Syllabus
Course Program

Methods of Optimization

Specialty
113 Applied mathematics

Institute
Educational and Scientific Institute of Computer Science and Information Technology.

Educational program
Intelligent Data Analysis

Department
Department of Computer Mathematics and Data Analysis.

Level of education
Bachelor's level

Course type
Special (professional), Mandatory.

Semester
5

Language of instruction
Ukrainian

Lecturers and course developers

Oleksii Haluza

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Doctor of Science (Physics&Mathematics), Full Professor, Professor of Computer Mathematics and Data Analysis Department.

Work experience – more than 20 years. The author of many scientific, educational, and methodological works. Leading lecturer in the courses: «Algorithmization and Programming», « Methods of Optimization», «Machine Learning», etc.

More about the lecturer on the department's website

General information

Summary

Theoretical approaches and numerical methods for solving the main types of continuous nonlinear optimization problems are considered: one-dimensional optimization, multi-dimensional unconstrained optimization, and multi-dimensional constrained optimization.

Course objectives and goals

The discipline is aimed at acquiring the necessary competencies in optimization methods: 1) studying and mastering the theoretical foundations and practical implementation features of mathematical programming methods that are most commonly used in solving optimization problems in engineering, economics, planning, and design; 2) developing practical skills in selecting optimal methods for solving specific problems and utilizing optimization methods and algorithms in engineering activities; 3) instilling skills for the practical application of theoretical knowledge.

Format of classes

Lectures, laboratory classes, consultations, self-study. Final control in the form of an exam.

Competencies

GC 1. Ability to learn and master modern knowledge.
GC 2. Ability to apply knowledge in practical situations.
GC 3. Ability to generate new ideas (creativity).
GC 6. Capability of abstract thinking, analysis and synthesis.
SC 2. Ability to perform tasks formulated in mathematical form.
SC 4. Ability to select and apply numerical methods to solve optimization problems.
SC 11. Ability to create documents of established reporting, use of regulatory documents.

Learning outcomes

LO 1. Demonstrate knowledge and understanding of basic concepts, principles, theories of applied mathematics and use them on practice.
LO 3. Formalize tasks formulated in the language of a particular subject fields; formulate their mathematical formulation and choose rational method of solution; solve the resulting problems with analytical and numerical methods, evaluate the accuracy and reliability of the results obtained.
LO 5. Be able to develop and use algorithms in practice, associated with the approximation of functional dependencies, numerical differentiation and integration, solution of algebraic, differential and integral systems of equations, solving of boundary value problems, searching for optimal solutions.
LO 10. To have methods for choosing rational methods and algorithms for solving mathematical optimization problems, research operations, optimal management and decision-making, and data analysis.
LO 14. Demonstrate the ability to self-learn and continue professional development.
LO 15. Be able to organize your own activities and get results within a limited time frame.

Student workload

The total volume of the course is 120 hours (4 ECTS credits): lectures – 30 hours, laboratory classes – 30 hours, self-study – 60 hours.

Course prerequisites

“Mathematical Analysis. Parts 1-3,” “Algorithmization and Programming,” “Linear Algebra,” “Analytic Geometry,” “Numerical Methods.”

Features of the course, teaching and learning methods, and technologies

In teaching this discipline, methods such as gamification and peer-to-peer learning are employed. Learning management systems (LMS) are used throughout the educational process.

Program of the course

Topics of the lectures

Topic 1: Introduction
Substantive formulation of the optimization problem. Mathematical formulation of the optimization problem. Concept of the objective function and constraints. Classification of optimization problems.

Topic 2: One-Dimensional Optimization
Methods of sequential search (dichotomy methods, golden section method, Fibonacci method); point evaluation methods (quadratic interpolation method, cubic interpolation method); methods for localizing the minimum.

Topic 3: Multi-Dimensional Unconstrained Optimization
Necessary and sufficient conditions for the extremum of a function of several variables. General scheme of descent methods; steepest descent method. Newton's method. Quasi-Newton methods. Conjugate direction methods. Zero-order methods.

Topic 4: Multi-Dimensional Constrained Optimization
Necessary and sufficient conditions for the constrained extremum of a function of several variables. Methods of possible directions; projective methods; penalty and barrier function methods.

Topics of the workshops

Workshops are not included within the framework of this discipline.

Topics of the laboratory classes

Topic 1: Sequential Search Methods
Topic 2: Point Evaluation Methods
Topic 3: Steepest Descent Method
Topic 4: Newton's Methods
Topic 5: Quasi-Newton Methods
Topic 6: Conjugate Direction Methods
Topic 7: Zero-Order Methods
Topic 8: Projective Methods
Topic 9: Penalty Function Methods

Self-study

The course involves completing individual assignments, the results of which are automatically checked using LMS tools and monitored and evaluated by instructors. Students are also recommended additional materials (videos, articles) for independent study.

Non-formal education

As part of non-formal education in accordance with the relevant regulation (http://surl.li/pxssv), the educational component or its individual topics may be considered in cases of independent completion of professional courses/training, obtaining civic education, online education, professional internships, etc.

Course materials and recommended reading

Basic literature

1. Belegundu A. D., Chandrupatla T. R. Optimization Concepts and Applications in Engineering. - Cambridge: Cambridge University Press, 2019. - 464 p. ISBN: 9781108347976
https://doi.org/10.1017/9781108347976
2. A. Antoniou, W.-S. Lu. Practical Optimization. – New York, NY: Springer, 2021. – 722 p. ISBN 978-1-0716-0841-8
https://doi.org/10.1007/978-1-0716-0843-2
3. A. Beck. Introduction to Nonlinear Optimization: Theory, Algorithms, and Applications with Python and MATLAB. - Philadelphia: SIAM, 2023. - 351 p. ISBN 978-161-197-761-5
https://doi.org/10.1137/1.9781611977622

Additional literature

1. F. Hillier, G. Lieberman. Introduction to Operations Research. – McGraw-Hill Higher Education, 2021. – 1088 p. ISBN 978-125-987-299-0
2. J. P. Wheeler. An Introduction to Optimization with Applications in Machine Learning and Data Analytics. -CRC Press, 2024. – 473 p. ISBN 978-036-742-550-0.
https://doi.org/10.1201/9780367425517

Internet resources

1. https://en.wikipedia.org/wiki/Mathematical_optimization
2. https://machinelearningmastery.com/optimization-for-machine-learning/

Assessment and grading

Criteria for assessment of student performance, and the final score structure

100% of the final grade consists of assessment results in the form of an exam (40%) and ongoing assessment (60%).

Exam: written assignment (2 theoretical questions and a problem) and an oral presentation.

Ongoing Assessment: grades for laboratory work, 2 control tests, and a calculation task.

Grading scale

Total points	National	ECTS
90–100	Excellent	A
82–89	Good	B
75–81	Good	C
64–74	Satisfactory	D
60–63	Satisfactory	E
35–59	Unsatisfactory (requires additional learning)	FX
1–34	Unsatisfactory (requires repetition of the course)	F

Norms of academic integrity and course policy

The student must adhere to the Code of Ethics of Academic Relations and Integrity of NTU «KhPI»: to demonstrate discipline, good manners, kindness, honesty, and responsibility. Conflict situations should be openly discussed in academic groups with a lecturer, and if it is impossible to resolve the conflict, they should be brought to the attention of the Institute's management.
Regulatory and legal documents related to the implementation of the principles of academic integrity at NTU «KhPI» are available on the website: http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/

Approval

Approved by

Date, signature
29.08.2024  Head of the Department
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29.08.2024  Guarantor of the Educational Program
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