Syllabus
Course Program

Methods for System Modeling

Specialty
172 – Electronic communications and radio engineering

Institute
Institute of Computer Modeling, Applied Physics and Mathematics

Educational program
Network technologies and telecommunications

Department
Information systems (169)

Level of education
Master's level

Course type
Special (professional)

Semester
1

Language of instruction
English

Lecturers and course developers

Pavlo Pustovoitov
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Professor

Author of 150 publications. Lecturer of courses "Parallel and Distributed Computing", "", "Software Testing", "Methods for System Modeling".

More about the lecturer on the department's website

General information

Summary

The "Methods for System Modeling" course equips you with the tools and techniques to effectively conceptualize, describe, and analyze complex systems. You'll explore diverse modeling methods, ranging from traditional mathematical approaches to cutting-edge computational techniques. Learn to represent system components, behaviors, and interactions through various formalisms, gaining the ability to capture key system characteristics and assess their impact on performance, stability, and reliability. Develop your critical thinking skills by applying these methods to solve real-world modeling problems and evaluate the suitability of different techniques for specific scenarios. Through hands-on practice and collaborative exercises, you'll gain proficiency in various modeling tools and software, preparing you to confidently analyze and optimize complex systems across diverse domains.

Course objectives and goals

This course provides mastering diverse modeling techniques, from traditional mathematical approaches to cutting-edge computational tools, equips you to effectively represent, analyze, and optimize systems across various domains. Learn to capture key characteristics through formalisms like diagrams and equations, enabling assessment of performance, stability, and reliability. Hone your critical thinking by applying these methods to real-world problems, evaluating different techniques for specific scenarios. Through hands-on practice and collaboration, gain proficiency in modeling software, confidently tackling complex systems and leaving you ready to become a valued asset in any field demanding deep system understanding..

Format of classes

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

Competencies

GC-1: Ability to think abstractly, analyze and synthesize.
GC-2: Ability to apply knowledge in practical situations.
GC-11: Ability to make informed decisions.
SC-3: Ability to think logically, build logical conclusions, use formal languages and models of algorithmic calculations, design, develop and analyze algorithms, evaluate their efficiency and complexity, solvability and unsolvability of algorithmic problems for adequate modeling of subject areas and creation of software and information systems.
SC-8: Ability to design and develop software using various programming paradigms: generalized, object-oriented, functional, logical, with appropriate models, methods and algorithms of calculations, data structures and control mechanisms.
SK-11: Ability to manage information resources and systems, organize and support the implementation of information systems and services

Learning outcomes

LO-1: Apply knowledge of basic forms and laws of abstract-logical thinking, fundamentals of scientific research methodology, forms and methods of information extraction, analysis, processing and synthesis in the field of computer science.
LO-4: Use methods of computational intelligence, machine learning, neural and fuzzy data processing, genetic and evolutionary programming to solve problems of recognition, forecasting, classification, identification of control objects, etc.
LO-10: Reasonably apply a developed ecosystem of libraries and tools for development and automation.

Student workload

The total volume of the course is 120 hours (4 ECTS credits): lectures - 16 hours, laboratory classes - 32 hours, self-study - 72 hours.

Course prerequisites

Basic programming skills, basic mathematics skills, average networks skills

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

Classes are made interactively using multimedia technologies for lecture presentations and online demonstrations of task execution examples. The lecture classes use explanatory-illustrative, reproductive, problem-oriented methods and the method of critical thinking. Training materials are available for students through OneNote (Class Notebook).

Program of the course

Topics of the lectures

Topic 1. Introduction to System Modeling: What is system modeling, why is it important? Types of models, applications across domains.
Topic 2. Basic Mathematical Modeling: Differential equations, state-space analysis, block diagrams, transfer functions.
Topic 3. Discrete-Event Modeling: Queuing theory, Petri nets, simulation techniques.
Topic 4. Agent-Based Modeling: Individual behavior, interaction rules, emergence in complex systems.
Topic 5. Data-Driven Modeling: Statistical methods, machine learning, system identification.
Topic 6. Component-Based Modeling: Modular design, interfaces, model composition.
Topic 7. Object-Oriented Modeling: UML, SysML, modeling software practices.
Topic 8. Multi-Modeling Approaches: Combining different techniques for comprehensive analysis.

