivation, and parametric synthesis of selected control algorithms for all the classical motion tasks (methods resulting from linear approximations and feedback linearization, a time-dependent Pomet's stabilizer, discontinuous controllers of the VFO method); rules for control designing with a utilization of the canonical chained-form model,
- qualitative comparative criteria of control algorithms; types of signal convergnce and their relation to control performance obtained in practice; robustness and sensitivity determined by control algorithms,
- practical issues concerning implementation of control systems for mobile robots: control performance in practical (non-ideal) conditions, limitations of control inputs and a velocity scaling block, problems in measuring feedback signals, physical realization of control signals, basic hardware blocks of control systems in wheeled mobile robots; selected examples of practical implementations of control systems for mobile robots.

Laboratory classes are organized in the form of fifteen 2-hour meetings in a laboratory room. The laboratory tasks are realized by teams of 2-3 students. The program is divided into two parts (the simulation one and the experimental one), which address the following topics:
- implementing and testing (in the Matlab-Simulink environment) of the differentially-driven mobile robot model, a velocity scaling block, and a reference signals generator,
- implementing and tuning (in the Matlab-Simulink environment) of the inner-loop velocity controllers with an anti-windup corrector,
- simulation verification (in the Matlab-Simulink environment) of open-loop control for a mobile robot of the (2,0) class,
- testing of testbeds with real mobile platforms in a fast-prototyping system,
- implementing and validating of selected control algorithms for classical motion tasks (trajectory tracking, path following, set-point stabilization, positional tasks) in the fast-prototyping control system equipped with real experimental mobile robots.

Teaching methods

A) Lectures: Multimedia presentation with slides illustrated by additional examples and derivations provided and analyzed on a blackboard.

B) Laboratory classes: Simulation tasks in the Matlab-Simulink environment (during the first part of classes); implementation and practical testing of selected control algorithms (during the second part of classes) using real mobile robots in a fast-prototyping system.

Bibliography

Basic
[1] Sterowanie robotów mobilnych. Laboratorium, M. Michałek, D. Pazderski, WPP, Poznań, 2012
[2] Theory of robot control. Part III: Mobile robots, The Zodiak, C. Canudas de Wit, B. Siciliano, G. Bastin, Springer, London, 1996
Additional
[3] Wheeled mobile robotics. From fundamentals towards autonomous systems, G. Klancar, A. Zdesar, S. Blazic, I. Skrjanc, B-H, 2017
[4] Introduction to Autonomous Mobile Robots, R. Siegwart, I. R. Nourbakhsh, The MIT Press, Cambridge, 2004
[5] 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
[6] Feedback Control of a Nonholonomic Car-like Robot. Robot Motion Planning and Control (red. J. P. Laumond), rozdział 4: Feedback Control of a Nonholonomic Car-Like Robot, A. DeLuca, G. Oriolo, C. Samson, Springer, 1998
[7] Motion control of wheeled mobile robots, P. Morin, C. Samson, Springer Handbook of Robotics, 2008
[8] Springer Handbook of Robotics, B. Siciliano, O. Khatib (ed.), rozdziały: 17, 34, 51, 54, Springer 2008
[9] Modeling and control of nonholonomic mechanical systems, A. De Luca, G. Oriolo, Kinematics and dynamics of multi-body systems. CISM International Centre for Mechanical Sciences, J. Angeles, A. Kecskemethy (ed.), vol. 360 , Springer, Viena, 1995
[10] Manipulatory i roboty mobilne. Modele, planowanie ruchu, sterowanie, K. Tchoń, A. Mazur, I. Dulęba, R. Hossa, R. Muszyński, Akademicka Oficyna Wydawnicza, Warszawa, 2000

Breakdown of average student's workload

	Hours	ECTS
Total workload	100	4,00
Classes requiring direct contact with the teacher	60	2,50
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	40	1,50