Syllabus
Course Program

Operations Research

Specialty
122 – Computer Science

Institute
Institute of Computer Science and Information Technology

Educational program
Computer Science and Intelligent Systems

Department
Software Engineering and Management Intelligent Technologies (321)

Level of education
Bachelor's level

Course type
Special (professional), Mandatory

Semester
6-7

Language of instruction
English, Ukrainian

Lecturers and course developers

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More about the lecturer on the department's website

Olena Nikulina
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Doctor of Technical Sciences, Professor, Professor of the Department of Software Engineering and Information Technologies of NTU "KhPI"

Prepared and published more than 100 scientific and educational works (Google Scholar: https://scholar.google.com/citations?user=ZEe2GlcAAAAJ; ORCID https://orcid.org/0000-0003-2938-4215; Scopus: https://www.scopus.com/authid/detail.uri?authorId=57541344600).
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Doctor of Technical Sciences, Professor, published more than 90 scientific papers, basic courses " Software Architecture Basics", "Discrete Mathematics".

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Oksana Ivashchenko

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Teaching experience since 2018. Number of scientific and educational publications – 8, among them: monographs – 1, works in Scopus и Web of Science – 1 (https://scholar.google.com.ua/citations?user=iwV1LAUAAAAJ; https://orcid.org/0000-0003-3636-3914).
Research areas: Data mining, web mining. Taught courses: “Data mining and knowledge extraction”, “Data mining”, “Fundamentals of intelligent systems design”. Curator of the joint Master’s Program “Information systems and technologies in entrepreneurship” between NTU “KhPI” and the School of Economics and Management in Public Administration in Bratislava (VŠEMvs).
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General information

Summary

The course involves the application of the methodology of system analysis for the systematic study of deterministic models of operations, the acquisition of the ability to describe subject areas, apply the principles of a systematic approach to modeling and studying operations of various nature.
The course examines the concepts of operations, operation models, stages of its development, classification of economic and mathematical models and optimization methods.
In the course of studying the course, students develop the ability to build a mathematical model of the problem of studying an operation, use modern analytical and computational tools of linear programming, find an optimal solution, adjust the model and solution based on new knowledge about the problem and operation, and apply modern software tools for studying operations.
The subject of the discipline is the technology and implementation of typical and modern methods of operations research for solving technical, physical and economic problems.

Course objectives and goals

The course aims to train specialists who are capable of: system thinking, applying the methodology of system analysis for operations research; formalized description of operations research problems in organizational, technical and socio-economic systems for various purposes, determining their optimal solutions; use of modern methods of mathematical modeling of operations, development of models and algorithms for numerical solution of operations research problems; research of mathematical models of operations, justification of
The course aims to form a set of knowledge and skills in the field of operations research and optimization methods, and to acquire skills in the practical use, formulation and solution of optimization problems. It involves the study of numerical methods of one-dimensional and multidimensional unconditional optimization, as well as global search methods and genetic algorithms.

Format of classes

Lectures, laboratory classes, calculation assignment (6th semester), course work (7th semester), independent work, consultations. Final control - exam (6th semester), test (7th semester).

Competencies

GC1. Ability to think abstractly, analyze and synthesize.
GC2. Ability to apply knowledge in practical situations.
GC3. Knowledge and understanding of the subject area and understanding of professional activities.
GC6. Ability to learn and master modern knowledge.
PC1. Ability to mathematically formulate and study continuous and discrete mathematical models, justify the choice of methods and approaches for solving theoretical and applied problems in the field of computer science, analysis and interpretation.
PC3. Ability to think logically, build logical conclusions, use formal languages and models of algorithmic computing, design, develop and analyze algorithms, evaluate their effectiveness and complexity, solvability and intractability of algorithmic problems for adequate modeling of subject areas and creation of software and information systems.
PC4. Ability to use modern methods of mathematical modeling of objects, processes and phenomena, to develop models and algorithms for numerical solution of mathematical modeling problems, to take into account the errors of approximate numerical solution of professional problems.
PC5. Ability to carry out a formalized description of the tasks of researching operations in organizational, technical and socio-economic systems for various purposes, to determine their optimal solutions, to build models of optimal management taking into account changes in the economic situation, to optimize management processes in systems of various purposes and hierarchy levels.
PC6. Ability to think systematically, apply the methodology of system analysis to study complex problems of different nature, methods of formalizing and solving systemic problems with conflicting goals, uncertainties and risks.
PC7. Ability to apply the theoretical and practical foundations of modeling methodology and technology to study the characteristics and behavior of complex objects and systems, to conduct computational experiments with processing and analysis of results.

