Syllabus
Course Program

Complex systems modeling methods

Specialty
121 – Software Engineering
122 – Computer Science

Institute
Institute of Computer Science and Information Technology

Educational program
Software Engineering
Computer Science and Intelligent Systems

Department
Software Engineering and Management Intelligent Technologies (321)

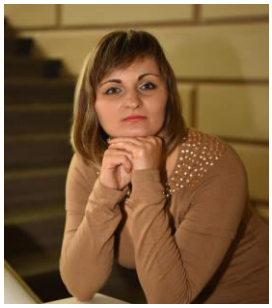
Level of education
Bachelor's level

Course type
Elective

Semester
6

Language of instruction
English, Ukrainian

Lecturers and course developers



First name and surname

Karina.Melnyk@khpi.edu.ua
Ph.D., Associate Professor, Associate Professor of Software Engineering and Information Technology Management

Author (co-author) of more than 70 publications, 5 collective monographs, 10 articles in publications indexed in Scopus and Web of Science. (h-index = 5, i10-index = 1 in Google Scholar -https: //scholar.google.com/citations? user = xCU7GMgAAAAJ & hl = ru; ORCID ID https://orcid.org/0000-0001- 9642-5414; Scopus Author ID https://www.scopus.com/authid/detail.uri?authorId=57195074119).
Leading lecturer of the courses: Basics of Software Engineering (Bachelors) (in English), Methods of Empirical Information Processing (Bachelors) (in English and Ukrainian), Basics of Intelligent Systems Design (Masters) (in English and Ukrainian)
More about the lecturer on the department's website

General information

Summary

The discipline "Complex systems modeling methods" is an educational discipline from the profiled package of disciplines VP01 "Research and Development" in specialties 121 "Software engineering", 122 "Computer science". The educational discipline is aimed at forming a complete system of theoretical and practical knowledge, which helps to analyze and model complex systems; and is also aimed at the development of the logical thinking of a specialist, at promoting the formation of the student's abilities and skills of independent research of problems, the ability to apply knowledge in practical situations.

Course objectives and goals

The purpose of studying the academic discipline is the formation of theoretical knowledge and practical skills of specialists in the basic principles of the general theory of systems and functional capabilities and the practical application of linear and nonlinear methods for building mathematical models of complex

systems, as well as for the development of applied tools and information technologies based on a systems approach.

Format of classes

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

Competencies

121 – Software engineering:

K01. Ability to abstract thinking, analysis and synthesis.
K02. Ability to apply knowledge in practical situations.
K05. Ability to learn and master modern knowledge.
K06. Ability to search, process and analyze information from various sources.
K20. Ability to apply fundamental and interdisciplinary knowledge to successfully solve software engineering tasks.
K25. The ability to reasonably choose and master software development and maintenance tools.
K26. Ability to algorithmic and logical thinking.

122 – Computer science

GC 1. Ability to abstract thinking, analysis and synthesis.
GC 2. Ability to apply knowledge in practical situations.
GC 3. Knowledge and understanding of the subject area and understanding of professional activity.
GC 6. The ability to learn and master modern knowledge.
GC 7. Ability to search, process and analyze information from various sources.
PC 1. Ability to mathematically formulate and investigate 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.
PC 3. The ability to think logically, draw logical conclusions, use formal languages and models of algorithmic calculations, design, develop and analyze algorithms, evaluate their effectiveness and complexity, solvability and unsolvability of algorithmic problems for adequate modeling of subject areas and creation of software and information systems.
PC 4. The ability to use modern methods of mathematical modeling of objects, processes and phenomena, to develop models and algorithms for the numerical solution of mathematical modeling problems, to take into account the errors of the approximate numerical solution of professional problems.
PC 5. The ability to carry out a formalized description of operations research tasks in organizational-technical and socio-economic systems of various purposes, to determine their optimal solutions, to build optimal management models taking into account changes in the economic situation, to optimize management processes in systems of various purposes and hierarchy levels.
PC 6. Ability to system thinking, application of system analysis methodology for researching complex problems of various nature, methods of formalization and solving system problems that have conflicting goals, uncertainties and risks.
PC 7. Ability to apply theoretical and practical foundations of modeling methodology and technology to study characteristics and behavior
PC 19. The ability to comprehensively use the methods of mathematical modeling and analysis to create intelligent control systems.

Learning outcomes

121 – Software engineering:

PR01. Analyze, purposefully search for and select the information and reference resources and knowledge necessary for solving professional tasks, taking into account modern achievements of science and technology.
PR05. Know and apply relevant mathematical concepts, methods of domain, system and object-oriented analysis and mathematical modeling for software development.
PR10. Conduct a pre-project survey of the subject area, system analysis of the design object.

PR18. Know and be able to apply information technologies for data processing, storage and transmission.

