Syllabus

Course Program

Neural Network Technologies

Specialty
113 Applied mathematics

Institute
Educational and Scientific Institute of Computer Sciences and Information Technologies

Educational program
Intelligent data analysis

Department
Computer Mathematics and Data Analysis

Level of education
Bachelor's level

Course type
Special (professional), Mandatory

Semester
7

Language of instruction
Ukrainian

Lecturers and course developers

Sergey Garder

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Candidate of technical sciences, associate professor of the department of computer mathematics and data analysis of NTU "KhPI".
Work experience - 32 years. Author of 89 scientific and educational and methodological works. Leading lecturer in the disciplines: "Data analysis", "Theory of time series", " Neural network technologies "
Learn more about the teacher on the department's website
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General information

Summary

The course "Neural Network Technologies" develops the knowledge and skills necessary to understand the mathematical principles of operation and design of artificial neural networks (ANN). In the course of training, students will learn on what principles neural networks are created, what types of their architecture exist, how to organize dataset preparation and neural network training. In the process of training, students acquire practical skills in developing NTs.

Course objectives and goals

Course goals, knowledge and skills that can be acquired as a result of training are presented in a form that is understandable for the student.
Acquisition of the necessary competencies for the use of models and methods of definition, development and application of ANN models:
1. The ability to mathematically formalize the formulation of tasks, to check the correctness of the formulation.
2. Ability to choose and apply special mathematical and numerical methods for solving practical problems of data research, construction of datasets for NT training, modeling, and forecasting.
3. Ability to develop algorithms and data structures, software tools and software documentation.
4. Ability to conduct mathematical and computer modeling, data analysis and processing, computational experiments, solving formalized problems using specialized software tools.

Format of classes

Lectures, laboratory classes, consultations, self-study. Final control 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 3: Ability to generate new ideas (creativity).
GC 6: Capability of abstract thinking, analysis and synthesis.
SC 3: Ability to choose and apply mathematical methods for solving applied problems, modelling, analysis, design, management, forecasting, decision-making.

Learning outcomes

LO 1. Demonstrate knowledge and understanding of basic concepts, principles, theories of applied mathematics and use them on 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 fields; formulate their mathematical formulation and choose rational method of solution; solve the resulting problems with analytical and numerical methods, evaluate the accuracy and reliability of the results obtained.
LO 14. Demonstrate the ability to self-learn and continue professional development.

Student workload

The total volume of the discipline is 120 hours. (4 ECTS credits): lectures – 30 hours, laboratory work – 30 hours, independent work – 60 hours..

Course prerequisites

Algorithmization and programming", "Numerical methods", "Analysis of data and time series"..

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

When teaching the discipline "Neural Network Technologies", active and interactive methods of teaching lectures, laboratory classes on real data in an active form, and collective discussion of problems are provided. The effectiveness of the educational process is manifested in the increase of self-awareness of students; formation of the ability to make independent decisions, acquisition of skills for collective discussion of problems; development of analytical and logical abilities. Study materials are available to students through OneNote Class Notebook, Teams..

Program of the course

Topics of the lectures

Topic 1. Introduction to artificial neural networks
A brief history of the emergence and development of SNM. About the structure of the human brain. Artificial neuron model. Types of activation functions of neurons. The concept of a neural network. General classification of ANNs. The principle of learning neural networks.
Topic 2. Perceptrons
Classification of images using a perceptron. Architecture of perceptrons. The principle of classification of input images. Perceptron training procedure (-rule).
Topic 3 Algorithm of inverse error propagation
. The architecture of neural networks that are trained using AZPP. Features of AZPP, increasing the speed of convergence. .Algorithm of conjugate gradient .

