STUDY MODULE DESCRIPTION FORM

Name of the module/subject **Non linear Systems**			Code **1010532111010559179**
Field of study **Automatic Control and Robotics**	Profile of study (general academic, practical) **general academic**		Year /Semester **1 / 1**
Elective path/specialty **Smart Aerospace and Autonomous Systems**	Subject offered in: **Polish**		Course (compulsory, elective) **obligatory**
Cycle of study: **Second-cycle studies**	Form of study (full-time,part-time) **full-time**		
No. of hours Lecture: **30** Classes: **30** Laboratory: **-** Project/seminars: **-**			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:

prof. dr hab. inż. Krzysztof Kozłowski
email: krzysztof.kozlowski@put.poznan.pl
tel. 61 6652199
Wydział Informatyki
ul.Piotrowo 3, 60-965 Poznań

Prerequisites in terms of knowledge, skills and social competencies:

1	**Knowledge**	Student starting this module should have basic knowledge regarding calculus, algebra and description of dynamical systems using Lagrange equations and state space representation.
2	**Skills**	In addition student is able to solve basic problems related to design of control linear systems, their stability analysis, and finally can manage to obtain necessary information from different sources. Student should understand the need to extend his/her competences.
3	**Social competencies**	In addition, in respect to the social skills the student should show attitudes as honesty, responsibility, perseverance, curiosity, creativity, manners, and respect for other people.

Assumptions and objectives of the course:

1. Student will obtain basic knowledge about description of nonlinear systems, their controllability, linearization and stability.
2. Student will be able to solve difficult problems related to nonlinear systems and will get knowledge how to use basic mathematical tools to solve these problems (tools are known form basic calculus course offered at technical universities).
3. Acquire such skills by solving practical tests during project classes.

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

Knowledge:

1. has extensive and in-depth knowledge in selected areas of mathematics useful for formulating and solving complex tasks in the field of control theory and modeling of complex automation systems; - [K_W1]
2. has well-established detailed theoretical knowledge of methods employed to ana-lyze and design of nonlinear control systems; - [K_W7]
3. has theoretical detailed knowledge related to control of nonlinear system; - [K_W11]
4. has knowledge of the development trends and most crucial new achievements in the field of nonlinear automatics and robotics and its related disciplines; - [K_W12]

Skills:

1. is able to evaluate information from literature, databases and other information sources (in Polish and English) - [K_U1]

2. is able to carry out simulation and analysis of the operation of complex automatics systems described in terms of nonlinear differential equations - [K_U9]

3. is able to determine models of complex systems and processes, and employ them to analyze and design automatics and robotics systems - [K_U10]

4. is able to formulate and test hypotheses (carry out simulations and experiments) regarding engineering problems and difficult research problems in the area of automatics and robotics - [K_U15]

5. is able to carry out critical analysis of the operation of control systems and robotics systems - [K_U19]

6. is able to evaluate usefulness of methods and tools for solving a robotics and automatics problem; is able to use innovative and mathematical tools in the field of automatics and robotics - [K_U22]

Social competencies:

1. is aware of responsibility for their own work, is able to collaborate and cooperate in a team, and take responsibility for the jointly performed tasks; is able to lead a team, set goals and assign priorities to realize a specific task; - [K_K3]

2. is aware of the necessity to approach technical aspects professionally, - [K_K4]

Assessment methods of study outcomes

Formative assessment:

a) lectures:

based on answers to question in the written exam,

b) project classes:

evaluation of doing correctly assigned tasks (following provided project 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 tutorial classes:

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

ii. monitoring students? activities during classes, two written tests during the classes,

c) defence and evaluation of project reports (partly started during classes, finished after them)

Course description

The lecture should cover the following topic:

1. Description of nonlinear systems in state space and tools used in linearization of these systems. The following new basic notions will be introduced: Lie derivative and Lie bracket with calculated illustrative examples.