122 – Computer science

PR1. Apply knowledge of the basic forms and laws of abstract and logical thinking, the basics of the methodology of scientific knowledge, the forms and methods of extracting, analyzing, processing and synthesizing information in the subject area of computer science.
PR2. To use the modern mathematical apparatus of continuous and discrete analysis, linear algebra, analytical geometry, in professional activities to solve problems of a theoretical and applied nature in the process of designing and implementing informatization objects.
PR6. Use the methods of numerical differentiation and integration of functions, solving ordinary differential and integral equations, features of numerical methods and the possibilities of their adaptation to engineering problems, have skills in software implementation of numerical methods.
PR7. Understand the principles of modeling organizational and technical systems and operations; use operations research methods, solving single- and multi-criteria optimization problems of linear, integer, nonlinear, stochastic programming.
PR8. 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.
PR18. Apply modern methods of decision-making theory to build intelligent management systems, including methods of ranking, formation and coordination of collective expert assessments, multi-criteria optimization, and others.
PR19. Create intelligent management systems using methods of mathematical modeling and analysis of complex systems, methods of modeling and analysis of business processes, information technologies for managing business systems..

Student workload

The total volume of the discipline is 120 hours (4 ECTS credits), in particular: lectures - 32 hours, laboratory hours - 16 hours, independent work - 72 hours. It is taught in the sixth semester. The discipline ends with a test.

Course prerequisites

The course "Complex systems modeling methods" is based on the disciplines "Theory of probability and mathematical statistics", "Mathematical models and analysis of systems".

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 method, problem-based learning.

Assessment forms:
written individual tasks for laboratory work (CAS), assessment of knowledge in laboratory classes (CAS), express survey (CAS), online tests (CAS), final/semester control in the form of a semester credit, according to the schedule of the educational process (FAS) .

Program of the course

Topics of the lectures

Topic 1. General concepts of systems theory, modeling and modeling languages
Basic concepts of systems theory. Classification of systems. Signs of complex systems. The main types of system structures. Types of hierarchical systems. Examples.
Topic 2. Basic approaches to system modeling
Basic approaches to system modeling. Stages of modeling.
Topic 3. Analytical methods of modeling complex systems

Matrix balance models. Model "Output - costs". Optimization problems of linear programming. Dual linear programming problem. Transport problem. Problems of integer programming. Problems of game theory. Problems of dynamic programming.

Topic 4. Construction of models based on these experiments

Passive experiment. Linear and non-linear models of paired and multiple regression. The method of least squares. F and t tests for testing the model and its coefficients for adequacy. Multicollinearity. Correlation and dispersion analysis of constructed models.

Topic 5. Statistical and simulation modeling of complex systems

Statistical support of simulation modeling. Monte Carlo method. Means of organization of model time. Overview of modern information technologies for modeling complex systems. AnyLogic package.

Topic 6. Models of intelligent systems

Intelligent model, fuzzy model, information model. Definition of a fuzzy model. Structure, main elements and operations in fuzzy models. Basic properties of fuzzy models. Completeness of a fuzzy model. Fuzzy systems and fuzzy logic output: Mamdani model, Takagi-Sugeno model.

Topics of the workshops

Practical classes within the discipline are not provided.

Topics of the laboratory classes

Topic 1. Mathematical modeling of the heat exchange process
Topic 2. Computer modeling of the temperature field in the rod using the finite element method
Topic 3. Computer modeling of the stress state during rod twisting using the finite element method
Topic 4. Paired regression model.
Topic 5. Multiple regression model.
Topic 6. Full factorial experiment.
Topic 7. Complex modeling of the system using simulation modeling in PP AnyLogic.

Self-study

Students are recommended additional materials (videos, articles) for independent study and processing.

Course materials and recommended reading

1. Hiroki Sayama, Introduction to the Modeling and Analysis of Complex Systems / State University of New York at Binghamton. Copyright Year: 2015. ISBN 13: 9781942341093. Publisher: Open SUNY
2. Jagdev Singh, Hemen Dutta, Devendra Kumar, Dumitru Baleanu, Jordan Hristov. Methods of Mathematical Modelling and Computation for Complex Systems Publisher: Springer Cham . 433 p. https://doi.org/10.1007/978-3-030-77169-03.
3. Modeling and Managing Complex Systems / Proceedings of the 17th International DSM Conference Book/ Carl Hanser Verlag, Munich, 2015
4. F. Stãnciulescu. Modelling of High Complexity Systems with Applications
Research Institute for Informatics, Bucharest, Romania- 2005. ISBN 978-1-85312-778-6 . - 376 p.
5. Samsudin, N., & Bradley, A. (2010). Nearest neighbour group-based classification. Pattern Recognition, 43(10), 3458-3467.

Assessment and grading

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

100% final assessment in the form of credit (10%) and current assessment (90%).
10% credit: semester credit, according to the schedule of the educational process
90% current assessment:
70% assessment of tasks in laboratory works;
20% intermediate control (2 independent individual works)

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 Guarantors of the educational programs
Andrii KOPP
Uliya LITVINOVA