Syllabus of the educational component
Program of educational discipline

Theory and design of algorithms

Specialty
113 Applied mathematics

Institute
National Institute of Computer Sciences and Information Technologies

Educational program
Intelligent data analysis

Department
Computer mathematics and data analysis

Level of education
Bachelor

Course type
Special (professional), Mandatory

Semester
4

Language of instruction
Ukrainian

Lecturers and course developers

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General information

Summary

The main principles and methods of algorithm development, their classification, typical and specialized algorithms, in particular sorting and searching, as well as issues related to the selection of the most appropriate and effective algorithms for solving practical problems, are considered.

Course objectives and goals

The discipline is aimed at acquiring the necessary competencies in the field of algorithm development and design. Studying and mastering the theoretical foundations of algorithmization, as well as their practical application. Methods of building complex algorithms for solving problems from various fields (automation, statistics, information protection, etc.) are considered. Special attention is paid to the analysis of the results of the application of the designed algorithms in various practical conditions and on various types of input data, which should contribute to the formation of students' practical skills in engineering activities.

Format of classes

Lectures and laboratory classes, independent work, consultations. The final control is 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 4. Ability to be critical and self-critical.
GC 6. Ability to think abstractly, analyze and synthesize.
GC 7. Ability to search, process and analyze information from various sources.
GC 8. Knowledge and understanding of the subject area and understanding of professional activities.
GC 10. Skills in the use of information and communication technologies.
SC 3. Ability to choose and apply mathematical methods for solving applied problems, modeling, analysis.
SC 5. Ability to develop algorithms and data structures, software tools and program documentation.
SC 7. Ability to solve professional problems with the help of computer equipment, computer networks and the Internet, in the environment of modern operating systems, using standard office applications.
SC 14. Ability to understand the task statement formulated in the language of a particular subject area, to search and collect the necessary initial data.
SC 15. Ability to formulate a mathematical statement of a problem, based on the statement in the language of the subject area, and choose a method of solving it that ensures the required accuracy and reliability of the result.
SC 20. Ability to develop and operate software tools for intelligent analysis of measurement and observation data, texts, signals and images.

Learning outcomes

LO 1. Demonstrate knowledge and understanding of the basic concepts, principles, theories of applied mathematics and apply them in practice.
LO 3. Formalize problems formulated in the language of a particular subject area; formulate their mathematical formulation and choose a rational method of solution; solve the obtained problems by analytical and numerical methods, evaluate the accuracy and reliability of the results obtained. ⦚ 4. Perform mathematical description, analysis and synthesis of discrete objects and systems, using the concepts and methods of discrete mathematics and algorithm theory. ⦚ 9. To build algorithms that are effective in terms of calculation accuracy, stability, speed and system resource consumption for numerical study of mathematical models and solving practical problems.
LO 11. Be able to apply modern technologies of programming and software development, software implementation of numerical and symbolic algorithms.
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.

Student workload

The total volume of the discipline is 120 hours (4 ECTS credits): lectures - 30 hours, laboratory work - 30 hours, independent work - 60 hours.

Course prerequisites

Disciplines "Algorithmization and Programming", "Computer Discrete Mathematics", "Discrete Structures and Data Structures", "Probability Theory".

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

When teaching this discipline, such teaching and learning methods as gamification and peer-to-peer are used. LMS (learning management systems) systems are used in the learning process.

Program of the course

Topics of the lectures

Topic 1. Sorting. Introduction.
Sorting task. Classification of sortings algorithms. Quadratic sorting and their comparative analysis.
Topic 2. Sorting using a "heap".
Heap data structure. Floyd's sorting.
Topic 3. Smooth sorting.
Sorting with a triple heap. Leonardo's numbers. Sorting with Leonardo heaps.
Topic 4. Quick sorting.
Basic quick sort scheme. Different implementations of quick sort and their comparative analysis.
Topic 5. Merge sort.
Merge operation. Ascending and descending merge sort and their characteristics.
Topic 6. External sorting.
External sorting problem. Simple multipath merge. Balanced multipath fusion. Multiphase fusion.
Topic 7. Digital sorting.
Terms of use of digital sorting. Binary quicksort. Sort by count. Bitwise sorting of MSD and LSD.
Topic 8. Linear sorting methods.
Scope of application. Sort by index. Cell sorting.
Topic 9. Search. Basic algorithms.
Search task. Sequential search. Binary search. Interpolation search.
Topic 10. Binary search trees.
Characteristics of search trees and basic operations on them. Implementation methods. Rotation.
Topic 11. Balanced binary search trees.
Classification. Randomized search trees. Extended search trees. AVL trees.
Topic 12. Optimal search trees.
2-3-4 search tree. Red and black search trees.
Topic 13. Hashing.
Hash function. Open Hashing. Closed hashing.
Topic 14. Regional search.
Problems of geometric search. Examples of regional search algorithms.
Topic 15. The task of localization.
Variants of problem formalization. Algorithms for solving localization problems.
Topic 16. Methods of reducing the search.
Complete search. Search with return. Method of branches and boundaries.
Topic 17. Dynamic programming. Greedy algorithms.
The principle of dynamic programming. Examples of algorithms. Greedy algorithms.
Topic 18. RSA algorithm.
Data encryption problem. Basic number theory algorithms. Implementation of the RSA algorithm.

