Syllabus
Course Program

BASICS OF NEUROCOMPUTING

Code and name of specialty
123 – Computer engineering

Institute
National Institute of Computer Sciences and Information Technologies

Educational program
Modern programming, mobile devices and computer games

Chair
Computer engineering and programming (326)

Educational level
Master's degree

Type of discipline
Special (professional), mandatory

Semester
9

Language of teaching
Ukrainian, English

Викладачі, розробники

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Doctor of technical sciences, professor, professor of the department of computer engineering and programming of NTU "KhPI".
Work experience - 40 years. Author of more than 230 scientific and educational and methodological works. Leading lecturer in the disciplines: «Computer systems», «Automated design of computer systems», «VHDL the language of designing high-level computing equipment» «Basics of artificial intelligence».
Learn more about the teacher on the department's website
https://web.kpi.kharkov.ua/cep/2022/05/15/leonov-serhii-yuriyovich/

General information

Abstract

Discipline **" Basics of neurocomputing "** is one of the core disciplines and will provide theoretical and practical preparation for the implementation of methods and algorithms of neurocomputing in the development of problem-oriented software and hardware, necessary for the development of advanced disciplines, as well as for coursework and diploma projects.

Course objectives and goals

The subject of the discipline "Fundamentals of neurocomputing" is the study of methods of building neurocomputers and intelligent systems and their software based on neural networks with the aim of applying this knowledge to the development of algorithmic and software for the appropriate operation of technical systems based on modeling the human brain as a biological and information system, in the conditions of a wide variety of possible situations and the absence of a detailed and unambiguous description of the external environment.
The purpose of the discipline is:
– students' acquisition of theoretical knowledge in the field of mathematics, computer hardware and software, based on the modeling of the human brain as a biological system;

– obtaining theoretical knowledge about general methods of learning neural networks for solving specific problems of artificial intelligence;
– acquiring knowledge about neural networks functioning in various fields of science, technology, production and society;
– acquiring knowledge in the field of quantitative justification of decisions with the help of neurocomputing in engineering, organizational, research and commercial activities;
– acquaintance of students with packages of applied programs.

Format of classes

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

Competencies

ZK 2. Ability to abstract thinking, analysis and synthesis.
ZK 7. Ability to make informed decisions.
CK1. Ability to determine technical characteristics, design features, application and operation of software, software and technical tools, computer systems and networks for various purposes.
CK2. Ability to develop algorithmic and software, components of computer systems and networks, Internet applications, cyber-physical systems using modern methods and programming languages, as well as design automation tools and systems.
CK4. Ability to build and investigate models of computer systems and networks.

Learning outcomes

RH1. Apply general cognitive approaches, methods of mathematics, natural and engineering sciences to solving complex problems of computer engineering.
RH3. Build and research models of computer systems and networks, evaluate their adequacy, determine applicability limits.

Scope of the discipline

The total volume of the discipline is 150 hours. (5 credits ECTS): lectures – 32 hours., practical classes – 16 hours., independent work – 86 hours.

Prerequisites for studying the discipline (prerequisites)

The discipline is based on the study of the disciplines "Theory of probability", "Discrete mathematics", mathematical packages Excel, MATLAB, etc.

Features of the course, teaching and learning methods and technologies

Lectures are conducted interactively using multimedia technologies. Lectures use: narration, explanation, demonstration, discussion.
In practical classes, students perform individual tasks for calculating model parameters and statistical characteristics of research objects. For this, they use personal computers and mathematical packages: Excel, Matlab, etc.
According to the sources of knowledge, the following teaching methods are used: verbal - narration, explanation, instruction; visual - demonstration, illustration; laboratory work, exercises, tests. According to the nature of the logic of knowledge, the following methods are used: analytical, synthetic, analytical-synthetic, inductive, deductive.
According to the level of independent mental activity, methods are used: problem-based, partially research-based, research.
Educational materials are available to students in the Google Disk cloud environment.

Program of the course

Topics of the lectures

Introduction.
Subject, purpose and tasks of the discipline, its scientific and engineering content. Brief historical background on the development of neurocomputing methods and neural networks. The place of the

discipline in the educational process and professional training of a programmer, engineer, and researcher. Distribution of study time by types of classes. Organizational and methodological guidelines for studying the discipline. Recommended Books.

Topic 1. *Biological and artificial neurons.*

Neurocomputing in modern research.
Brief information about the structure of the human brain.
Biological neuron and its different models.
Artificial neurons. Activation functions of artificial neurons.
The simplest recognition system based on one neuron.
Hebb neural network. Hebb's algorithm.

Topic 2. *Neural-like networks. Topology of artificial neural networks.*

Levels of modeling neural networks.
Forward propagation artificial neural networks.
Backpropagation artificial neural networks.
Fully connected artificial neural networks.

Topic 3. *Architecture of the simplest neural networks.*

Rosenblatt's elementary perceptron. Rosenblatt's perceptron as a brain model.
Rosenblatt elementary perceptron training. Comparison of perceptron learning systems.
Convergence theorems for the Rosenblatt perceptron.
Two-layer perceptrons and their training method.
Comparative analysis of three-layer perceptrons with discrete and continuous activation functions of network neurons.

Topic 4. *Multilayer neural networks.*

Multilayer perceptrons on discrete neurons.
Multilayer perceptrons on continuous neurons.
The method of backpropagation of the error.

Topic 5. *Hamming neural network.*

The architecture of the Hamming neural network.
Learning the Hamming neural network.
Maxnet neural network.

