POZNAN UNIVERSITY OF TECHNOLOGY

EUROPEAN CREDIT TRANSFER AND ACCUMULATION SYSTEM (ECTS)

COURSE DESCRIPTION CARD - SYLLABUS

Course name
Elements of convex optimization [S1SI1E>EOW]

Course

Field of study
Artificial Intelligence

Year/Semester
2/4

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
English

Form of study
full-time

Requirements
elective

Number of hours

Lecture
15

Laboratory classes
0

Other
0

Tutorials
15

Projects/seminars
0

Number of credit points

3,00

Coordinators

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Lecturers

Prerequisites

A student starting this course should have basic knowledge of: a) linear algebra and geometry (interpretation of vectors and matrices, simple operations on vectors and matrices), b) mathematical analysis (properties and derivatives of basic analytical functions). They should also have the ability to design, implement and test simple computer programs (in any programming language) performing basic vector-matrix operations. In terms of social competences, the desired features include: cognitive curiosity and perseverance in the pursuit of expanding one's knowledge.

Course objective

Presentation of selected problems of continuous optimization (mainly convex, unconstrained), which is the substantive basis for the efficient solution of many tasks in modern data analysis and engineering. The presented course focuses on the classic problems of continuous optimization, dealing with model problems whose solutions are relatively easy thanks to numerous assumptions (unimodality, convexity), but which can be used to construct solutions to more complex, practical problems.

Course-related learning outcomes

Knowledge

1. Has an extended, in-depth knowledge of mathematics, which is helpful in formulating and solving complex computer and IT tasks concerning continuous optimization with applications to data analysis
2. Has a detailed, well-grounded knowledge of fundamental computer science problems within the scope of optimization techniques
3. Knows and understands the basic techniques, methods, algorithms, and tools used for solving computing problems in convex optimization with emphasis on the applications to data analysis and artificial intelligence
4. Has a basic knowledge of key directions and the most important successes of artificial intelligence understood as an essential sub-domain of computer science, making use of the achievements of other scientific disciplines and providing solutions with a high practical impact

Skills
1. Can formulate and solve complex problems within the scope of computer science and, in particular, artificial intelligence by applying appropriately selected methods (including analytical, simulation, or experimental approaches)
2. Can carry out a critical analysis and an assessment of the functioning of computer systems, data analysis and AI methods in terms of convex optimization
3. Can adapt the existing algorithms as well as formulate and implement novel optimization algorithms, including the algorithms typical for AI and data analysis, using at least one well-known tool
4. Can retrieve, analyze and transform different types of data, protect it against undesired access, and carry out data synthesis to knowledge and conclusions useful for solving a variety of problems that occur in the work of a computer scientist - a specialist in the field of AI, including issues of industrial, business, and administrative nature.

Social competences
1. Understands that knowledge and skills quickly become outdated in computer science and, in particular, AI, and perceives the need for constant additional training and raising one's qualifications.
2. Is aware of the importance of scientific knowledge and research related to computer science and AI in solving practical problems which are essential for the functioning of individuals, firms, organizations, as well as the entire society.

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Formative assessment:
(a) lectures: on the basis of answers to questions on the material discussed in previous lectures;
b) for laboratories: on the basis of the assessment of the current progress of tasks
Summative evaluation:
a) lectures: the knowledge acquired during the lecture is verified by a written test consisting of a number of optimization questions. The condition for passing the course is to obtain at least 50% of the points
b) laboratories: learning outcomes are verified through a test and continuous assessment at each class. The condition to obtain a positive evaluation from the classes is to obtain at least 50% of points.

Programme content

The course syllabus includes the following topics:
The concept of optimization, mathematical optimization problem and its components (objective function and constraints), local and global minima.
One-dimensional optimization: analytical solutions, uniform search, optimization of unimodal functions: dichotomous search and golden section method, optimization of differentiable functions: bisection method and Newton's method.
Mathematical fundamentals: vectors and matrices, and operations on them, scalar product and outer product, matrix determinant, inverse of a matrix, eigenvectors and eigenvalues of symmetric matrices, quadratic form, partial derivatives, gradient, chain rule, directional derivative, derivatives of higher orders, hessian, local minimum, Taylor polynomials.
Convexity: convex combinations, convex sets, convex functions, minimization of convex functions, differentiable convex functions, examples of convex functions, operations preservng convexity.
Methods of decent direction: surface and contour plots of functions of two arguments, descent methods, gradient descent algorithm, the steepest descent algorithm, convergence for quadratic function, Armijo's rule, Newton-Raphson method, modifications of Newton-Raphson method: variable step length, Levenberg-

Marquardt method, conjugate gradient method, analysis of conjugate gradient method for quadratic function, Fletcher-Reeves and Polak-Ribière methods.
Linear regression, stochastic gradient descent, advantages and disadvantages of the method, applications in practice, convergence

Course topics

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Teaching methods

Lecture: multimedia presentation with additional examples solved on the board
Laboratories: solving tasks and implementing their solutions, performing experiments, discussing results and results

Bibliography

Basic
1. S. Boyd, L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004
2. D. Luenberger, Y. Ye: Linear and Nonlinear Programming, Springer, 2016
3. M. Bazaraa, H. Sherali, C. Shetty: Nonlinear Programming: Theory and Algorithms. Willey, 2006

Additional
1. J. Kusiak, A. Danielewska-Tułecka, P. Oprocha: Optymalizacja. PWN, 2009
2. R. Wit: Metody Programowania Nieliniowego. WNT, 1986
3. A. Stachurski: Wprowadzenie do optymalizacji. Oficyna Wyd. PW, 2009

Breakdown of average student's workload

	Hours	ECTS
Total workload	75	3,00
Classes requiring direct contact with the teacher	30	1,50
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	45	1,50