Syllabus
Course Program

Discrete Structures And Data Structures

Specialty
113 Applied mathematics

Institute
Educational and Scientific Institute of Computer Science and Information Technology

Educational program
Intelligent Data Analysis

Department
Computer Mathematics and Data Analysis

Level of education
Bachelor's level

Тип дисципліни
Special (professional), Mandatory

Semester
3

Language of instruction
Ukrainian

Lecturers and course developers

Sergii Iglin

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Candidate of technical sciences, associate professor, professor of the department of computer mathematics and data analysis.

Author of more than 120 scientific and methodical papers. Basic courses: higher mathematics, linear programming, graph theory, numerical methods. More about the lecturer on the website
http://iglin.epizy.com

General information

Summary

The course is aimed at mastering the theoretical foundations of linear programming and graph theory. Graphical and simplex methods, duality theory, transport problem, integer programming are considered in linear programming. For undirected graphs, tasks of packing, covering, dominating sets, colorings, matroids and minimal spanning trees, cycles and cocycles are solved. For digraphs - strongly connected components, shortest paths, flows and cuts, PERT project management task.

Course objectives and goals

Acquisition of necessary competencies in the field of discrete structures and data structures. Formation of students' basic theoretical knowledge and practical skills in solving problems of linear programming and graph theory. Development of students' skills in building mathematical models and their research using modern methods and tools.

Format of classes

Lectures, practical classes and laboratory works, self-study, calculation tasks, consultations. Final control in the form of an exam.

Competencies

GC 4. The ability to be critical and self-critical.

SC 3. The ability to choose and apply mathematical methods for solving applied problems, modeling, analysis, design, management, forecasting, decision-making.
SK 4. Ability to choose and apply numerical methods for solving optimization problems.
SK 5. Ability to develop algorithms and data structures, software tools and software documentation.
SK 14. The ability to understand the statement of the task, formulated in the language of a certain subject area, to search and collect the necessary initial data.
SK 18. Ability to choose and apply mathematical models and methods for statistical and intellectual analysis of data in conditions of uncertainty.
SK 22. Ability to use information technologies for statistical and intellectual data analysis, forecasting, decision-making, information search and knowledge extraction.

Learning outcomes

LO 3. Formalize tasks formulated in the language of a specific subject area; formulate their mathematical statement and choose a rational solution method; to solve the obtained problems by analytical and numerical methods, to evaluate the accuracy and reliability of the obtained results.
LO 4. Perform mathematical description, analysis and synthesis of discrete objects and systems, using the concepts and methods of discrete mathematics and the theory of algorithms.
LO 9. Build algorithms that are effective in terms of calculation accuracy, stability, speed, and consumption of system resources for numerical research of mathematical models and solving practical problems.
LO 11. To be able to apply modern technologies of programming and software development, software implementation of numerical and symbolic algorithms.
LO 22. To know and understand the methods of solving mathematical problems of intellectual information search and knowledge extraction.

Student workload

The total volume of the course is 180 hours (6 ECTS credits): lectures – 42 hours, practical classes – 16 hours, laboratory classes – 32 hours, self-study – 90 hours.

Course prerequisites

"Mathematical analysis", "Mathematical logic".

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

Programming skills are required. Study materials are available to students on the teacher's website.

Program of the course

Topics of the lectures

Topic 1. General solution of SALE. Change of the basis. Plane, line, segment and other objects in E_n. Convex areas and functions.
Topic 2. The extremum of a function of several variables. The method of uncertain Lagrange multipliers. Penalty function method. Karush-Kuhn-Tucker conditions.
Topic 3. Formulation of the linear programming problem. Different forms of its wroting.
Topic 4. Basic properties of the linear programming problem. Graphic method of solution.
Topic 5. Theoretical foundations of the simplex method. Corner points and permissible reference solutions.
Topic 6. Simplex transformations.
Topic 7. Peculiarities of solving problems by the simplex method: unlimited domain of the solution, non-unique solution, degenerate solutions.
Topic 8. Two-step simplex method (artificial basis method).
Topic 9. Elements of duality theory. Symmetric dual problems. Duality theorems. Asymmetric dual problems.
Topic 10. Transport problem of linear programming: its formulation and features. Permissible reference solutions in the transport problem, different methods of finding them.