Topics of the workshops

Practical classes are not provided

Topics of the laboratory classes

Topic 1. Quadratic sorting.
Topic 2. Sorting using a "heap".
Topic 3. Smooth sorting.
Topic 4. Quick sorting.
Topic 5. Merge sort.
Topic 6. External sorting.

Topic 7. Digital sorting.
Topic 8. Linear sorting problems.
Topic 9. Binary search. Interpolation search.
Topic 10. Binary search trees.
Topic 11. Randomized search trees.
Topic 12. Optimal search trees.
Topic 13. Hashing.
Topic 14. Regional search.
Topic 15. The task of localization.
Topic 16. Method of branches and boundaries.
Topic 17. Dynamic programming.
Topic 18. RSA algorithm.

Independent work

In this discipline, such methods of development and development as gamification and peer-to-peer are used. In the process, LMS (learning management systems) systems are being developed.

Course materials and recommended reading

Basic literature

1. Кормен Т., Лейзерсон Ч., Рівест Р., Стайн К. Вступ до алгоритмів. – К.: К. І. С., 2019. – 1288 с.
ISBN 978-617-684-239-2
2. Кормен Т. Алгоритми доступно. – К.: К. І. С., 2021. - 194 с.
ISBN 978-617-684-269-9
3. Адіт'я Бхаргава Грокаємо алгоритми. Ілюстрований посібник для програмістів і допитливих. - ArtHuss, 2023. –м 256с.
ISBN 978-617-8025-57-1
4. Васильєв О. Алгоритми. – Ліра-К, 2022. – 424 с.
ISBN 978-617-520-353-8
5. Imran Ahmad 50 Algorithms Every Programmer Should Know: Tackle computer science challenges with classic to modern algorithms in machine learning, software design, data systems, and cryptography. – Packt Publishing, 2023. – 538 с.
ISBN 978-180-3247-76-2

Additional literature

6. Jay Wengrow A Common-Sense Guide to Data Structures and Algorithms, Second Edition: Level Up Your Core Programming Skills. – Pragmatic Bookshelf, 2020. – 508 с.
ISBN 978-168-0507-22-5
7. Kumar S. Ray, Bimal Kumar Ray Polygonal Approximation and Scale-Space Analysis of Closed Digital Curves. – Apple Press, 2021. – 288с.
ISBN 978-177-4632-64-2

Internet resources

1. https://www.hackerrank.com – a database of tasks for the development of algorithms
2. https://projecteuler.net – database of algorithmic problems

Assessment and grading

Criteria for evaluating student performance and distribution of points

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

Exam: written task (2 theoretical and task) and oral report.
Current assessment: grades for laboratory work, 2 tests and individual assignments

Rating scale

Total points	National assessment	ECTS
90–100	Perfectly	A
82–89	Good	B
75–81	Good	C
64–74	Satisfactorily	D
60–63	Satisfactorily	E
35–59	Unsatisfactorily (further study required)	FX
1–34	Unsatisfactorily (further study required)	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": show discipline, education, benevolence, honesty, responsibility. Conflict situations should be openly discussed in study groups with the teacher, and if it is impossible to resolve the conflict, it should be brought to the attention of the employees of the institute's directorate.
Regulatory and legal support for the implementation of the principles of academic integrity of NTU "KhPI" is posted on the website: http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/

Approval

Approved by	Date, signature 28.06.2024		Head of the Department Olena AKHIIEZER
	Date, signature 29.08.2024		Guarantor of the Educational Program Olena AKHIIEZER