Syllabus
Course Program

Metaheuristic Optimization 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
Master's level

Course type
Special (professional), Mandator

Semester
2

Language of instruction
Ukraine, English

Lecturers and course developers

Oksana Sira

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Doctor of Science (Technical), Full Professor, Professor of Computer Mathematics and Data Analysis Department.

Work experience – more than 20 years. Author and co-author of more than 170 scientific and educational and methodological works. Leading lecturer in the disciplines: "Mathematical logic", "Fundamentals of scientific research", "Metaheuristic Optimization Methods ".
More about the lecturer on the department's website and http://sira.pro/
ORCID: https://orcid.org/0000-0002-4869-2371,
Scopus Author ID: 42262785900

General information

Summary

The discipline is aimed at mastering the main metaheuristic methods of optimization. We consider a powerful and extremely popular class of optimization methods that allow finding solutions for a wide range of tasks from various applications, and also provide an opportunity to solve intractable optimization problems.

Course objectives and goals

Acquiring the necessary competencies for using metaheuristic optimization methods: solving complex optimization tasks without knowledge of the search space using the necessary method, finding close to optimal solutions to various optimization tasks in an acceptable time.

Format of classes

Lectures, practical classes, calculation tasks, independent work, consultations. The final control is an exam.

Competencies

SC 1. Ability to formulate a mathematical problem, relying on the language of the subject area, verifying the correctness of the formulation, including under conditions of uncertainty .
SC 3. Ability to choose, develop, investigate, and apply mathematical methods for solving practical problems of modeling, design, management, forecasting, decision-making. .
SC 10. Ability to choose, develop, investigate, and apply mathematical models and methods for intelligent data analysis under conditions of uncertainty..
SC 11. Ability to develop, investigate, and apply mathematical methods and algorithms of machine learning, soft computing, and computational intelligence for the analysis of uncertain data, forecasting, and decision-making..

Learning outcomes

LO 1. Demonstrate knowledge and understanding of the fundamental and applied mathematics concepts, principles, and theories and apply them in practice.
LO 3. Master methods for the development, research, and application of mathematical models of complex objects and processes, including the use of computational intelligence methods.
LO 4. Be able to combine methods of mathematical and computer modeling with informal expert analysis procedures to search for optimal solutions..
LO 6. Be able to choose, develop, and investigate methods and algorithms for solving mathematical problems of optimization of systems, operations research, optimal control, and decision-making.
LO 12. Know and understand modern methods for solving mathematical problems of statistical and intelligent data analysis, forecasting, etc.
LO 14. Be able to apply existing and develop new algorithms and software tools for statistical and intelligent analysis of uncertain data.
LO 15. Be able to apply existing and develop new algorithms and software tools for data processing, text, signals, and images.

Student workload

The total volume of the discipline is 120 hours. (4 ECTS credits): lectures – 16 hours, laboratory work – 32 hours, independent work – 72 hours.

Course prerequisites

To successfully pass the course, you must have knowledge and practical skills in the discipline "Mathematical methods of machine learning 1"

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

When teaching this discipline, such teaching and learning methods as gamification and peer-to-peer are used. LMS (learning management systems) systems are used in the learning process.

Program of the course

Topics of the lectures

Topic 1. Classification of optimization methods. Evolutionary methods. Genetic algorithms. Metols that mimic the immune system of organisms.
Topic 2. Scattering method. Evolutionary strategy of covariance matrix transformation.
Topic 3. The method of dynamic grids. The method of differential evolution.
Topic 4.. Methods of "pack" intelligence. The method of particles in a swarm. Method of ant colonies.
Topic 5. Method of imitating the behavior of bacteria. Method of bee colonies.
Topic 6. Methods that simulate physical processes. The method of gravitational kinematics. Method of simulation of annealing.

Topic 7. An adaptive method of simulating annealing. The method of finding harmony.
Topic 8. Multistart methods. Greedy adaptive random search method. Method of directed tabu search.

Topics of the workshops

Workshops classes within the discipline are not provided.

Topics of the laboratory classes

Topic 1. Genetic algorithms. Genetic algorithms with binary and real coding.
Topic 2. Method of artificial immune systems and its extension. Analysis of the effectiveness of methods and their comparison.
Topic 3. Scattering method and its modification.
Topic: 4. Evolutionary strategy of covariance matrix transformation.
Topic 5. The method of dynamic grids.
Topic 6. The method of differential evolution.
Topic 7. The method of particles in a swarm.
Topic 8. Method of ant colonies.
Topic 9. A method of simulating the behavior of bacteria.
Topic 10. Method of bee colonies.
Topic 11. The method of gravitational kinematics.
Topic 12. Method of simulating annealing.
Topic 13. Adaptive annealing simulation method.
Topic 14. The method of finding harmony.
Topic 15. Greedy adaptive random search method.
Topic: 16. Method of directed tabu search.

