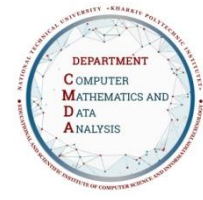




Syllabus Course Program



Fuzzy Models and Methods

Specialty

113 Applied mathematics

Institute

Educational and Scientific Institute of Computer Science and Information Technology

Educational program

Intelligent Data Analysis

Department

Computer Mathematics and Data Analysis

Level of education

Bachelor's level

Course type

Professional training, Mandatory

Semester

8

Language of instruction

Ukrainian

Lecturers and course developers

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Author of scientific and educational and methodical works. Leading lecturer in the disciplines: "Decision theory", "Big data infrastructure and management", "Introduction to the specialty and engineering activity"

General information

Summary

The discipline is aimed at mastering the theoretical foundations of fuzzy models, methods and soft calculations. Methods of building mathematical models of approximate human reasoning and their use in computer systems, solving practical problems of analyzing specific technical and economic situations, in which the initial data are unreliable and weakly formalized, are considered.

Course objectives and goals

The goal of studying the discipline is to acquire the necessary competencies for applied application of the basics of fuzzy mathematics, in particular: the ability to develop and implement informational and linguistic support for the interface and knowledge bases of intelligent computer systems; the ability to develop and implement new information technologies and software for management, design, decision-making, search, analysis and data processing.

Format of classes

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

Competencies

GC 1. Ability to learn and master modern knowledge.

GC 2. Ability to apply knowledge in practical situations.

GC 8. Knowledge and understanding of the subject area and understanding of professional activities.

SC 3. Ability to choose and apply mathematical methods for solving applied problems, modeling, analysis, design, management, forecasting, decision-making.

SC 7. Ability to solve professional problems with the help of computer equipment, computer networks and the Internet, in the environment of modern operating systems, using standard office applications.

SC 14. Ability to understand the task statement formulated in the language of a particular subject area, to search and collect the necessary initial data.

SC 18. Ability to select and apply mathematical models and methods for statistical and intellectual analysis of data under conditions of uncertainty.

SC 19. Ability to apply mathematical methods and algorithms of machine learning, soft computing and computational intelligence to analyze uncertain data, forecasting and decision-making.

Learning outcomes

LO 1. Demonstrate knowledge and understanding of basic concepts, principles, theories of applied mathematics and use them in practice.

LO 2. To know the basic principles and methods of mathematical, complex and functional analysis, linear algebra and theory numbers, analytic geometry, theory of differential equations, in particular partial differential equations, probability theory, mathematical statistics and random processes, and numerical methods.

LO 3. Formalize tasks formulated in the language of a particular subject field; formulate their mathematical formulation and choose a rational method of solution; solve the resulting problems with analytical and numerical methods; evaluate the accuracy and reliability of the results obtained.

LO 13. To use specialized software programs in practical work products and software systems for computer mathematics.

LO 14. Demonstrate the ability to self-learn and continue professional development.

LO 21. Know and understand modern methods of solving mathematical problems of statistical and intellectual data analysis, forecasting, etc.

LO 23. Be able to apply existing and develop new algorithms and software tools for statistical and intellectual analysis of uncertain data.

Student workload

The total volume of the course is 90 hours (3 ECTS credits): lectures – 10 hours, laboratory classes – 20 hours, self-study – 60 hours.

Course prerequisites

"Mathematical logic", "Algorithmization and programming", "Computer discrete mathematics", "Probability theory", "Decision theory"

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

A feature of teaching is the use of elements of project work.

Program of the course

Topics of the lectures

Topic 1. General information about methods of mathematical representation and processing of vague information. Basic concepts and definitions of the theory of fuzzy sets

- the linguistic approach of L.A. Zadeh;
- basic questions and problems of computational intelligence and soft computing.
- elements of Boolean algebra;
- concept of fuzzy set;
- the concept of belonging;

- typical membership functions, their properties;
- principles of construction of membership functions of fuzzy sets;
- stochastic and linguistic uncertainty.

Topic 2. Mathematical aspects of the theory of fuzzy sets. Fuzzy numbers

- operations on fuzzy sets: inclusion, equality, addition, intersection, combination, algebraic sum and algebraic product, limit sum and limit product, drastic sum and drastic product, disjunctive sum;
- ordinary set closest to vague;
- ordinary subset α - level;
- decomposition theorem;
- Cartesian product of fuzzy sets;
- basic definitions, arithmetic operations;
- examples of using fuzzy numbers for economic calculations.

Topic 3. Fuzzy relation and its properties. Fuzzy logical inference

- operations on fuzzy relations - combination, intersection, algebraic sum and algebraic product, disjunctive sum;
- laws of vague composition;
- types of compositions of two fuzzy relations.
- the concept of a linguistic variable;
- display of fuzzy sets, their main applications;
- the structure of the rules and the diagram of the inference mechanism.
- fuzzy implication operator models Mamdani, Larsen.

Topic 4. Fuzzy implication operator models. Fuzzy control systems

- FLI models Tsukamoto, Sugeno;
- simplified algorithm of fuzzy logical conclusion;
- descending vague conclusions;
- solving problems under the conditions of descending fuzzy conclusions.
- appointment of unclear management systems;
- classification and features of fuzzy control systems.

