Syllabus
Course Program

Algorithms and data structures

Specialty
125 – Cybersecurity and information protection

Institute
Educational and Scientific Institute of Computer Science and Information Technology

Educational program
Cybersecurity

Department
Cybersecurity (328)

Level of education
Bachelor's level

Course type
Special (professional), Mandatory

Semester
2

Language of instruction
English

Lecturers and course developers

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Candidate of Technical Sciences, senior researcher of the cyber security department of National Technical University "Kharkiv Polytechnic Institute".

The number of scientific publications: more than 60 publications, 25 articles in foreign publications and specialized publications of Ukraine, 6 patents for a useful model, guarantor of the educational and professional program of the first (bachelor) level of higher education. Leading lecturer in the disciplines: "Network Programming", "Development and Analysis of Algorithms", "Programming Technologies", "Programming Tools", "Web Security", "Fundamentals of Technical Information Protection", for undergraduate and graduate students.
More about the lecturer on the department's website

General information

Summary

The educational discipline "Algorithms and data structures" is a mandatory educational discipline. The discipline is aimed at familiarizing students with modern views on algorithmic processes; teach the basic technological means of developing and analyzing algorithms.

Course objectives and goals

Formation of students' system of knowledge about basic data structures and basic computational algorithms, as well as acquisition of practical skills in designing, developing and analyzing algorithms, evaluating their effectiveness and complexity.

Format of classes

Lectures, laboratory classes, consultations, self-study. Final control – exam.

Competencies

GC1. Ability to apply knowledge in practical situations..
GC2. Knowledge and understanding of the subject area and understanding of professional activity.

GC3. Ability to communicate in the state language both orally and in writing.
GC5. Ability to learn and master modern knowledge.
PC2. Ability to use information technologies, modern methods and models of cybersecurity and information security systems.

Learning outcomes

LO1. Freely speak the state language orally and in writing when performing professional duties.
LO4. Organize own professional activity, choose optimal methods and ways of solving complex specialized tasks and practical problems in professional activity, evaluate their effectiveness.
LO5. Analyze, argue, make decisions when solving complex specialized tasks and practical problems in professional activity, which are characterized by complexity and incomplete determination of conditions, be responsible for the decisions made.
LO6. Adapt to new conditions and technologies of professional activity, predict the end result.
LO7. Apply and adapt information and coding theories, mathematical statistics, numbers, cryptography and steganography, signal processing and transmission, etc., principles, methods and concepts of cybersecurity and information protection in training and professional activity.
LO8. Apply knowledge and understanding of mathematics and physics in professional activity, formalize the objectives of the subject area of cybersecurity and protection of information, formulate their mathematical production and choose a rational method of solution.
LO10. Be able to use modern information technologies, methods and models of cybersecurity and information security systems for professional activity.

Student workload

The total volume of the course is 150 hours (5 ECTS credits): lectures - 32 hours, laboratory classes - 32 hours, self-study - 86 hours.

Course prerequisites

Basics of programming.

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

In the course of teaching the discipline, the teacher uses explanatory-illustrative (informational-receptive) and reproductive teaching methods. Presentations, conversations, and master classes are used as teaching methods aimed at activating and stimulating the educational and cognitive activities of applicants.

Program of the course

Topics of the lectures

Topic 1. Introduction to data structures and algorithms.
The concept of data structures and their classification. Formalization of the concept of algorithm. Main directions in the theory of algorithms. Practical application of the results of the theory of algorithms.
Topic 2. Basic data structures.
arrays stacks queues Linked lists. Hash tables. Direct addressing. Hash functions. Binary search trees. Red and black trees.
Topic 3. Algorithms of sorting, merging and searching.
Sorting in quadratic time. Sort by selection. Sort by exchange. Sorting in O(n log n). Quick sorting. Selecting an element to split. Merge sort. Memory consumption during merge sort. Merging sequences. Binary search. Lower estimates of sorting speed. Solution tree. Sort by count.
Topic 4. Combinatorial algorithms.
Generators of pseudo-random numbers. Properties of random and pseudorandom numbers. Common disadvantages of pseudorandom number generators. Linear congruent method. Mersenne vortex.
Topic 5. Fundamental algorithms on graphs and trees.

Representation of graphs. Vertices Ribs. Directed and undirected graphs. List of adjacent vertices. Adjacency matrix. Sparse graph. Weighted count. Search in depth. Broad search. Search trees. Recursive and non-recursive implementations of graph search. Topological sorting.

Topic 6. Geometric algorithms.

Properties of segments. Convex combination. Vector product. Direction of rotation. Checking the intersection of segments. Bounding rectangle. Order relations on segments. Construction of a convex shell. Graham's algorithm. Jarvis' algorithm. The method of adding points.Complexity of convex hull construction algorithms.

Topic 7. Cryptographic algorithms.

Classification of cryptographic algorithms. Cryptosystems with a private key. The concept of a private key. Caesar's Cipher. Viginer cipher. Cracking the Caesar and Viginer ciphers.
Public key cryptosystems. The concept of a public key. Euler's function. Cryptographic hash functions. The need for cryptographic encryption.