Topic 11. Load transfer by cycle. Properties of cycles of the transport problem. The potentials method.
Topic 12. Integer linear programming. Graphical method. Gomory cutting-plane method.
Topic 13. Basic definitions of graph theory. Matrix representations of graphs.
Topic 14. Packing and covering as binary linear programming problems. Mutual duality of packing and covering tasks.
Topic 15. Dominant sets and cliques as binary linear programming problems. Their dual tasks.
Topic 16. Minimum regular coloring of graph vertices as a problem of integer linear programming.
Topic 17. The minimum regular coloring of an edge graph as a problem of integer linear programming.
Topic 18. Basic definitions of matroid theory. Definition of a matroid through independent sets. The partition matroid.
Topic 19. Greedy algorithm. Rado-Edmonds theorem. Graph matroid.
Topic 20. Minimum spanning trees. Kruskal's and Prim's algorithms.
Topic 21. Eulerian cycles. Fleury's method.
Topic 22. Hamiltonian cycles. Ore's and Dirac's theorems.
Topic 23. A fundamental system of cycles, its construction from a minimal spanning tree. Definition of matroid by cycles.
Topic 24. A fundamental system of cocycles, its construction from a minimal spanning tree. Definition of a matroid by cocycles.
Topic 25. Binary relations, their classification. Binary relation of mutual reachability in digraph.
Topic 26. Strongly connected digraph components, their definition and partial ordering.
Topic 27. The shortest path. Algorithms of Dijkstra and Floyd-Warshall.
Topic 28. Metric characteristics of a graph.
Topic 29. Maximum flow and minimum cut in the network.
Topic 30. PERT network diagrams.
Topic 31. Graph isomorphism.
Topic 32. Graph invariants.

Topics of the workshops

Topic 1. The Jordan-Gauss method of solving SALE. Change of the basis. Graphical method of solving the linear programming task.
Topic 2. The simplex method and its features.
Topic 3. Transport task of linear programming.
Topic 4. Solving problems on packing, covering, dominating sets, cliques.
Topic 5. Minimal spanning trees. Kruskal's and Prim's algorithms.
Topic 6. Build of fundamental systems of cycles and cocycles.
Topic 7. Algorithms of Dijkstra and Floyd-Warshall.
Topic 8. PERT network diagrams.

Topics of the laboratory classes

Topic 1. Software installation. Overview of tools for solving linear programming problems.
Topic 2. Programming simplex transformations.
Topic 3. Programming the solution of the transport task.
Topic 4. Overview of MATLAB tools for solving problems on graphs.
Topic 5. Solving problems of minimum regular coloring.
Topic 6. Build of Eulerian cycles.
Topic 7. Decomposition the digraph to strongly connected components and their partial ordering.
Topic 8. Maximum flow and minimum cut in the network.

Self-study

During self-stury, students study lecture material, perform individual homework (IHW), prepare for tests, colloquiums, and exams. Correctly performed IHW are counted, incorrect ones are returned for revision. IHW are evaluated as completed after correcting errors.