Topic 4. artificial neural network of radial basis functions
The principle of operation of an artificial neuron with a radial-basis activation function. Architecture of RBSHNM. Training at RBSHNM. Function approximation and image classification using radial-basis ANN.
Topic 5. Architecture and principle of operation of a single-layer competitive network.
Shar Kohonen. Concept of "dead neurons". Topology types of Kohonen maps. Means of calculating the distance between neurons. Advantages and disadvantages of Kohonen ANN, vector quantization ANN.
Topic 6. Recurrent neural networks.
Elman's ANN architecture. Elman's ANN training. The concept of the stability of ANNs. Modeling time series using Elman's recurrent network
Topic 7. Hopfield's ANN architecture. Neurodynamics in the Hopfield network. Hopfield network learning.
Advantages and disadvantages of Hopfield's ANN Modeling associative memory using Hopfield's neural network.
Topic 8. Adaptive resonance theory.
The main idea of adaptive resonance theory (ART). Architecture of the ART1 network Algorithm of the ART1 network. Training of ART1 network.
Topic 9. Convolutional artificial neural networks.
Architecture, varieties. Structure:. Convolution layer. Pulling layer. Fully connected layer. Output layer. Types Features of construction and application.

Topics of the workshops

Practical classes within the discipline are not provided.

Topics of the laboratory classes

Topic 1. Multivariate variance analysis
Topic 2. Construction of a classical linear model of paired regression under conditions of multicollinearity and statistical evaluation of its parameters.
Topic 3. Construction of a classical linear model of multiple regression with autocorrelation of residuals and statistical evaluation of its parameters.
Topic 4. Carrying out factor analysis.
Topic 5. Time series smoothing methods
Topic 6. Identification of a time series trend by analytical methods and analysis of a series of residuals.
Topic 7. Calculations of the autocorrelation function and the private autocorrelation function.
Topic 8. Study of the stationary series and identification of the AR(r) model.
Topic. 9. Investigation of the stationary series and identification of the MA(q) model
Topic 10. Study of a stationary series and identification of the ARMA(p, q) model.

Self-study

1. Image classification using a single-layer perceptron.
Linear divisibility.
2. Classification of images using a multilayer perceptron
3. Approximation of the function using the radial-basis ANN.
4. Classification of images with the help of radial-basis ANN.
5. Clustering using Kohonen ANN, Kohonen map.
6. Modeling time series using Elman's recurrent network.
7. Modeling associative memory using the Hopfield neural network
8. Modeling associative memory using the Hopfield neural network.
9. Training of the ART1 network.
Filled in if available in the plan of laboratory classes.

Non-formal education

Within the framework of 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 the 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 2. "Perceptrons"
https://www.coursera.org/learn/machine-learning?specialization=machine-learning-introduction
- Topic 9. https://www.youtube.com/watch?v=JVQ8ZGxJdfg

Course materials and recommended reading

Basic literature
1. I. A. Tereykovskyi, D. A. Bushuev, L. O. Tereykovskaya ARTIFICIAL NEURAL NETWORKS: BASIC PROVISIONS Study guide.: Kyiv KPI named after Igor Sikorskyi, 2022. 122 p.
https://ela.kpi.ua/server/api/core/bitstreams/9fee52b6-83fc-4e99-8541-c2767f634c7c/content
2. Subbotin S. O. Neural networks: theory and practice: teaching. manual / S. O. Subbotin. - Zhytomyr: Ed. O. O. Evenok, 2020. - 184 p. . – ISBN 978-966-995-189-2.
https://moodle.znu.edu.ua/pluginfile.php/569622/mod_resource/content/2/Subbotin_Neural.pdf
3. Perceptron. Material from Wikipedia.
https://uk.wikipedia.org/wiki/Perceptron
4. Kolesnytskyi O.K., Mesyura V.I. Neural network models and technologies of computational intelligence. Neurocomputers. Part 1. Study guide, Vinnytsia: VNTU, 2021. 66 p. . – ISBN 978-966-641-871-8.
5. Analytica. User's Guide. Lumina Decision Systems, Inc. [Electronic resource].
https://docs.analytica.com/index.php/Analytica_User_Guide
6. Analytica Tutorial.– Lumina Decision Systems, Inc. [Electronic resource].
https://docs.analytica.com/index.php/Analytica_Tutoria
7. I. V. Gushchin Introduction to the methods of organization and optimization of neural networks: study guide / V. Gushchin, O. V. Kyrychok, V. M. Kuklin. – Kh.: V.N. Karazin KhNU, 2021 – 152 p. . – ISBN 978-966-285-754-2/
8. Kuklin V. M. Presentation of knowledge and operations on it; Tutorial. / V. M. Kuklin. Kh.: KhNU named after V. N. Karazin, 2019. 164 p. . – ISBN: ISBN 978-966-285-606-4/

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