Syllabus
Course Program

Methods of artificial intelligence in control algorithms

Specialty
122 – Computer sciences

Institute
Institute of Computer Modeling, Applied Physics and Mathematics

Educational program
Computer science. Modeling, design, and computer graphics

Department
Computer modeling of processes and systems

Level of education
Master's level

Course type
Specialized, Elective

Semester
2

Language of instruction
English

Lecturers and course developers

Uspenskyi Valerii

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Dr. of Engineering, Associate professor,
Professor at the Department of Computer Modeling of Processes and Systems

Area of scientific interests: control and navigation systems. Author and co-author of more than 120 scientific and methodological publications, 7 patents. Courses: control theory, operations research, mathematical methods of the theory of artificial intelligence, methods of artificial intelligence in UAV control problems
More about the lecturer on the department's website

General information

Summary

The course consists of two sections: *methods of artificial intelligence* (methods and problems of evolutionary modeling; the basics of fuzzy logic and fuzzy inference systems using the example of control systems; basic concepts of neural networks and their architecture); *UAV and control tasks* (general information about UAVs, on-board equipment and tasks of its design; mathematical model of controlled multicopter movement, general algorithms and flight control algorithms; perspective tasks of UAV group management and methods of solving them).

Course objectives and goals

Master the fundamental methods of functioning of modern artificial intelligence systems. Have an idea of the practical application of the theory of artificial intelligence in control systems using the example of UAV movement control

Format of classes

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

Competencies

GC01. Ability to think abstractly, analyze and synthesize.
GC02. Ability to apply knowledge in practical situations.
GC05. Ability to learn and master modern knowledge.
PC01. Understanding of the theoretical foundations of computer science.
PC02. Ability to formalize the subject area of a particular project in the form of an appropriate information model.
PC03. Ability to use mathematical methods to analyze formalized models of the subject area.
- Knowledge and understanding of the subject area and understanding of professional activities in the direction of artificial intelligence.
- The ability to create and further develop software for control systems, including the use of artificial intelligence meters.

Learning outcomes

LO1. Have specialized conceptual knowledge, including modern
scientific achievements in the field of computer science and is the basis for original thinking and research, critical thinking of problems in the field of computer science and on the border of knowledge fields.
LO2. Have specialized skills/abilities to solve computer science problems necessary for research and/or innovation activities to develop new knowledge and procedures.
LO9. Develop algorithmic and software for data analysis (including big data).
LO19. Analyze the current state and global trends in the development of computer science and information technology.
- 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 control systems
- Use artificial intelligence methods when solving professional problems
- Create software for management systems based on advanced information technologies

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

Knowledge of computational methods, management theory, programming skills

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

The student must have a computer or laptop with the Linux, macOS or Windows operating system installed. When performing laboratory work, a student can use any programming language and environment

Program of the course

Topics of the lectures

Topic 1. Genetic algorithm. General concepts
Concept of genetic algorithms. Evolution. Natural selection. Population. Chromosome. Block diagram of the classical genetic algorithm. Selection. Crossover and mutation operators. An example of solving an optimization problem using a genetic algorithm. Specialized genetic algorithms. Evolutionary strategies. Genetic programming
Topic 2. Fuzzy system. Basic principles of the theory of fuzzy sets
Vague plural. Ways of solving the fuzzy set. The carrier of the vague plural. The kernel of a fuzzy set. Set alpha level. The height of the fuzzy set. Normal, subnormal fuzzy set. Operations on fuzzy sets.
Topic 3. Mathematical objects built on the basis of FS
Operations on fuzzy numbers, intervals.Fuzzy variable. Linguistic variable. Unclear relationship. Fuzzy derivation system, fuzzy derivation rule base. Fuzzification, aggregation, activation, accumulation, and