2. Definition of a dyfeomorphic transformation of the state variables and a relative degree for systems described by linear differential equations and nonlinear systems type of SISO (single input single output) with illustrative analytical examples.

3. Definition of a relative degree for nonlinear systems type of MIMO (multiple input multiple output) with dynamic model of an n degrees of freedom manipulator as an illustrative example.

4. Definition of zero dynamics for systems type of SISO and MIMO with analytical illustrative example.

5. Definition of distribution and involutive distribution. Definition of co-distribution and its annihilator. Illustrative analytical examples will be discussed.

6. Introduction of Frobenius theorem with constructive necessary integration condition including its proof. An illustrative example wiil be discussed.

7. Discussion of linearization method based on the first Lyapunov principle with practical illustrative examples.

8. Introduction of linearization method based on transformation of the state space equations and description of Krener?s conditions of local linearization with illustrative examples discussion.

9. Introduction of linearization method based on feedback with proof of the necessary condition for SISO type of systems, illustrative example will be analyzed.

10. Linearization method based on feedback for MIMO type of system with illustrative example.

11. Description of linearization method based on dynamical feedback with necessary and sufficient conditions.

12. Discussion on practical linearization methods for one input systems with illustrating examples.

13. Discussion on practical linearization methods for multiple input systems with illustrating examples.

14. Set point stabilization problem of angular velocity of a D.C motor with its full nonlinear model description using zero dynamics and output function depending on angular velocity. Calculation of a relative degree will be carried out along with conditions concerning asymptotic stability of this system.

15. Derivation of one link robot model that is driven by a D.C. motor with gear and elastic joint represented by torsional spring. Definition of an output function, calculation of a relative degree and zero dynamics and linearization of the system.

The tutorial classes (15 hours) students have to solve examples illustrating 15 lectures described above. Examples considered are among others mobile robot with differential drive, car-like robot, manipulator with two degrees of freedom, hopping robot having two degrees of freedom and biped robot having three and five degrees of freedom, respectively. Due to the fact that considered examples are complicated it is recommended to solve them analytically to some extend and later on when it is not possible to carry our hand calculations students have to use supporting software for symbolic calculations such as Maple. These problems have to be solved by students in groups consisting of two or maximally three students. This part is related to project classes (15 hours). For solving simpler problems having numerical nature it is recommended to use Maple and Simulink supporting software.

Learning methods:

1. Lectures: multimedia presentation, presentation illustrated with examples presented on black board, solving tasks, multimedia showcase
2. Labs: solving tasks, practical exercises, discussion, teamwork, multimedia showcase, competitions or case studies

Basic bibliography:

1. Nonlinear Control Systems, A. Isidori, Springer-Verlag London, 1995

2. Linearyzacja przez sprzężenie zwrotne w syntezie algorytmów regulacji dla obiektów termoenergetycznych, W.Bolek, T. Wiśniewski, Oficyna Wydawnicza Politechniki Wrocławskiej, 2006

Additional bibliography:

1. Applied Nonlinear Control, J.E. Slotine, W. Li, Prentice Hall, 1991

2. Nonlinear Dynamical Systems, N. Nijmeijer, A.J. van der Schaft, Springer, 1990

3. Robot Modeling and Control, M. Spong, S. Hutchinson, M. Vidyasagar, John Wiley and Sons, Inc., 2006

Result of average student's workload

Activity	Time (working hours)
1. participating in tutorials	15
2. preparing to tutorials	5
3. participating in projects classes	15
4. consulting issues related to the subject of the course; especially related to projects	5
5. writing and running programs not related to projects	10
6. participating in lectures	30
7. studying literature / learning aids (10 pages of research paper = 1 hours)	8
8. exam outcome discussion	2
9. preparing to and participating in exams	10

Student’s workload

Source of workload	hours	ECTS
Total workload	100	4
Contact hours	69	3
Practical activities	40	1