Topic 5. The main areas of application of fuzzy control systems. Examples of practical use of the theory of fuzzy sets

- structure and elements of a vague analogue of a PID controller;
- fuzzification operation;
- tabular representation of a set of rules;
- defuzzification methods;
- structure options.
- adaptive fuzzy control;
- fuzzy control with prediction;
- fuzzy computing systems;
- the theory of fuzzy decisions;
- fuzzy expert systems;
- application of the theory of fuzzy sets in economics.

Topics of the workshops

Workshops are not provided for in the curriculum.

Topics of the laboratory classes

Laboratory work 1. Basic questions and problems of the theory of fuzzy sets. Typical membership functions of fuzzy sets, their properties

Laboratory work 2. Operations on distinct and fuzzy sets

Laboratory work 3. Basic operations on fuzzy numbers

Laboratory work 4. Making decisions under conditions of uncertainty

Laboratory work 5. NLV algorithms Mamdani, Larsen

Laboratory work 6. Algorithms Tsukamoto, Sugeno. A simplified fuzzy logic inference algorithm

Laboratory work 7. Study of a control system with a fuzzy controller

Laboratory work 8. Synthesis of fuzzy control systems

Laboratory work 9. Synthesis of the ANFIS system and comparison of its effectiveness with a neural network

Laboratory work 10. Construction and application of the ANFIS model for forecasting time series

Self-study

Representation and use of vague knowledge.

Classification of vague and uncertain information in various subject areas of engineering activity and technical systems.

Classification of operations on fuzzy sets. Hamming distance. Fuzzy linguistic variables. Operators: t-norm, t-conorm.

Using fuzzy models based on fuzzy rules.

Examples of practical use of the theory of fuzzy sets. Unclear classification.

Non-formal education

Within the framework of non-formal education according to the relevant Regulation ([z0328-22](#)), the educational component or its separate topics can be taken into account in case of independent completion of professional courses/training, obtaining civic education, online education, professional internship, etc.

In particular, individual topics of this component may be taken into account upon successful completion of the following courses:

- Topic 1. General information about methods of mathematical representation and processing of vague information. Basic concepts and definitions of the theory of fuzzy sets

<https://www.coursera.org/learn/comparative-research-designs-and-methods>

- Topic 3. Fuzzy relation and its properties. Fuzzy logical inference

[Practical Introduction to Fuzzy Logic with Matlab](#)

- Topic 4. Fuzzy implication operator models. Fuzzy control systems

[Practical Introduction to Fuzzy Logic with Matlab](#)

Course materials and recommended reading

Basic literature

1. Fuzzy Logic Toolbox. User's Guide. The MathWorks, Inc., 2018. – 528 p.. Режим доступу:

<https://person.dibris.unige.it/masulli-francesco/lectures/ML-CI/lectures/MATLAB%20fuzzy%20toolbox.pdf>

2. Нечіткі множини в системах управління та прийняття рішень: навч. посіб. / Т.А. Желдак, Л.С. Коряшкіна, С.А. Ус, за редакцією С.А. Ус ; М-во освіти і науки України, Нац. техн. ун-т «Дніпровська політехніка». – Дніпро : НТУ «ДП», 2020. – 387 с.

<https://ir.nmu.org.ua/jspui/bitstream/123456789/156356/1/CD1239.pdf>

3. Прохорова О. М. Моделі і методи нечіткої логіки: навч. посіб. /О. М. Прохорова, Н. В. Кальчук; Нац. аерокомс. ун-т ім. Н. Є. Жуковського "ХАІ". – Х., 2021. – 166 с.

4. Кирик, В. В. Математичний апарат штучного інтелекту в електроенергетичних системах [Електронний ресурс] : підручник / В. В. Кирик – Київ : КПІ ім. Ігоря Сікорського, Вид-во «Політехніка» 2019. – 226 с. <https://ela.kpi.ua/handle/123456789/30080>

5. Zadeh L. A. Fuzzy Logic Theory and Applications: Part I and Part II / Lofti A. Zadeh, Rafik A. Aliev. - NJ: World Scientific Publishing Co., 2018 – P.610

Additional literature

6. Fuzzy Logic Toolbox. Design and simulate fuzzy logic systems

<https://se.mathworks.com/help/fuzzy/>

7. Кондратенко Ю. П. Нечіткі множини та нечітка логіка. Методичні рекомендації та вказівки для виконання лабораторних робіт студентами спеціальності 122 «Комп'ютерні науки» / Ю. П. Кондратенко, Г. В. Кондратенко, Є. В. Сіденко ; під ред. д-р техн. наук, професора Ю. П. Кондратенка. – Миколаїв : ЧНУ ім. Петра Могили, 2019. – 36 с.

8. Методичні вказівки до лабораторних занять з курсу "Нечіткі моделі та методи" : для студентів напрямку "Прикладна математика" / уклад.: Ю. І. Дорофеев, О. В. Костюк ; Нац. техн. ун-т "Харків. політехн. ін-т". – Харків : НТУ "ХПІ", 2014. – 48 с.

<http://repository.kpi.kharkov.ua/handle/KhPI-Press/45510>

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
29.08.2024

Head of the Department
Olena AKHIEZER

Date, signature
29.08.2024

Guarantor of the Educational Program
Olena AKHIEZER