Learning outcomes

PLO2. To use the modern mathematical apparatus of continuous and discrete analysis, linear algebra, analytical geometry in professional activities to solve theoretical and applied problems in the design and implementation of information objects.
PLO5. Design, develop and analyze algorithms for solving computational and logical problems, evaluate the effectiveness and complexity of algorithms based on the use of formal models of algorithms and computable functions.
PLO6. To use methods of numerical differentiation and integration of functions, solution of ordinary differential and integral equations, features of numerical methods and possibilities of their adaptation to engineering problems, to have skills in software implementation of numerical methods.
PLO7. Understand the principles of modeling organizational and technical systems and operations; use methods of researching operations, solving single and multi-criteria optimization problems of linear, integer, nonlinear, stochastic programming.
PLO8. To use the methodology of system analysis of objects, processes and systems for the tasks of analysis, forecasting, management and design of dynamic processes in macroeconomic, technical, technological and financial objects.

Student workload

The total volume of the course is 240 hours (8 ECTS credits): lectures - 64 hours, laboratory classes - 48 hours, self-study - 128 hours.

Course prerequisites

The basis for studying the discipline is the general mathematical training of students and the content of the disciplines "Higher Mathematics", "Algorithmization and Programming", "Numerical Methods", as well as the use of mathematical packages.

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

Teaching and learning methods:

interactive lectures with presentations, discussions, laboratory classes, teamwork, case method, student feedback, problem-based learning.
Forms of assessment:
written individual assignments for laboratory work (CAS), assessment of knowledge in laboratory classes (CAS), express surveys (CAS), online tests (CAS), final/semester control in the form of a semester exam, according to the schedule of the educational process (FAS).

Program of the course

Topics of the lectures

Semester 6

Topic 1: Peculiarities of implementing the principles of a systematic approach in the process of operation research.
Topic 2. Examples of substantive tasks of operations research.
Topic 3. General properties of linear programming problems.
Topic 4. Analytical apparatus of linear programming
Topic 5. Finite element methods for solving linear programming problems.
Topic 6. The problem of choosing an initial reference plan, methods of its solution.
Topic 7. Modern computing apparatus of linear programming.
Topic 8. The theory of duality in linear programming.
Topic 9. Post-optimization analysis of operations research problems.
Topic 10. Operations research using transportation problems.
Topic 11. Methods for solving transportation problems.
Topic 12: Methods of parametric programming.

Semester 7

Topic 1. Subject of optimization methods. Concepts and definitions of optimization theory. Examples of optimization problems. Classification of optimization methods.
Topic 2. Methods of one-dimensional search. Sven's method. The method of dichotomy. Method of dividing a segment in half.
Topic 3. Methods of one-dimensional search. The method of the golden ratio. Method of step adaptation.
Topic 4. Methods of multidimensional search. Methods of the first order. Cauchy method.
Topic 5. Gradient methods. Methods of conjugate direction. Fletcher-Reeves and Polak-Ribier methods.
Topic 6. Newton's method. Quasi-Newtonian methods.
Topic 7. Direct search methods. The simplex method. The method of deformed polygon
Topic 8. Basic theoretical provisions. Weyl's method. Genetic algorithms.

Topics of the workshops

Workshops are not provided within the discipline.

Topics of the laboratory classes

Semester 6

Topic 1: Study of the principles of the systematic approach.
Topic 2. Study of substantive tasks of operations research.
Topic 3. Geometric interpretation of linear programming problems.
Topic 4. Properties of reference plans of a binary pair of linear programming problems.
Topic 5. The first and second algorithms of the method of sequential plan improvement.
Topic 6. The first and second algorithms of the M-method for solving linear programming problems.
Topic 7. Modern software tools for solving linear programming problems.
Theme 8: Investigation of the properties of solutions of a binary pair of linear programming problems.
Topic 9: Numerical experiments on post-optimization analysis of substantive problems of operations research.
Topic 10. Modeling of operations by transportation problems.
Topic 11. The method of potentials for solving closed transportation problems.
Topic 12: Investigation of stability of operations research problems.

Semester 7

Topic 1: Development of generic programs for one-dimensional search methods.
Topic 2. Sven's method. The method of dichotomy. The method of dividing a segment in half.
Topic 3. The method of the golden ratio. The method of step adaptation. The Fibonacci method.
Topic 4. Numerical finding of the gradient and hessian. Programming of the Cauchy method.
Topic 5. Programming of Fletcher-Reeves and Polak-Ribier methods.
Topic 6. Programming of second-order methods.
Topic 7. Programming of the deformed polygon method.
Topic 8: Programming the Weyl method and genetic algorithms.

Self-study

Semester 6

Study of the systematic principle, integration principle, three-level consideration principle and formalization principle.
Substantive problems of operations research: optimal planning of the product range of an IT industry enterprise; optimal use of resources of an IT industry enterprise; optimal purchase of computers by an IT industry enterprise; problems of a cheap diet, a cheap animal diet, a cheap technological mixture, etc.
Study of technology for solving linear programming problems based on their geometric interpretation.
Study of the technology of solving linear programming problems based on the theorem of the existence of a reference solution.
Study of the technology of solving linear programming problems by the first and second algorithm of the method of sequential improvement of the plan.
Study of modern software tools for solving linear programming problems.
Study of modern software tools for solving linear programming problems.
Study of the analytical apparatus of linear programming.
Study of modern technologies for post-optimization analysis of operations research problems
Study of technologies for modeling operations by transportation problems.
Study of technologies for solving closed-loop transportation problems.
Study of technologies for studying the stability of linear programming problems.

