STUDY MODULE DESCRIPTION FORM

Name of the module/subject		Code
Control of Underactuated Systems		**1010532131010559190**
Field of study: **Automatic Control and Robotics**	Profile of study (general academic, practical): **general academic**	Year /Semester: **2 / 3**
Elective path/specialty: **Smart Aerospace and Autonomous Systems**	Subject offered in: **Polish**	Course (compulsory, elective): **elective**
Cycle of study: **Second-cycle studies**	Form of study (full-time,part-time): **full-time**	
No. of hours: Lecture: **30** Classes: **-** Laboratory: **-** Project/seminars: **45**		No. of credits: **4**
Status of the course in the study program (Basic, major, other): **major**	(university-wide, from another field): **from field**	
Education areas and fields of science and art		ECTS distribution (number and %)

Responsible for subject / lecturer:

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Prerequisites in terms of knowledge, skills and social competencies:

1	**Knowledge**	Student starting this module should have basic knowledge regarding control theory, foundations of autonomous systems, measurement and microprocessor systems
2	**Skills**	He/she should have skills allowing solving basic problems related to programming in Matlab/Simulink environment, high level and low-level programming in C/C++, simulation of dynamic continuous and discrete systems and skills that are necessary to acquire information from given sources of information. Student should understand the need to extend his/her competences.
3	**Social competencies**	In addition, in respect to the social skills the student should represent such features as honesty, responsibility, perseverance, curiosity, creativity, manners, and respect for other people.

Assumptions and objectives of the course:

1. Provide students knowledge regarding classification of underactuated systems, modeling of kinematics and dynamics of systems with nonintegrable dynamics, description of fundamental properties of underactuated systems, description of selected open and closed-loop control methods.
2. Develop students? skills in modeling and simulation of kinematics and dynamics of underactuated systems and motion control algorithms.

Study outcomes and reference to the educational results for a field of study

Knowledge:

1. acquire knowledge on real-time control structure at kinematic and dynamic level - [K_W3]
2. have wide and in-depth knowledge on modeling of kinematics and dynamics of underactuated systems - [K_W5]
3. have wide and in-depth knowledge on design of control algorithms for nonlinear systems - [K_W7]
4. have wide and in-depth knowledge on mobile robotics - [K_W10]

Skills:

1. is able to conduct simulations of control algorithms and to implement the algorithms in practice - [K_U9]
2. is able to implement numerical models of robot environment - [K_U10]
3. is able to verify hypothesis related to problem of autonomization of mobile robots - [K_U14]

Social competencies:

1. is able to work in group to solve engineering and scientific problems - [K_K3]

Assessment methods of study outcomes

Formative assessment:

a) project classes:

evaluation of doing correctly assigned tasks (following provided lab. instructions),

Total assessment:

a) verification of assumed learning objectives related to lectures:

i. evaluation of acquired knowledge on the basis of the written exam.

ii. discussion of correct answers in the exam

b) verification of assumed learning objectives related to laboratory classes:

i. evaluation of student?s knowledge necessary to prepare, and carry out the lab tasks,

ii. monitoring students? activities during classes,

iii. evaluation of project report

iv. showing how to improve the instructions and teaching materials.

Course description

The lecture should cover the following topics

Fundamental concepts: underactuated system, classification of underactuated systems in robotics, modelling of kinematics and dynamics, integrable and non-intergrable phase constraints, motion control algorithms, strutures of control architectures. Basic definitions: underactuated system, types of underactuated systems and their examples (nonholonomic wheeled mobile robots, multi-body mechanical systems, inverted pendulum, flying vehicles, water vehicles, walking and hopping machines). Modeling of nonholonomic systems, source of nonholonomic constaints. Description of selected nonholonomic systems (vehicles with trailer, flying multi body structures) at kinematic and dynamic level. Analysis of fundamental properties of nonholonomic systems referring to differential geometry, controllability and properties of linear approximation. Symmetry of configuration space, systems defined on Lie groups, examples. Integrable and nonintegrable dynamics, underactuated systems with nonintegrable dynamics, examples. Discussion considering stabilizability of underactuated systems. Open-loop control algoritms: Lie-algebraic method, jacobian method. Closed-loop control algorithms: discontinuous techniques, time-varying techniques, transverse function approach. Underactuated systems with hybrid dynamics. Stability of periodic cycle based on Pioncare maps. Zero dynamics and decoupling method in control of selected dynamic systems.

The project will be focused on practical oriented problems which will be solved by students working in groups. The classes cover:

Studying literature considering subject of the given problem. Modeling of underactuated system at kinematic and dynamic level in numerical environment. Implementation of selected motion control algorithms in simulation environment. Analysis and comparative study of the control algorithms, discussion of possibility of implementation in practice, formulation of engineering and technical requirements for the implementation.

Learning methods:

1. Lectures: multimedia presentation, presentation illustrated with examples presented on black board, solving tasks
2. Project: solving tasks, practical exercises, experiments, teamwork

Basic bibliography:

1. S. Sastry, Nonlinear Systems, Springer Verlag, 1999

2. Tchoń, Mazur, Hossa, Dulęba, Manipulatory i roboty mobilne, Akademia Oficyna Wydawnicza PLJ, 2002.

3. B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, Robotics: Modelling, Planning and Control, Springer 2009.

4. M. Michałek, D. Pazderski, Sterowanie robotów mobilnych. Laboratorium, Wydawnictwo Politechniki Poznańskiej, Poznań 2012

5. R. C. Arkin (edytor), Principles of Robot Motion Theory, Algorithms and Implementation, Massachussets Institute of Technology (MIT), 2005

6. R. Siegwart, I. R. Nourbakhsh, D. Scaramuzza, Introduction to Autonomous Mobile Robots, MIT, 2011

7. S. Sastry, Nonlinear Systems, Springer Verlag, 1999

8. Tchoń, Mazur, Hossa, Dulęba, Manipulatory i roboty mobilne, Akademia Oficyna Wydawnicza PLJ, 2002.

9. B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, Robotics: Modelling, Planning and Control, Springer 2009.

10. M. Michałek, D. Pazderski, Sterowanie robotów mobilnych. Laboratorium, Wydawnictwo Politechniki Poznańskiej, Poznań 2012

11. R. C. Arkin (edytor), Principles of Robot Motion Theory, Algorithms and Implementation, Massachussets Institute of Technology (MIT), 2005

12. R. Siegwart, I. R. Nourbakhsh, D. Scaramuzza, Introduction to Autonomous Mobile Robots, MIT, 2011

Additional bibliography:

1. B. Siciliano, O. Khatib (Ed.), Handbook of Robotics, Springer 2009.

2. J. Borenstein (edytor), Where am I - Systems and Methods for Mobile Robot Positioning, 1996, http://www-personal.umich.edu/~johannb/shared/pos96rep.pdf

3. B. Siciliano, O. Khatib (Ed.), Handbook of Robotics, Springer 2009.

4. J. Borenstein (edytor), Where am I - Systems and Methods for Mobile Robot Positioning, 1996, http://www-personal.umich.edu/~johannb/shared/pos96rep.pdf

Result of average student's workload	
Activity	**Time (working hours)**
1. participating in lectures	30
2. participating in project classes	45
3. finishing report from project	5
4. consulting issues related to the subject of the course	2
5. studying literature / learning aids	16
6. participating in exam	2

Student's workload		
Source of workload	**hours**	**ECTS**
Total workload	100	4
Contact hours	79	3
Practical activities	47	2