Topic 6. *Hopfield's autoassociative neural networks.*

The basics of Hopfield's theory of neural networks.
Architecture of Hopfield's discrete neural networks.
Learning discrete Hopfield neural networks.
Hopfield continuous neural networks.
Solving the traveling salesman problem using a continuous Hopfield neural network.

Topic 7. *Neural network bidirectional associative memory (BAM).*

The architecture is discrete *BAM*.
Learning discrete bidirectional associative memory.
Modified structures and learning algorithms *BAM*.
Multidirectional associative memory.
A neural network for memorizing chains of associations.

Topic 8. *Neural networks with self-organization based on competition.*

Distinctive features of a network with self-organization based on competition.
Kohonen's neural network.
Kohonen's neural network learning algorithm.

Topic 9. *Neural networks based on the theory of adaptive resonance.*

The problem of stability - plasticity in neural networks.
Architecture and learning algorithms of neural networks ART-1.
Architecture and learning algorithms of neural networks ART-1U with compact storage of information and modes of learning with a teacher.
New single-module and hierarchical neural networks ART.
ART networks with several solutions.
BAM on ART neural networks.
Stable-plastic neural networks based on Hebb, Hamming and perceptron networks.

Topic 10. *Collapsing neural networks.*

Properties of convolutional neural networks. Principles of organization and functioning.

Architecture of converging neural network.
Peculiarities of learning convolutional neural networks. Deep learning with reinforcement.
Advantages and disadvantages of convolutional neural networks.
Topic 11. *Neurocomputers.*
To the definition of the term "neurocomputer". Characteristics of neurocomputers.
Implementation of neurocomputers. Principles of building their software and hardware. Commercial products and their fields of application.
Prospects for the development of neurocomputing.
Modern neural network modeling packages.

Topics of the workshops

Topic 1. Biological neuron and its different models. Examples of the use of neurons.
Topic 2. Architecture and learning algorithms of the Hebb network.
Topic 3. Rosenblatt perceptron learning algorithms.
Topic 4. Multilayer neural networks and their learning algorithms.
Topic 5. Architecture and learning algorithms of the Hamming network.
Topic 6. Architecture and learning algorithms of the Hopfield network.
Topic 7. Network learning architecture and algorithms BAM.
Topic 8. Kohonen neural network architecture and learning algorithms.
Topic 9. Architecture and learning algorithms of the ART-1 network.
Topic 10. Convolutional neural network.
Topic 11. Stable-plastic neural networks based on Hebb and perceptron networks.

Topics of laboratory work

Laboratory work within the discipline is not provided.

Self-study

The student's independent work is reduced to studying the lecture material, preparing for laboratory classes, performing an individual version of the calculation task using methodical recommendations. The topics of the tasks for performing the computational and graphic task correspond to the topics of the master's thesis (the abstract of the master's thesis is being performed). This encourages students to correctly allocate time for the completion of the master's work, more in-depth study of the theoretical part of the master's work and, as a result, better performance of the master's work.
Students are also recommended additional materials (videos, articles, textbooks) for independent study and analysis, preparation for lectures, practical and laboratory classes.

Course materials and recommended reading

Primary literature
1. Yampolsky L.S. Neurotechnologies and neurosystems / K.: Monograph. – "Dorado-Druk", 2015. – 508 p.
2. Yampolsky L.S. Flexible computer-integrated systems: planning, modeling, verification, management: complex at hand. 2 books with multimedia computer-integrated DVN tools for students. higher education closing / L.S. Yampolskyi, P.P. Melnychuk, K.B. Ostapchenko, O.I. Lisovychenko. - Zhytomyr: ZHTU, 2010. – 786 p.
3. Dmytrienko V.D., Zakovorotny O.Yu. Fundamentals of neurocomputing: a laboratory workshop. – Kharkiv: NTMT,2012. – 128 c.
4. Dmytrienko V.D., Zakovorotny O.Yu., Noskov V.I., Mezentsev M.V. Fundamentals of neurocomputing: an educational and methodological guide to practical classes. - Kharkiv: NTMT, 2014. – 140 p.
5. Yampolsky L.S. Artificial intelligence systems in planning, modeling and management: tutorial. for students higher education closing / L.S. Yampolskyi, B.P. Tkach, O.I. Lisovychenko. – K.: SE "Vid Dim "Personal",2011. – 544 p.
6. Chornodub O.M. Dmytrienko V.D., Rasras R.D. Application of neural networks for processing measurement information. Tutorial. – Kharkiv: KhDPU 2000. – 114 p.
7. Schmidhuder J. Deep Learning in Neural Networks: An Overview / J. Schmidhuder // Neural Networks, 2015. – Vol. 61. – P. 85 – 117.

Additional literature
8. Fausett L. Fundamentals of Neural Networks, Architectures, Algorithms and Applications / L . Fausett – New Jersey: Prentice Hall International, Inc., 2006. – 483 P.
9. Calafiore G.C., El Chaoui L. Optimization Models, Cambridge University Press, 2014.
10. Dataset Shift in Machine Learning / J. Quionero-Candela et al., The MIT Press, 2009.
11. Murphy K.P. Machne Learning a Probabilistic Perspective, Cambridge University Press, 2013.

Assessment and grading

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

The final grade consists of the assessment results in the form of an exam (40%) and ongoing assessment (60%). Exam: written assignment (2 theory questions + problem-solving) and an oral presentation. Ongoing assessment: 2 online tests (15%), laboratory works (35%), and a computational assignment (10%).

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 Oleksandr ZAKOVOROTNYI
	Date, signature	Guarantor of the educational program Svitlana GAVRYLENKO