Syllabus
Course Program

Mathematical methods of computer vision

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 (324)

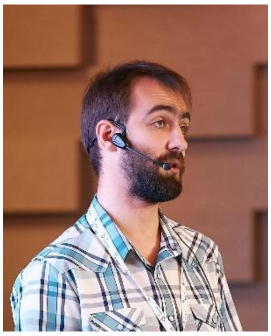
Level of education
Bachelor's level

Discipline type
Special (professional), Selective

Semester
8

Language of instruction
Ukranian

Lecturers and course developers



Vladyslav Kolbasin

vladyslav.kolbasin@khpi.edu.ua
Senior teacher of the Department of Computer Mathematics and Data Analysis

Work experience - 15 years. Leading lecturer in the disciplines: "Object-oriented programming", "Computer geometry and graphics"

More about the lecturer on the website

General information

Summary

The discipline is aimed at mastering the theoretical and practical foundations of computer vision. Both basic but outdated methods of computer vision and modern methods based on artificial neural networks are considered.

Course objectives and goals

The purpose of the discipline is the formation of ideas about the main problems, mathematical methods, models and some practical tools of computer vision.

Format of classes

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

Competencies

GC 1. The ability to learn and master modern knowledge.
GC 2. Ability to apply knowledge in practical situations.
GC 3. The ability to generate new ideas (creativity).
GC 4. The ability to be critical and self-critical.
GC 6. Ability to abstract thinking, analysis and synthesis.

GC 7. Ability to search, process and analyze information from various sources.
GC 8. Knowledge and understanding of the subject area and understanding of professional activity.
GC 10. Skills in the use of information and communication technologies.
SC 1. Ability to use and adapt mathematical theories, methods and techniques for proving mathematical statements and theorems.
SC 2. Ability to perform tasks formulated in mathematical form.
SC 3. The ability to choose and apply mathematical methods for solving applied problems, modeling, analysis, design, management, forecasting, decision-making.
SC 5. Ability to develop algorithms and data structures, software tools and software documentation.
SC 7. The ability to solve professional tasks using computer equipment, computer networks and the Internet, in the environment of modern operating systems, using standard office applications.
SC 8. Ability to operate and maintain software of automated and information systems for various purposes.
SC 14. The ability to understand the statement of the task, formulated in the language of a certain subject area, to search and collect the necessary initial data.

Learning outcomes

LO 1. Demonstrate knowledge and understanding of basic concepts, principles, theories of applied mathematics and use them in practice.
LO 2. To have basic principles and methods of mathematical, complex and functional analysis, linear algebra and number theory, analytical geometry, theory of differential equations, in particular partial differential equations, theory of probabilities, mathematical statistics and random processes, numerical methods.
LO 8. Combine mathematical and computer modeling methods with informal procedures of expert analysis to find optimal solutions.
LO 10. To know the methods of choosing rational methods and algorithms for solving mathematical problems of optimization, operations research, optimal management and decision-making, data analysis.
LO 14. Demonstrate the ability to self-study and continue professional development.
LO 15. To be able to organize one's own activity and obtain a result within a limited time.
LO 24. To be able to apply existing and develop new algorithms and software tools for processing measurement and observation data, texts, signals and images.

Student workload

The total volume of the course is 150 hours (5 ECTS credits): lectures – 20 hours, laboratory classes – 30 hours, self-study – 100 hours.

Course prerequisites

"Machine learning methods and tools", "Optimization methods", "Computational geometry and computer graphics", "Neural network technologies".

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

Programming skills are required. Study materials are available to students on the teacher's website.

Program of the course

Topics of the lectures

Topic 1. Introduction to the subject. General scheme of computer vision methods. Comparison of old methods of computer vision (descriptors, filters) with new ones (neural networks).
Topic 2. Basic elements of convolutional neural networks: convolution, pooling layer, dropout, batch normalization, softmax layer. Examples of problems that can be solved using convolutional networks.
Topic 3. Historical overview of the architecture of neural networks for solving the problem of classification of unstructured data using the example of images.
Topic 4. The task of object detection in the image.
Topic 5. The problem of object detection in the image, approaches that can work in real time.

Topic 6. The task of semantic and instance segmentation of images.
Topic 7. The task of semantic and instance segmentation of images, approaches that can work in real time.
Topic 8. Meta-Learning and domain adaptation (Domain adaptation) for solving computer vision problems.
Topic 9. Self-attention mechanism. A Transformer architecture for image processing tasks
Topic 10. Diffusion models.

Topics of the laboratory classes

Topic 1. General information about programs for building deep neural networks.
Topic 2. Using the transfer learning approach to build neural networks for image classification.
Topic 3. Construction of quality functions for image object detection problems.
Topic 4. Construction of networks for semantic segmentation of images.
Topic 5. Getting to know the Transformer architecture for image processing tasks.

Self-study

During self-stury, students study lecture material, prepare for tests, and exams.

Non-formal education

In non-formal education according to the relevant Regulation (http://surl.li/pxssv), the educational component or its individual 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:

- Topics 1-5.
https://www.coursera.org/learn/convolutional-neural-networks?specialization=deep-learning
https://www.coursera.org/projects/deep-learning-with-pytorch--object-localization
- Topics 6-7.
https://www.coursera.org/projects/deep-learning-with-pytorch-image-segmentation
- Topic 10.
https://www.coursera.org/projects/how-diffusion-models-work-project

Course materials and recommended reading

Main literature

1. Richard Szeliski. Computer Vision: Algorithms and Applications (Texts in Computer Science) 2nd ed. 2022 Edition.
2. Mohamed Elgendy. Deep Learning for Vision Systems. Simon and Schuster, 2020 – 480 pages.
3. V Kishore Ayyadevara, Yeshwanth Reddy. Modern Computer Vision with PyTorch: Explore deep learning concepts and implement over 50 real-world image applications. Packt Publishing, 2020 - 824 pages.
4. Ian Goodfellow, Yoshua Bengio and Aaron Courville, Deep Learning, – MIT Press, 2016. http://www.deeplearningbook.org/
5. Christopher M. Bishop, Pattern Recognition and Machine Learning. – Springer, 2006. http://users.isr.ist.utl.pt/~wurmd/Livros/school/Bishop%20-%20Pattern%20Recognition%20And%20Machine%20Learning%20-%20Springer%20%202006.pdf
6. Simon Prince, Computer Vision: Models, Learning, and Inference, 2012.
7. Yoshua Bengio, Learning Deep Architectures for AI, 2009
8. Michael Nielsen, Neural Networks and Deep Learning, 2016

Additional literature

9. David Forsyth, Jean Ponce, Computer Vision: A Modern Approach, 2002.

10. https://papers.nips.cc/paper/4824-imagenet-classification-with-deep-convolutional-neural-networks.pdf
11. https://arxiv.org/abs/1409.1556
12. https://arxiv.org/abs/1409.4842
13. https://arxiv.org/abs/1512.03385
14. https://arxiv.org/abs/1411.4038
15. https://arxiv.org/abs/1311.2524
16. https://arxiv.org/abs/1504.08083
17. https://arxiv.org/abs/1506.01497
18. https://arxiv.org/abs/1506.02640
19. https://arxiv.org/abs/2104.14294
20. https://lilianweng.github.io/lil-log/2019/11/10/self-supervised-learning.html

Assessment and grading

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

A necessary condition for passing the test or exam is the completion of laboratory work.

30 points are awarded for writing control tests.

Passing laboratory tests - 30 points.

Exam – 40 points.

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 AKHIIEZER
	Date, signature 29.08.2024		Guarantor of the educational program Olena AKHIIEZER