**Syllabus**
Course Program

# Computational Intelligence

Specialty
113 – Applied Mathematics

Institute
Institute of Computer Modeling, Applied Physics and Mathematics

Educational program
Computer and Mathematical Modeling

Department
Mathematical Modeling and Intelligent Computing in Engineering (161)

Level of education
Master's level (1 year 4 months)

Course type
Special (professional), Mandatory

Semester
2

Language of instruction
English

## Lecturers and course developers

**Yulia Vyazovychenko (responsible lecturer)**

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Candidate of technical sciences, associate professor of the Faculty of Mathematical Modeling and Intelligent Computing in Engineering, work experience - 8 years. Author of more than 25 scientific and methodical works. Lecturer in the disciplines: "Mathematical methods of modeling and data processing", "Probability theory", "Introduction to the specialty", "Neural networks and machine learning", "Modeling in CAD systems"

Learn more about the teacher on the department's website

**Ksenia Potopalska (assistant in laboratory practice)**

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Candidate of technical sciences, associate professor of the department of mathematical modeling and intellectual calculations in engineering, work experience - 7 years. Author of more than 40 scientific and methodical works works. Leading lecturer on disciplines : " Modeling and reverse engineering based on data ",
Modeling and reverse engineering based on of data " , teacher of practice

Learn more about the teacher on the department's website

## General information

### Summary

The curriculum of the discipline "Computational Intelligence" defines the content and scope of knowledge necessary for a specialist in intelligent technologies. The discipline covers the problems of studying the modern state of computer intelligence technologies used for formalization and processing of knowledge in systems functioning technologies, studying modern software tools and technologies for designing and

implementing intelligent systems and their debugging and research. For the practical assimilation of educational materials, a number of topics of the discipline are studied in depth in laboratory classes

## Course objectives and goals

The discipline is aimed at mastering the theoretical and practical skills of applying computational intelligence methods in solving practical modeling problems.

## Format of classes

Lectures, laboratory work. Final control - credit

## Competencies

Program competencies according to the educational program:
GC3. Ability to master modern knowledge, formulate and solve problems.
GC7. Ability to think abstractly, analyse and synthesise.
PC1. Ability to solve tasks and problems that can be formalised, require updating and integrating knowledge, in particular in conditions of incomplete information.
PC4. Ability to develop and research mathematical and computer models, conduct computational experiments and solve formalised problems using specialised software.
PC5. Ability to build and research models for decision-making using intelligent systems.
PC6. Ability to apply artificial intelligence methods, develop and implement machine learning algorithms in practice.
PC7. Ability to design and develop software to solve formalised problems, including systems with large amounts of data.
PC8. Ability to formalise and build data or knowledge models, obtain relevant knowledge from large amounts of data, choose data mining methods to solve problems.

## Learning outcomes

Program learning outcomes according to the educational program:
LO5. Justify and, if necessary, develop new algorithms and software tools for solving scientific and applied problems, apply, modify and investigate analytical and computational methods for solving them.
LO6. Apply procedures for formal description of systems, checking their adequacy for the study of socio-economic, technical, natural and other systems.
LO7. Solve computer modelling problems by using and developing modern software tools, in particular, distributed, parallel and cloud programming methods.
LO8. Develop and implement algorithms for solving applied problems, system and application software of information systems and technologies.
LO9. Be able to analyse and design systems with large amounts of data, apply and adapt methods of knowledge acquisition, methods of evaluation and interpretation of the found patterns.
LO10. Develop and apply modern concepts of machine learning and data mining.
LO11. Possess skills of abstract thinking, analysis and synthesis.
LO15. To be able to carry out mathematical and computer modelling, computational experiment, solve formalised problems using specialised software.

## Student workload

The total volume of the discipline is 90 hours. (3 credits and ECTS): lectures – 16 hours, laboratory work – 16 hours, independent work – 58 hours.

## Course prerequisites

Basic concepts of mathematical analysis, linear algebra and analytic geometry, discrete mathematics, mathematical logic, programming, computational methods, probability theory, mathematical statistics, optimization theory, artificial intelligence systems.
Methods of mathematical modelling and data analysis

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

Studying the subject "Computational Intelligence" provides students with a deep and comprehensive consideration of the key aspects of modern intelligent technologies. Starting with an introduction to computational intelligence, students get a general idea of the main principles and directions of development of this field. Studying swarm techniques and artificial immune systems allows students to gain a deeper understanding of the nature of collective intelligence and adaptive systems.
A detailed study of genetic and evolutionary algorithms reveals the principles of evolution and genetic inheritance, which find their application in optimization and solving complex problems. A review of fuzzy set theory and its application to decision making teaches students to effectively model and manage fuzziness in real-world situations.
The final block on the application of computational intelligence in engineering considers the practical use of the acquired knowledge in the areas of development, optimization of systems and solving engineering tasks. This subject provides a platform for students to understand the importance of computational intelligence in today's technical world and develop the skills to apply these concepts in real-world projects. In laboratory classes, students practice the skills of creating algorithms in the Python environment.

