COURSE DESCRIPTION CARD - SYLLABUS

Course name
Control theory [S1AiR2P>TS]

Course

Field of study
Automatic Control and Robotics

Year/Semester
3/5

Area of study (specialization)
–

Profile of study
practical

Level of study
first-cycle

Course offered in
Polish

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
30

Laboratory classes
15

Other
0

Tutorials
15

Projects/seminars
0

Number of credit points

5,00

Coordinators

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Lecturers

Prerequisites

Knowledge: The student starting this subject should have basic knowledge of subjects such as Fundamentals of Automation, Mathematical Analysis, General Mechanics. Skills: Should have the ability to solve basic problems covered by the required knowledge and the ability to obtain information from the indicated sources. He should also understand the need to expand his competences. Social competences In addition, in terms of social competences, the student must present attitudes such as honesty, responsibility, perseverance, cognitive curiosity, creativity, personal culture, respect for other people.

Course objective

1. To provide students with knowledge of control theory and, in particular, knowledge related to dynamic control systems in order to prepare them substantively for issues related to their stability and the synthesis and analysis of control algorithms. 2. To develop students' skills related to modelling of dynamic systems, transformation of linear systems to equivalent forms, interpretation and study of controllability and observability of linear systems, study of state input and input-output stability, basic stability analysis according to the Lyapunov methodology. In addition, students will be skilled in the design of various observers and in solving selected optimisation problems in control.

Course-related learning outcomes

Knowledge:
1.has extended and in-depth knowledge of mathematics including algebra, geometry, analysis, probability and elements of discrete mathematics and logic, including mathematical methods and numerical methods necessary for the description and analysis of the properties of linear and basic nonlinear dynamic and static systems, description and analysis complex quantities, - [K1_W1]
2.description of random processes and uncertain quantities, description and analysis of combinational and sequential logic systems, description of control algorithms and analysis of the stability of dynamic systems, description, analysis and methods of signal processing in the time and frequency domains, numerical simulation of dynamic systems in the domain of continuous and time discreet; - [K1_W1]
3. has ordered advanced knowledge of the theory of linear dynamical systems, including selected modeling methods and the theory of stability; knows and understands the basic properties of linear dynamic elements in the time and frequency domain and the properties of selected non-linear elements; knows and understands the design techniques of linear control systems using the description in the state space - [K1_W14]
4. is familiar with the current state and the latest development trends in the field of automation and robotics; - [K1_W21]

Skills:
1. obtain information from literature, technical documentation and other sources, also in English; - [K1_U1]
2. can check the stability of linear and selected nonlinear objects and dynamical systems; - [K1_U12]
3. can design simple control systems for processes with one input and one output; can consciously use standard functional blocks of automation systems and shape dynamic properties of measurement paths; - [K1_U29]

Social competences:
1. is aware of the need for a professional approach to technical issues, meticulous study of the documentation and environmental conditions in which devices and their components may operate; is ready to comply with the principles of professional ethics and demand the same from others, respecting the diversity of views and cultures; - [K1_K5]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Formative assessment:
a) in the field of lectures: on the basis of answers to questions about the material discussed in previous lectures,
b) in terms of exercises and labs: based on the assessment of the current progress of the tasks being solved,
Summative assessment:
a) in the field of lectures, verification of the assumed learning outcomes is carried out by:
i. assessment of the knowledge and skills shown in the written exam in the subject, which consists of 10 tasks for which 20 points can be obtained (2 points per task).
ii. assessment of knowledge and skills on the basis of individual discussion of written results (additional control questions),
b) in the field of exercises and labs, verification of the assumed learning outcomes is carried out by:
i. assessment of the student's preparation for individual auditorium exercises and assessment of skills related to the implementation of laboratory exercises,
ii. continuous assessment during each class (oral answers) - rewarding the increase in the ability to use

the learned rules and methods,
iii. assessment of knowledge and skills related to the implementation of learning outcomes through one written test.
Obtaining additional points for activity during classes, especially for:
i. discuss additional aspects of the issue,
ii. effectiveness of applying the acquired knowledge while solving a given problem, iii. comments related to the improvement of teaching materials,
iv. identifying students' perceptual difficulties enabling ongoing improvement of the teaching process.

Programme content

Classification of dynamic systems, modelling of basic dynamic systems in the state space, linear systems and their normal forms, state and input transformations, equivalent forms, solution of state equations, selected properties of linear systems, controllability/observability, system stability, Lyapunov function, deterministic and stochastic observers, state and output feedback, selected control methods, elements of optimal control.