Non-formal education

In non-formal education according to the relevant Regulation (http://surl.li/pxssv), the educational component or its individual topics can be taken into account in case of independent completion of professional courses/trainings, obtaining civic education, online education, professional internship, etc. In particular, individual topics of this component may be taken into account upon successful completion of the following courses:

Topic 6. Simplex transformations.
https://www.coursera.org/learn/linear-programming-and-approximation-algorithms?#modules
module 1 (Linear Programming)

Topic 12. Integer linear programming. Graphical method. Gomory cutting-plane method.
https://www.coursera.org/learn/linear-programming-and-approximation-algorithms?#modules
module 2 (Integer Linear Programming)

Topic 20. Minimum spanning trees. Kruskal's and Prim's algorithms.
https://www.coursera.org/learn/algorithms-on-graphs
module 5 (Minimum Spanning Trees)

Topic 21. Eulerian cycles. Fleury's method.
https://www.coursera.org/learn/graphs?
module 2 (Cycles)

Topic 22. Hamiltonian cycles. Ore's and Dirac's theorems.
https://www.coursera.org/learn/linear-programming-and-approximation-algorithms?#modules
module 4 (Travelling Salesperson Problem and Approximation Schemes)

Topic 29. Maximum flow and minimum cut in the network.
https://www.coursera.org/learn/graphs?
module 5 (Flows And Cuts)

Course materials and recommended reading

Main literature

1. Iglin S. P. Linear Programming. Tutorial / Iglin S. P., Zaitsev Yu. I., Reshetniak Yu. B. – Kharkiv: NMMT, 2022. – 120 p. (in Ukrainian)
https://repository.kpi.kharkov.ua/server/api/core/bitstreams/384866bb-5028-4546-996c-eb0a5cb346f6/content
2. Iglin S. P. Graph theory based on MATLAB. Tutorial / Iglin S. P., Zaitsev Yu. I., Reshetniak Yu. B. – Kharkiv: NMMT, 2023. – 236 p. (in Ukrainian)
https://repository.kpi.kharkov.ua/items/1e4aa40c-fed3-4663-98b0-7e93276f25b5
3. Beineke L. W. Line Graphs and Line Digraphs / L. W. Beineke, J. S. Bagga. – Springer Nature, 2021. – 300 p.
https://books.google.com.ua/books/about/Line_Graphs_and_Line_Digraphs.html?id=um1LEAAAQBAJ&redir_esc=y
4. Beineke L.W. Topics in Algorithmic Graph Theory / L. W. Beineke, M. C. Golumbic, R. J. Wilson. – Cambridge University Press, 2021. – 340 p.
https://www.cambridge.org/core/books/topics-in-algorithmic-graph-theory/4AD9538A0062A16AC1D53D2BD01A5AF9#fndtn-information
5. Chong E. K. P. An Introduction to Optimization, Fifth Edition With Applications to Machine Learning / E. K. P. Chong, W.-Sh. Lu, S. H. Żak. – NY: John Wiley & Sons, Inc. – 672 p.
https://www.engr.colostate.edu/~echong/book5/
6. Needham M. Graph Algorithms / M. Needham M., A. E. Hodler. – O'Reilly Media, Inc., 2019. – 268 p.
https://www.oreilly.com/library/view/graph-algorithms/9781492047674/

7. Shrimali N. P. Recent Advancements in Graph Theory / N. P. Shrimali, N. H. Shah. – CRC Press, 2020. – 410 p.
https://www.taylorfrancis.com/books/edit/10.1201/9781003038436/recent-advancements-graph-theory-shrimali-nita-shah
8. Zhao Y. Graph Theory and Additive Combinatorics / Y. Zhao. – Cambridge University Press, 2023. – 340 p.
https://yufeizhao.com/gtacbook/gtacbook.pdf

Additional literature

9. Iglin S. P. Personal Page. – http://iglin.epizy.com
10. Mathworks. – 2024. – https://www.mathworks.com/
11. Mathworks File Exchange Central. – https://www.mathworks.com/matlab-central/fileexchange/

Assessment and grading

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

A necessary condition for passing the test or exam is the fulfillment of all individual home tasks.
60 points are awarded for writing control papers.
Passing colloquiums – 40 points.

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 Olena AKHIIEZER
	Date, signature 29.08.2024		Guarantor of the educational program Olena AKHIIEZER