## Program of the course

### Topics of the lectures

Topic 1. **Introduction to computational intelligence**
Basic principles and definitions of computational intelligence.
The role of computational intelligence in modern technologies and practical applications
Topic 2. **Swarm methods (Swarm Intelligence)**
Studying the principles of swarm methods that model the collective behavior of a group of agents.
Examples of the use of swarm techniques in various fields such as optimization and robotics.
Topic 3. **Artificial Immune System**
A review of the principles of the artificial immune system and its applications in computer science.
Examples of the use of an artificial immune system in anomaly detection and optimization.
Topic 4. **Genetic algorithms**
Overview of the principles of genetic algorithms and their structure.
Examples of optimization using genetic algorithms.
Topic 5. **Evolutionary algorithms**
Work and application of evolutionary algorithms in solving optimization problems.
Examples of adaptability of evolutionary algorithms
Topic 6. **Overview of the theory of fuzzy sets**
Definition of fuzzy sets and basic principles of their functioning.
Consideration of basic operations and properties of fuzzy sets
Topic 7. **Application of fuzzy sets**
Studying the use of fuzzy sets in decision making and modeling uncertainty.
Examples of practical applications of fuzzy sets in management systems and risk analysis.
Topic 8. **Application in engineering**
Use of computational intelligence in engineering calculations and optimization.
Modeling and analysis of engineering systems using computational intelligence.

### Topics of the workshops

There are no classes.

### Topics of the laboratory classes

**Topic 1. Genetic algorithm:**
**Laboratory work "Implementation of the basic genetic algorithm":**
Code development for generating the initial population and calculating the fitness function.
Implementation of crossover and mutation procedure for population evolution.
Determination of termination condition and analysis of optimization results.
**Laboratory work "Genetic algorithm for optimization of the traveling salesman problem":**

Using a genetic algorithm to solve the classic traveling salesman problem.
Application of weighting coefficients and determination of eigenvalue functions.

**Topic 2. Swarm algorithm:**

**Laboratory work "Swarm algorithm simulation using Python":**

Implementation of the main functions of the swarm algorithm: initialization, calculation of the fitness function, designation of local and global optima.
Determination of parameters and experimental optimization.

**Topic 3. Evolutionary computing:**

**Laboratory work "Evolutionary algorithms in optimization":**

Generating code to implement various evolutionary algorithms, such as evolutionary programming or evolutionary game strategies.
Analysis and comparison of the results of different evolutionary approaches for specific problems.

**Topic 4. Fuzzy logic:**

**Laboratory work "Using fuzzy logic in control systems":**

Development of fuzzy rules and functions on the example of a control system.
Using fuzzy logic for adaptive control and decision-making.
Comparison of results with traditional methods.

### Self-study

Completion of calculated individual tasks on the topics of laboratory works. The teacher checks the reports.

## Course materials and recommended reading

### Main literature


1 Russell, S., & Norvig, P. (2021). "Artificial Intelligence: A Modern Approach." ( Third edition ).
2. Sutton, RS, & Barto, AG (2018). "Reinforcement Learning: An Introduction."
3. Goodfellow, I., Bengio, Y., & Courville, A. (2016). "Deep Learning."
4. Nilsson, NJ (2018). "Artificial Intelligence: A New Synthesis."
5. De Jong, KA (2017). "Evolutionary Algorithms: The Role of Mutation and Recombination."
6. Eberhart, RC, Shi, Y., & Kennedy, J. (2001). "Swarm Intelligence: Principles, Advances, and Applications."
7. Ross, TJ (2019). "Fuzzy Logic with Engineering Applications."
8. Nourbakhsh, F., & Shouraki, SB (2013). "Artificial Immune Systems: A New Computational Intelligence Approach."
9. Poole, DL, & Mackworth, AK (2010). "Computational Intelligence: A Logical Approach."
10. Mohri, M., Rostamizadeh, A., & Talwalkar, A. (2018). "Foundations of Machine Learning."


## Assessment and grading

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

100% of the final grade consists of the results of the assessment in the form of credit (40%) and current assessment (60%).
Assessment: written assignment and oral report.
Current assessment: assessment for completed laboratory work and individual assignment (60% each).

### 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

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|---|---|---|
| Approved by | Date<br>August 30, 2023 | Head of the department<br>Oleksii VODKA |
| | Date<br>August 30, 2023 | Guarantor of the educational and professional program (1 year 4 months)<br>Oleksiy LARIN |