Course topics

The lecture program covers the following topics:
1. Dynamical systems and description of systems in the state space.
a) definition of a dynamical system
b) classes of dynamical systems
c) typical forms of dynamic systems in the continous time domain
d) the case of dynamic systems in the discrete time domain
e) LTI and LTV linear systems
f) relation between state space description and operator transmittance
g) example models
2. State and input transformations. Equivalent systems.
a) basic concepts
b) linear transformations and normal forms
c) transformation into controllable and observable normal forms (the LTI case)
d) transformation to modal form (diagonal and Jordan form, real Jordan form)
e) Kalman decomposition and minimal representation
3. Selected properties of linear systems
a) solution of the equation of state and properties of the transfer matrix
b) the concepts of controllability and observability
c) derivation of Kalman conditions
4. Selected stability issues
a) BIBO stability (of finite input finite output type), BIBS stability (of finite input finite state type)
b) Lyapunov stability
c) definition of positive, negative, semi-positive, semi-negative Lyapunov functions with examples for linear and non-linear systems
d) stability criteria for LTI systems
e) classes of trajectories for the solution of an autonomous LTI system
5. Observers for linear systems
a) derivation of the Luenberger observer and condition of applicability
b) Kalman filter as a case of stochastic observerc
c) interpretation of the Kalman filter equations
6. Dynamic correction and design of linear control systems
a) state feedback and output feedback
b) stabilizability condition
c) definition of input-output decoupling
d) design of a decoupling algorithm for a linear system
e) control algorithm using dynamic expansion
f) design of decoupling control algorithm
g) application of an observer application and separation principle
7 Elements of optimal control
a) Elements of discrete minimisation of functions of many variables with equality constraints
b) Definition of the Hamiltonian and Lagrange multipliers

c) Necessary and sufficient conditions for quadratic optimisation,
d) Pontriagin's maximum principle
e) description of dynamic programming method for discrete systems
f) quadratic optimisation of discrete systems using dynamic programming,
The lecture program covers the following topics:
1. Dynamical systems and description of systems in the state space.
a) definition of a dynamical system
b) classes of dynamical systems
c) typical forms of dynamic systems in the continous time domain
d) the case of dynamic systems in the discrete time domain
e) LTI and LTV linear systems
f) relation between state space description and operator transmittance
g) example models
2. State and input transformations. Equivalent systems.
a) basic concepts
b) linear transformations and normal forms
c) transformation into controllable and observable normal forms (the LTI case)
d) transformation to modal form (diagonal and Jordan form, real Jordan form)
e) Kalman decomposition and minimal representation
3. Selected properties of linear systems
a) solution of the equation of state and properties of the transfer matrix
b) the concepts of controllability and observability
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a) BIBO stability (of finite input finite output type), BIBS stability (of finite input finite state type)
b) Lyapunov stability
c) definition of positive, negative, semi-positive, semi-negative Lyapunov functions with examples for linear and non-linear systems
d) stability criteria for LTI systems
e) classes of trajectories for the solution of an autonomous LTI system
5. Observers for linear systems
a) derivation of the Luenberger observer and condition of applicability
b) full and reduced state observer
c) Kalman filter as a case of stochastic observerc
d) interpretation of the Kalman filter equations
6. Dynamic correction and design of linear control systems
a) state feedback and output feedback
b) stabilizability condition
c) definition of input-output decoupling
d) design of a decoupling algorithm for a linear system
e) control algorithm using dynamic expansion
f) design of decoupling control algorithm
g) application of an observer application and separation principle
7. Elements of optimal control
a) definition of optimal control and synthesis of optimal feedback
b) Pontriagin's maximum principle
c) description of dynamic programming method for discrete systems
d) synthesis of optimal linear-quadratic regulator
Auditorium exercises and laboratory exercises are conducted in the form of seven 2-hour classes each. In the auditorium exercises, students solve calculus tasks that cover the content taught in the lectures. The modelling of systems, transformation of dynamics into normal forms, the study of stability, controllability, and observability, as well as the design of state feedback and linear observers, are considered in detail. The laboratory includes numerical and simulation exercises that complement the content covered in the exercises, mainly due to the possibility of addressing more complex cases.

Teaching methods

1. Lecture: traditional presentation on the board illustrated with examples.
2. Auditorium exercises: solving problems, case studies.
3. Laboratory exercises involve working on a computer in a numerical/simulation environment, such as

Matlab/Simulink, Python, etc.

Bibliography

Basic:
1. T. Kaczorek, Teoria układów regulacji automatycznej, Wydawnictwa Naukowo - Techniczne, 1974
2. P. De Larminat, Yves Thomas, Automatyka - układy liniowe, tom 2, Sterowanie, Wydawnictwa Naukowo - Techniczne, 1983
3. P. De Larminat, Yves Thomas, Automatyka - układy liniowe, tom 3, Sterowanie, Wydawnictwa Naukowo - Techniczne, 1983
4. Jean-Jacques E. Slotine, Weiping Li, Applied Nonlinear Control, Prentice Hall, 1995
5. R. C. Dorf, R. H. Bishop, Modern Control Systems, tenth edition, Pearson Educational International, Prentice Hall, 2005

Additional:
1. A. Isidori, Nonlinear Control Systems, Springer Verlag, 1995

Breakdown of average student's workload

	Hours	ECTS
Total workload	125	5,00
Classes requiring direct contact with the teacher	62	2,50
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	63	2,50