Topic 8. Heuristic algorithms.

Evaluation of the quality of the approximate algorithm. Approximation scheme for a given optimization problem. Vertex coverage problem. An approximate algorithm for finding vertex coverage. The maximum error of an approximate algorithm for finding vertex coverage. The task of the traveling salesman. Triangle inequality. An approximate algorithm for the traveling salesman problem. The maximum error of the approximate algorithm for the traveling salesman problem.

Topic 9. Mathematical foundations of algorithm analysis.

Asymptotic notation. Growth rate of functions. Logarithmic growth. Linear growth. Quadratic growth. Exponential growth. Standard functions and notation. Sums and their properties. Progressions. Amounts of differences. Estimates of sums. Induction. Member-by-member comparison.

Topic 10. Recursion.

Algorithmic system based on recursive functions. Stand method. Ways to guess the estimate (analogy, successive approximations). Induction and the paradox of the inventor. Substitution of variables. Conversion to sums. Iterations of ratios. Recursion tree. A general solution of a large class of recurrence relations. The main theorem on recursive estimates. Examples of using the main theorem on recursive estimates.

Topic 11. Algorithmic strategies.

The principle of "Divide and conquer".Division into subtasks. Dynamic programming.
Matrix multiplication problem. Assessment of the complexity of the algorithm for solving the matrix multiplication problem. The problem of finding the greatest common subsequence. The length of the greatest common subsequence. Reproducing the greatest common subsequence. Greedy algorithms. The problem of distribution of applications. Depreciation analysis. Grouping method. Subscription method. The method of potentials.

Topic 12. Basics of computability theory.

Concept of computability and computational procedures. Concept of relative algorithm and relative computability, concept of summation. Turing machine. Components of a Turing machine. Turing machine capabilities. Illustration of a Turing machine for simple algorithms. The main hypothesis of the theory of algorithms. Algorithmically unsolvable problems.

Topic 13. Difficulty classes.

Polynomial time. An efficient algorithm. Abstract task. Polynomial problem. Formal languages for solvability problems. Language Belonging Check and NP Class. The problem of a Hamiltonian cycle in a graph. Verification algorithm. NP-hard and NP-complete problems. Class NP.

Topics of the workshops

Not provided for in the curriculum.

Topics of the laboratory classes

Topic 1. Basic data structures: (list, queue, stack).
Topic 2. Basic data structures: hash tables; red and black trees.
Topic 3. Sorting algorithms.
Topic 4. Combinatorial algorithms.
Topic 5. Fundamental algorithms on graphs and trees.
Topic 6. Geometric algorithms.

Topic 7. Cryptographic algorithms.
Topic 8. Heuristic algorithms.
Topic 9. Mathematical foundations of algorithm analysis.
Topic 10. Recursion. Recursive evaluations
Topic 11. Dynamic programming. Greedy algorithms
Topic 12. Basics of computability theory.

Self-study

A student's independent work is one of the forms of organization of learning, the main form of mastering educational material in free time from classroom training. During independent work, students study lecture material, do individual homework, prepare for tests, tests and exams. Students are also recommended additional materials (videos, articles) for self-study and analysis.

Non-formal education

Within the framework of non-formal education, according to the relevant Regulation (http://surl.li/pxssv), the educational component or its individual topics may be taken into account in the case of independent completion of professional courses/trainings, civic education, online education, vocational training, etc.
In particular, certain topics of this component can be taken into account in case of successful completion of the following CISCO courses:
C++ 2, Introduction to Data Science
https://www.netacad.com/catalogs/learn?category=course.

Course materials and recommended reading

Basic literature:

1. Marcello La Rocca. Advanced Algorithms and Data Structures. / Marcello La Rocca. - New York: Manning Publications Co., 2021. - 768 p.
https://books.google.com.ua/books/about/Advanced_Algorithms_and_Data_Structures.html?id=XPQ1EAAAQBAJ&redir_esc=y
2. Krenevich A.P. Algorithms and data structures. Textbook. / A.P. Krenevich – K.: Kyiv University, 2021. – 200 p.
https://www.mechmat.univ.kiev.ua/wp-content/uploads/2021/09/pidruchnyk-alhorytmy-i-struktury-danykh.pdf
3. Helmut Knebl. Algorithms and Data Structures: Foundations and Probabilistic Methods for Design and Analysis / Helmut Knebl. – Cham: Springer Nature Switzerland AG, 2020. – 349 p. – Access mode: http://repository.kpi.kharkov.ua/handle/KhPI-Press/50239.
4. Algorithms and data structures: workshop: teaching. guide/N.K. Stratienko, M.D. Godlevskyi, I.O. Borodina. - Kharkiv: NTU "KhPI", 2017. - 224 p.
https://repository.kpi.kharkov.ua/server/api/core/bitstreams/8be9ee4f-7db1-45d5-8f57-9c8e6d0bd982/content
5. Methodological instructions for performing laboratory work from the course "Algorithms and data structures" [Electronic resource] / comp. N. K. Stratienko, I. O. Borodina; Kharkiv Polytechnic Institute, National technical Univ. - Electron. text data. - Kharkiv, 2017. - 36 p. – Access mode: http://repository.kpi.kharkov.ua/handle/KhPI-Press/26426.
6. Yevseyev S.P. CYBER SECURITY: CRYPTOGRAPHY WITH PYTHON: training. manual / S.P. Yevseev, O.V. Shmatko, O.H. Korol - Kharkiv: "New World - 2000" Publishing House, 2021. -120 p.
https://drive.google.com/drive/u/1/folders/1wOTN8N-GBGO06AnvjQHU1SdBl3xCaUju.