defuzzification procedures in the fuzzy inference algorithm. Examples of development and use of fuzzy control systems.
Topic 4. General provisions and mathematical models of neurons.
Concept of neural network. Purpose of artificial neural networks. Examples of using artificial networks. Simplified structure of a biological neuron. Brain plasticity. Mathematical model of neurons. McCulloch-Pitts neuron model.
Topic 5. The simplest neural networks.
Single layer perceptron. The rule of adaptation of the vector of weight coefficients of the perceptron. The problem of solving the XOR problem with a single-layer perceptron. Neuron type WTA. Hebb neuron model, learning rule.
Topic 6. Architecture of neural networks. Multilayer perceptron. Multilayer perseptron's learning and example of functioning
Types of neural network architectures. Multilayer perceptron. Backpropagation Algorithm for Multilayer Perceptron Training. The RPROP algorithm for training a multilayer perceptron. The generalizing ability of the neural network. The strategy of organizing neural network learning and its use.
Topic 7. Classification of UAVs, composition of on-board equipment and tasks facing the control system. Mathematical model of UAV controlled movement and flight control algorithms.
Classification of UAVs, composition of rig equipment, typical control tasks. Mathematical model of controlled flight of a UAV. Control algorithms.
Topic 8. Tasks of UAV group management and methods of solving them.
Relative navigation of UAV in a swarm. Optimal planning of the UAVs large group reconfiguration.

Topics of the workshops

Not included in the curriculum

Topics of the laboratory classes

Topic 1.
Application of the genetic algorithm for function optimization.
Topic 2
Development and simulation of a fuzzy control system.
Topic 3.
Simulation of a two-layer perceptron. Training and testing.
Topic 4.
Software implementation of regulators for UAV altitude control.
Topics 5,6.
Software implementation of the mathematical model of controlled UAV flight.

Self-study

During independent work, students study the following topics:
- Basic concepts of control theory;
- Types of onboard navigation systems, their purpose and characteristics;
- Types of regulators and their comparison with each other.

Individual work is carried out in the form of a report on the topic: "Application of neural networks in UAV control systems".
The work will be assessed by answering the questions posed.

Course materials and recommended reading

1. Chen, G. (Guanrong) Introduction to fuzzy sets, fuzzy logic, and fuzzy control systems / Guanrong Chen, Trung Tat Pham. https://pzs.dstu.dp.ua/logic/bibl/chen.pdf
2. Jaiton Vatsanai, Rothomphiwat Kongkiat, Ebeid Emad, Manoonpong Poramate Neural Control and Online Learning for Speed Adaptation of Unmanned Aerial Vehicles // Frontiers in Neural Circuits. - v.16. - 2022. https://www.frontiersin.org/articles/10.3389/fncir.2022.839361.

3. V. B. Uspenskyi and N. V. Shyriaieva, "Controlled Flight Model of Hybrid Multicopter for Computer Implementation," *2022 IEEE 3rd KhPI Week on Advanced Technology (KhPIWeek)*, Kharkiv, Ukraine, 2022, pp. 1-7, doi: 10.1109/KhPIWeek57572.2022.9916487
4. V. B. Uspenskyi and N. V. Shyriaieva, "Optimal Reconfiguration Planning for Large UAV Groups," 2023 IEEE International Workshop on Technologies for Defense and Security (TechDefense), Rome, Italy, 2023, pp. 203-208, doi: 10.1109/TechDefense59795.2023.10380899.
5. V. B. Uspenskyi and N. V. Shyriaieva, "Relative navigation of UAV in a swarm," 2023 IEEE 4th KhPI Week on Advanced Technology (KhPIWeek), Kharkiv, Ukraine, 2023, pp. 1-5, doi: 10.1109/KhPIWeek61412.2023.10312895.
6. Electronic summary of lectures.
7. Description for laboratory work.

Assessment and grading

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

Description of the final score structure, course requirements, and necessary steps to earn points, especially paying attention to self-study and individual assignments.

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 Dmytro BRESLAVSKY
	Date, signature	Guarantor of the educational program Oleksii VODKA