Self-study

The course involves the implementation of individual calculation tasks, the results of which are checked and monitored and evaluated by teachers. Students are also recommended additional materials (videos, articles) for independent study.

Non-formal education

Within the framework of non-formal education according to the relevant Regulation (http://surl.li/pxssv), the educational component or its separate topics can be taken into account in case of independent completion of professional courses/trainings, 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 – https://www.udemy.com/course/geneticalgorithm/?utm_source=adwords&utm_medium=udemyads&utm_campaign=LongTail_la.EN_cc.ROW&campaigntype=Search&portfolio=ROW-English&language=EN&product=Course&test=&audience=DSA&topic=&priority=&utm_content=deal4584&utm_term
https://www.udemy.com/course/the-ultimate-beginners-guide-to-genetic-algorithms-in-python/?couponCode=2021PM25
- Topic 8. Combinatorial Problems and Ant Colony Optimization Algorithm
https://www.udemy.com/course/antcolonyoptimization/?couponCode=2021PM25
https://www.coursera.org/specializations/applied-data-science
- Topic 7-10 - Bio-inspired Artificial Intelligence Algorithms https://www.udemy.com/course/bio-inspired-artificial-intelligence-algorithms-for-optimization/?couponCode=2021PM25

Course materials and recommended reading

Basic literature

1. Glover F. and Kochenberger G., eds. Handbook of Metaheuristics. – Norwell: Kluwer Academic Publishers, 2002.

https://www.academia.edu/35281087/Glover_Handbook_of_Metaheuristics
2. P. Agrawal, H. F. Abutarboush, T. Ganesh and A. W. Mohamed, "Metaheuristic Algorithms on Feature Selection: A Survey of One Decade of Research (2009-2019)," in IEEE Access, vol. 9, pp. 26766-26791, 2021.
https://doi.org/10.1109/ACCESS.2021.3056407.
3. Agrawal, P., Abutarboush, H. F., Ganesh, T., & Mohamed, A. W. (2021). Metaheuristic Algorithms on Feature Selection: A Survey of One Decade of Research (2009-2019). IEEE Access, 9, 26766–26791.
https://doi.org/10.1109/ACCESS.2021.3056407
4. Dorigo M. and St¨utzle T. Ant Colony Optimization: Overview and Recent Advances // M. Gendreau and J.-Y. Potvin, editors, Handbook of Metaheuristics, volume 146 of International Series in Operations Research & Management Science, chapter 8, pages 227-263. – New York: Springer, 2010.
https://dipot.ulb.ac.be/dspace/bitstream/2013/298088/3/ACO-MetaHandbook_preprint.pdf
5. Dehghani, M., Trojovská, E., & Trojovský, P. (2022). A new human-based metaheuristic algorithm for solving optimization problems on the base of simulation of driving training process. Scientific Reports, 12(1), 9924.
https://doi.org/10.1038/s41598-022-14225-7
6. Ahmad, S. (2022). Electromagnetic Field Optimization Based Selective Harmonic Elimination in a Cascaded Symmetric H-Bridge Inverter. Energies, 15 (20), 7682.
https://doi.org/10.3390/en15207682

Additional literature

7. Вступ до генетичних алгоритмів машинного навчання. – [Електронний ресурс].
https://uk.myservername.com/introduction-genetic-algorithms-machine-learning
8. Динамічне програмування, жадібні алгоритми. – [Електронний ресурс].
https://www.coursera.org/learn/dynamic-programming-greedy-algorithms

Інтернет-ресурси

9. Електронний ресурс. – Режим доступу:
https://uk.myservername.com
10. Vinicius Fulber-Garcia, Heuristics vs. Meta-Heuristics vs. Probabilistic Algorithms, May 2023. – [Електронний ресурс].
https://www.baeldung.com/cs/heuristics-vs-meta-heuristics-vs-probabilistic-algorithms

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

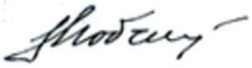
Total points	National	ECTS
90–100	Excellent	A
82–89	Good	B
75–81	Good	C
64–74	Satisfactory	D
60–63	Satisfactory	E
35–59	Unsatisfactory (requires additional learning)	FX
1–34	Unsatisfactory (requires repetition of the course)	F

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 31 08 2023		Head of the department Olena AKHIIEZER
	Date, signature 31 08 2023		Guarantor of the educational program Leonid LYUBCHYK