Semester 7

Extremum of a function of one variable.
Unimodal functions and their properties.
The method of uniform search.
The Fibonacci method.
Methods of interpolation and approximation.
Methods of quadratic and cubic interpolation.
Hessian matrix.
Properties of conjugate vectors.
First-order optimality condition.
The condition of optimality of the second order.
Marquardt's method.
Rafson's method.
The Davidson-Fletcher-Powell method.
The Broyden-Goldfarb-Shannon method.
Particle swarm method.
Random search methods.

Individual assignment

The plan provides for a calculation task in the 6th semester and a course work in the 7th semester.
Calculation task
During the calculation task, it is necessary to design and implement a graphical user interface program that allows you to solve a linear programming problem.
The topic of the calculation task: development of a graphical user interface application program for finding a solution to a linear programming problem using the first or second algorithm of the method of sequential plan improvement, the M-method, etc.
Course work

During the course work, you need to design and implement a graphical user interface program that allows you to solve a multidimensional optimization problem.
The topic of the course work: development of a graphical user interface application program for finding the minimum of a function using various multidimensional optimization methods.

Evaluation

Evaluation is based on the following criteria:
1) understanding, degree of mastery of the theory and methodology of the problems under consideration;
2) the degree of mastery of the work material;
3) implementation of a software product on the topic of the course work;
4) testing and demonstration of a graphical user interface program that allows you to solve a specific data processing task;
5) logic, structure, style of presentation of material in written works and in classroom presentations, ability to justify one's position, generalize information and draw conclusions.
The grade of "excellent" is assigned if the student's completed assignment or oral response meets all five of these criteria.
The absence of a particular component reduces the grade by the corresponding number of points.
The assessment pays attention to the quality and independence of the student's work, as well as the timeliness of submitting the completed assignments to the teacher (according to the schedule of the educational process). If any of the requirements are not met, the grade will be lowered.

Course materials and recommended reading

Key literature

1. Lavrov, E. A., Perkhun, L. P., Shendrik, V. V. (2017). Mathematical methods of operations research. Sumy: Sumy State University.
2. Synieglazov, V. M., Zelenkov, O. A., Askerov, S. I. (2018). Mathematical methods of optimization: Study guide. Kyiv: Education of Ukraine.
3. Lysenko, O. I., Alekseeva, I. V. (2016). Operations research. Lecture notes. Kyiv: NTUU "KPI".
4. Severin V.P., Nikulina O.M. Methods of one-dimensional search: in the course "Methods of optimization." - Kh. NTU "KPI", 2013. - 124 p.
5. Severyn, V.P., Nikulina, O.M. (2023) Methods and algorithms of multidimensional unconditional optimization. Kharkiv : NTU "KhPI".
6. Nesterov Y. Lectures on Convex Optimization. - Springer, 2018. - 590 p.
7. Mykel J., Tim A. Algorithms for Optimization - MIT Press, 2019. - 520 p.
8. Andrunyk V.A., Vysotska V.A., Pasichnyk V.V., Chirun L.B., Chirun L.V. Numerical Methods in Computer Science: A Study Guide - Lviv: Novyi Svit 2000 Publishing House, 2020. 470 p.

Additional literature

1. Garcia Marquez Fausto Pedro, Lew Benjamin. (2021). Introduction to internet of Things in Mamagement science and operathions research inplented studies.
2. Larionov, Y. T., Levikin, V. M., Khazhmuratov, P. V. (2005). Operations research in information systems. Kharkiv: SMIT Company.
3. Luenberger, D. G. (2021). Linear and nonlinear programming.
4. Gerald J. Libetman, Frederick S. Hillier. (2019). Operathions research.
5. Zaychenko, Y. P. (2003). Operations research. (6th ed.). Kyiv: Slovo.
6. Bundy B. Optimization methods. Introductory course. - Edward Arnold, 1984. - 136 p.
7. Himmelblau D. Applied nonlinear programming. - McGraw-Hill, 1972. - 498 p.
8. Lysenko O.I., Tachynina O.M., Alekseeva I.V. Mathematical methods of modeling and optimization. - K.: NAU, 2017. - 212 p.
9. Lazarev Y. F. MATLAB Handbook / Electronic textbook for course and diploma design. - K.: NTUU "KPI", 2013. - 132 p.

Assessment and grading

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

Semester 6

100% final assessment in the form of an exam (30%) and a current assessment (70%).
30% exam: semester exam, according to the schedule of the educational process
70% current assessment:
- 30% assessment of tasks in laboratory work;
- 30% intermediate control (2 tests);
- 10% calculation task.

Semester 7

100% final assessment in the form of a test (30%) and current assessment (70%).
30% test: semester test, according to the schedule of the educational process
70% current assessment:
- 30% evaluation of tasks in laboratory work;
- 30% intermediate control (2 tests);
- 10% course work.

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	08.06.2023	Head of the department Ihor HAMAIUN
	08.06.2023	Guarantor of the educational program Andrii KOPP