Topic 9. Optimization & Decision Making: Model-based optimization techniques, control theory.
Topic 10. Uncertainty & Risk Analysis: Monte Carlo simulations, sensitivity analysis, probabilistic modeling.
Topic 11. Large-Scale Modeling & Simulation: High-performance computing, parallel models, cloud-based solutions.
Topic 12. Human-in-the-Loop Modeling: Human factors, cognitive aspects, human-system interaction.
Topic 13. Digital Twins: Creating virtual representations of real systems for monitoring and prediction.
Topic 14. Cyber-Physical Systems Modeling: Integrating physical and computational components.
Topic 15. Sustainable Systems Modeling: Modeling for environmental impact assessment and optimization.
Topic 16. Ethical Considerations in System Modeling: Bias, fairness, transparency, explainability of models

Topics of the workshops

Not included

Topics of the laboratory classes

Topic 1. Modeling a Simple Physical System: Build a mathematical model and validate it using simulation tools for a mechanical or electrical system (e.g., pendulum, spring-mass system, RC circuit).
Topic 2. Discrete-Event System Simulation: Implement a queuing model in a simulation software (e.g., Arena, AnyLogic) to analyze waiting times and resource utilization.
Topic 3. Agent-Based Modeling Experiment: Design and run an agent-based model (e.g., NetLogo) to explore emergent behavior in a complex system (e.g., traffic flow, epidemic spread).
Topic 4. Data-Driven Modeling with Machine Learning: Use regression or classification techniques to identify relationships in system data and build predictive models.
Topic 5. Component-Based Design and Modeling: Develop a modular model of a larger system using a modeling language (e.g., SysML) and analyze its behavior.
Topic 6. Object-Oriented Modeling with UML: Create UML diagrams to represent system classes, relationships, and behavior for a chosen problem.
Topic 7. Model-Based Optimization of a Control System: Develop a model of a real-world control system (e.g., temperature control) and optimize its parameters for desired performance.
Topic 8. Uncertainty Analysis and Risk Assessment: Implement Monte Carlo simulations and sensitivity analysis to evaluate the influence of uncertain parameters on model outcomes.
Topic 9. Sustainable System Design with Modeling: Build and compare models of alternative system designs considering environmental impact and resource usage.
Topic 10. Human-Computer Interaction Modeling: Implement a model of a human-computer system and analyze its usability and performance through simulated user interactions.
Topic 11. Model Comparison and Critique: Work in teams to compare different modeling approaches applied to the same scenario and discuss their advantages and limitations.
Topic 12. Open-Source Model Contribution: Contribute to an existing open-source system model by adding components, functionalities, or improving documentation.
Topic 13. Case Study Competition: Analyze a real-world system of your choice (e.g., transportation network, supply chain) and propose a solution through system modeling, presenting your results to the class.
Topic 14. Emerging Technology Exploration: Investigate and present on a new or emerging technology relevant to system modeling (e.g., digital twins, cyber-physical systems modeling).

Self-study

Processing of lecture material. Preparation for laboratory work. Independent study of topics and questions related to the topics of lecture classes (5 points). The computational task involves the use of different types of containerization and infrastructure formation (15 points). Students are recommended additional materials (articles in scientific publications) for independent study and analysis.

Course materials and recommended reading

1. Systems Modeling and Simulation: Theory and Practice by Andrew Ford and David J. Forrester (2020)

2. Modeling and Analysis of Dynamic Systems by Brian P. Luce and John W. C. Robinson (2021)
3. System Modeling and Analysis: An Introduction to Mathematical Modeling by Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers, and Keying Ye (2018)
4. Systems Modeling: A Unified Approach by Michael J. Crawley (2022)
5. Agent-Based Modeling and Simulation: A Practical Introduction by Steven F. Railsback and Volker Grimm (2021)
6. Data-Driven Modeling and Simulation: A Practitioner's Guide by Daniel T. P. Yu and James A. C. Sterne (2020)
7. Large-Scale System Modeling and Simulation: A Survey of Recent Advances by Alexander K. Hartmann and Peter Fritzon (2019)
8. Human-in-the-Loop Modeling: Methods and Applications by Patrick C. Mann and David M. Buede (2018)
9. Sustainable Systems Modeling: A Framework for Decision-Making by Daniel A. Vallero and J. David Allen (2017)
10. Ethical Considerations in System Modeling by Brian D. Smith and John D. Sterman (2016)

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

The final grade is made up of 100% assessment results in the form of an exam (50%) and current assessment (50%).

Breakdown of the grading:

Laboratory work: 30%
Independent work and computational tasks: 20%

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	Head of the department Pavlo PUSTOVOITOV
	Date, signature	Guarantor of the educational program Vitalii BRESLAVETS