POZNAN UNIVERSITY OF TECHNOLOGY

EUROPEAN CREDIT TRANSFER AND ACCUMULATION SYSTEM (ECTS)

COURSE DESCRIPTION CARD - SYLLABUS

Course name

Theory and optimization methods [S2AiR1E-ISLiSA>TiMO]

Course

Field of study
Automatic Control and Robotics

Year/Semester
1/2

Area of study (specialization)
Smart Aerospace and Autonomous Systems

Profile of study
general academic

Level of study
second-cycle

Course offered in
English

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
30

Laboratory classes
0

Other
0

Tutorials
15

Projects/seminars
0

Number of credit points

4,00

Coordinators

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Lecturers

Prerequisites

Knowledge: Student attending the course should have basic knowledge on linear algebra, matrix calculus, mathematical analysis and calculus, as well as graph theory. Skills: Student should be capable of solving basic tasks from algebra, mathematical analysis, and geometry, as well as should be able to find information in indicated sources. Student should also understand the necessity of extend his/her competences. Social competences: Student should have such attitudes as: honesty, responsibility, persistence, cognitive curiosity, creativity, personal culture, respect for other people.

Course objective

1. Transfer of basic knowledge on theory and methods of optimization, including linear and nonlinear optimization, discrete optimization, and activity networks models. 2. Developing students' capabilities of solving linear programming problems by the Simplex method and the graphical method, nonlinear programming problems by the Lagrange method and the KKT method, integer linear problems by the Gomory method, as well as performing time and time/cost analyses of activity networks by the CPM and CPM/MCX methods, respectively.

Course-related learning outcomes

Knowledge
1. has extensive and in-depth knowledge in selected areas of mathematics useful for formulating and solving complex tasks in the field of optimization theory - [K2_W1]
2. has extensive knowledge in the field of modelling and identifying linear and nonlinear decision problems - [K2_W5]
3. has well-established detailed theoretical knowledge in the field of designing and analyzing optimization methods - [K2_W8]
4. knows basic optimization methods used for solving mathematical programming problems (linear and nonlinear), integer linear programming problems, and activity networks analyses - [-]
Skills
1. is able to evaluate information from literature, databases and other information sources (in Polish and English) - [K2_U1]
2. is able to determine models of simple decision problems, and employ them to analyze and design optimization methods - [K2_U10]
3. is able to discern the nontechnical aspects, e.g. environmental, economic and legal ones, when formulating and solving optimization problems - [K2_U14]
4. is able to evaluate usefulness of methods and tools for solving an optimization problem - [K2_U22]
5. is able to correctly solve simple linear and nonlinear programming problems, integer linear programming problems, as well as perform time and time/cost analyses of activity networks - [-]
Social competences
1. understands the need to continue self-education and knows the possibilities of further education - raising professional, personal and social competences, is able to inspire and organize self-education of others - [K2_K1]
2. is aware of the necessity to approach technical aspects professionally, to acquaint themselves in detail with documentation and environmental conditions in which devices and elements will operate - [K2_K4]
3. is able to think and act in a creative and entrepreneurial way - [K2_K5]
4. is aware of the social role of technical university graduates, and especially understands the need of informing the society (especially through mass-media) about new developments, information and opinions in the field of optimization theory in relation to research and application and other aspects of engineering; attempts to present the information and opinions in a commonly-understood way, from different points of view - [K2_K6]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Learning outcomes presented above are verified as follows:
Knowledge acquired during lectures is verified by a 90-mins exam. The threshold for a positive grade is reaching 50% of points. Successive grades follow from applying a linear scale to the interval [50%; 100%] of points gained.
Skills acquired during tutorials are verified by one 90-mins test. The threshold for a positive grade is reaching 50% of points. Successive grades follow from applying a linear scale to the interval [50%; 100%] of points gained. The final grade follows from the grade obtained from the test and grades received for being active during tutorials.

Programme content

The programme contains chosen elements of theory and methods of optimization, including linear and nonlinear optimization, discrete optimization, and activity networks models.

Course topics

The programme content for lectures include:
Introduction to the theory of optimization. Mathematical programming problems. Linear programming (LP) problems. Formulations of LP problems – general, matrix, vector. Standard form of an LP problem. Properties of an LP problem in the standard form. Graphical interpretation of an LP problem. Solving LP problems by the graphical method. Formulations of linear decision models. Examples of linear models: continuous, discrete (integer), and binary (0-1 LP). Theoretical basics of the Simplex method. The Simplex table. The Simplex algorithm. Defining the initial feasible base solution. Solving LP problems by the Simplex method - examples. The artificial base method. The penalty factors method. Special cases of LP problems – an infinite optimal solution and a contradictory problem. Duality in linear programming. A pair of

symmetrical dual problems. The theorem on duality.
Nonlinear programming (NLP). Classification of NLP problems and methods. NLP problems that can be converted to LP – hyperbolic objective function, sum of absolute values. The Charnes-Cooper method. Convex programming problems. Standard form of an NLP problem. NLP problems with equation constraints. The Lagrange function. The Lagrange conditions. The Lagrange theorem. The Lagrange method. NLP problems with inequation constraints. The Karush-Kuhn-Tucker (KKT) conditions. The KKT theorem. The KKT method. Solving NLP problems – examples.
Discrete optimization. Integer linear programming (ILP) problems. The idea of cutting planes method. The Gomory algorithm. Solving ILP problems – examples.
Activity networks. Activity-on-Arc (AoA) and Activity-on-Node (AoN) representations. Properties of an AoA graph. Dummy activities and dummy nodes. Constructing an AoA network. The algorithm for topological numbering of nodes and examining acyclicity of a graph. Defining the earliest and the latest possible occurrence time of a node. Critical nodes. Activity floats: free, safety, independent, and total. A critical activity. Critical path in a graph. The properties of the critical path. Time analysis of an activity network – the Critical Path Method (CPM). Finding the minimum execution time of a project by the CPM method – examples. The time/cost trade-off model. The average cost rate. Time/cost analysis of an activity network – the Critical Path Method/Minimum Cost Expediting (CPM/MCX) method. Finding the minimum cost of the activity network compression by the CPM/MCX method – examples.
Project scheduling under limited resources. Renewable resources – definition and examples. Resource-Constrained Project Scheduling Problem (RCPSP). Activity list (AL). Serial Schedule Generation Scheme (SGS). Finding a time-optimal schedule in an RCPSP – examples.
Tutorials are carried out in the form of seven 90-mins meetings. During tutorials students solve problems from the material presented at lectures. The programme content for tutorials include: linear programming, nonlinear programming, integer linear programming, and activity network analyses.

Teaching methods

1. Lecture: multimedia presentation with additional examples shown on a board
2. Tutorials: solving optimization problems, practical exercises, discussion

Bibliography

Basic
1. Linear and Nonlinear Programming, Fourth Edition, Luenberger D.G., Springer, 2015.
2. Project Scheduling - A Research Handbook, Demeulemeester E.L., Herroelen W.S., Kluwer, 2002.
Additional
1. Badania operacyjne, Siudak M., Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 1994.
2. Badania operacyjne w przykładach i zadaniach, Jędrzejczak Z., Skrzypek J., Kukuła K., Walkost A., PWN, Wyd. IV zmienione, Warszawa, 2002.
3. Badania operacyjne dla informatyków, Błażewicz J., Cellary R., Słowiński R., Węglarz J., WNT, 1983.
4. Optymalizacja, Kusiak J., Danielewska-Tułecka A., Oprocha P., PWN, 2009.

Breakdown of average student's workload

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