Additional literature:

1. Donald Knuth. The Art of Computer Programming, Volume 4, Fascicle 5: Mathematical Preliminaries Redux; Introduction to Backtracking. / Donald Knuth. - Boston: Pearson Education (US), 2020. - 320 p.
https://api.pageplace.de/preview/DT0400.9780134671833_A39997762/preview-9780134671833_A39997762.pdf
2. Florian Jaton, Geoffrey C. Bowker. The Constitution of Algorithms: Ground-Truthing, Programming, Formulating. / Florian Jaton, Geoffrey C. Bowker. - MIT Press Ltd, United States, 2021. - 400 p.

https://florian-jaton.com/resources/jaton_2021_the-constitution-of-algorithms.pdf
3. Shmuel Tommy Klein. Basic Concepts In Algorithms. / Shmuel Tomi Klein. - Singapore: World Scientific Publishing Co Pte Ltd, 2021. - 364 p.
https://books.google.com.ua/books/about/Basic_Concepts_in_Algorithms.html?id=8NpdzgEACAAJ&redir_esc=y
4. Hemant Jain. Problem Solving in Data Structures & Algorithms Using Python. /Hemant Jain. - Independently Published, 2019. - 416 p.
https://books.google.com.ua/books/about/Problem_Solving_in_Data_Structures_and_A.html?id=XpdKMQAACAAJ&redir_esc=y
5. Hemant Jain, Problem Solving in Data Structures & Algorithms Using C. /Hemant Jain. - Independently Published, 2018. - 556 p.
https://books.google.com.ua/books/about/Problem_Solving_in_Data_Structures_and_A.html?id=6ln_MAAACAAJ&redir_esc=y
6. Steven S. Skiena. The Algorithm Design Manual. 3rd ed. / Steven S. Skiena. – Cham: Springer Nature Switzerland AG, 2020. – 793 p.
https://mimoza.marmara.edu.tr/~msakalli/cse706_12/SkienaTheAlgorithmDesignManual.pdf
7. Meleshko E.V., Yakymenko M.S., Polishchuk L.I.Algorithms and data structures: Study guide for full-time and part-time technical students. – Kropyvnytskyi: Publisher – V.F. Lysenko, 2019. – 156 p.
https://dspace.kntu.kr.ua/server/api/core/bitstreams/46a115be-c271-4ab0-bfb5-62dca34b7d6a/content
8. Algorithms, data and structures. [Text], academic manual / V.M. Ilman, O.P. Ivanov, L.O. panic Dnipropetrovsk National Railway University. transp.im. Acad. V. Lazaryan. - Dnipro, 2019. - 134 p.
https://crust.ust.edu.ua/server/api/core/bitstreams/16eada7c-c082-46f7-af81-1d6e97ac9320/content
9. Borodkina I.L. The theory of algorithms: a guide for students of higher educational institutions - Center for educational literature, 2018. - 184 p.
http://irb.nubip.edu.ua/cgi-bin/irbis64r_14/cgiirbis_64.exe?LNG=&C21COM=F&I21DBN=BOOKS_READER&P21DBN=BOOKS&Z21ID=&Image_file_name=Borodkina_Teorij%20algorutmiv.pdf&mfn=356&FT_REQUEST=&CODE=213&PAGE=1
10. Allen Downey. Think Data Structures / Allen Downey. - O'Reilly Media, Inc, USA, 2017. - 155 p.
https://greenteapress.com/thinkdast/thinkdast.pdf
11. Marcin Jamro. C# Data Structures and Algorithms: Explore the possibilities of C# for developing a variety of efficient applications / Marcin Jamro. - Birmingham: Packt Publishing Limited, 2018. - 292 p.
https://books.google.com.ua/books/about/C_Data_Structures_and_Algorithms.html?id=Cd9YDwAAQBAJ&redir_esc=y.

Assessment and grading

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

Points are awarded according to the following ratio:
- laboratory work: 40% of the semester grade;
- independent work: 10% of the semester grade;
- control work: 10% of the semester grade;
- exam: 40% of the semester grade.

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	17.01.2025		Head of the department Serhii YEVSEIEV
	17.01.2025		Guarantor of the educational program Serhii YEVSEIEV