MD-2068, CHISINAU, 9/7 STUDENȚILOR STR., PHONE: 022 50-99-63, www.utm.md

Neural Networks and Deep Learning

1. Course/Module information

Faculty	Computer, Informatics and Microelectronics				
Department	Informatics and Systems Engineering				
Study cycle	Master, II cycle				
Study program	Data Science				
Year of study	**Semester**	**Evaluation type**	**Formative category**	**Optionality category**	**ECTS credits**
1st year *(full-time education)*	2	E	F	A	5

2. Estimated total time

Total hours in the curriculum	**Including**				
	Auditory hours		**Individual work**		
	Lecture	**Laboratory/ seminar**	**Term paper**	**Study of theoretical material**	**Application development**
Full-time education	20	20	-	110	-

3. Prerequisites for access to the course/module

According to the curriculum plan	Linear algebra, Advanced mathematics, Probability and information theory, Mathematical statistics, Mathematical models and optimization, Exploratory data analysis and modeling, Data visualization, Machine learning and Data mining.
According to competencies	Skills in data manipulation and preprocessing: knowledge of techniques for cleaning, normalization, feature scaling, and handling missing data. Data visualization: the ability to create and interpret visualizations to represent data effectively. Critical thinking and problem-solving for the efficient approach to ML problems. Self-learning skills: the ability and desire to engage in self-directed learning and research to deepen understanding and keep up with the rapidly evolving field of artificial intelligence. Understanding of the business context: awareness of how AI integrates into business and real-world applications.

4. Conditions for conducting the educational process

Lecture	For presenting the theoretical material in the classroom, a projector and computer are required. Student tardiness, as well as phone conversations during the lecture, will not be tolerated.
Laboratory/ seminar	Students will engage in laboratory work under the guidance of the professor and the assistant and will finalize the reports according to the methodological instructions. The deadline for submitting the laboratory work is one week from its completion. If the work is submitted late, a penalty of 1 point per week of delay will be applied.

5. Specific competencies acquired

Professional competencies	***CP2. Application design and development:*** • Appropriate software programs/modules. • Functional and technical design. • Cutting-edge technologies. • Programming languages. • Database management systems (DBMS). • Operating systems and software platforms. • Integrated development environment (IDE). • Quick application development. • Technical modeling technology and languages. • Interface definition languages (IDL).

	• Security issues. ***CP3. Component integration:*** • Hardware/software components/modules, whether old, existing, or new. • The impact of system integration on the organization or existing system. • Interface techniques between modules, systems, and components. • Integration testing techniques. • Development tools (e.g., development environment, management, change control, and access to source code). • Best design practices.
Transversal competencies	**CTL1 Autonomy and responsibility.** Demonstrates responsible execution of professional tasks under conditions of autonomy. **CTL2 Social interaction.** Performs teamwork-specific roles and activities and distributes tasks among members at subordinate levels. **CTL3 Personal and professional development.** Acknowledges the need for continuous training, using resources and learning techniques effectively for personal and professional growth.

6. Course/Module objectives

General objective	The development of a comprehensive understanding of artificial intelligence concepts and techniques, neural network architectures, and applications in NLP. The development of the necessary skills to create intelligent systems that understand, process, and generate human-like language, revolutionizing communication and automation.
Specific Objectives	• Understanding fundamental principles: developing a solid foundation in neural network principles, deep learning architectures, and NLP concepts. • Implementing neural networks: designing, implementing, and optimizing neural network models for various tasks and applications. • Deep learning techniques: advanced deep learning techniques – CNN, RNN, and attention mechanisms for handling complex data and tasks. • Basics of natural language processing (NLP): the fundamentals of NLP, including tokenization, part-of-speech tagging, named entity recognition, and sentiment analysis. • NLP applications: NLP techniques for solving real-world problems, such as text classification, language modeling, and machine translation. • Model training and evaluation: strategies for training and evaluating neural network models for optimal performance and accuracy. • Ethical considerations: the implications and ethical considerations related to the use of artificial intelligence, neural networks, and NLP technologies. • Integrating artificial intelligence techniques, neural networks, and NLP to create intelligent applications for understanding, generating, and interacting in natural language.

7. Course/Module content

Syllabus of teaching activities	**Number of hours**
	Full-time education
Course topics	
T1. **Natural Language Processing (NLP)** Tokenization and tokens. N-grams and stopwords. Building vocabulary and normalization. Case folding, stemming, and lemmatization.	**4**
T2. **Word Embedding** Self-organizing maps. Word2vec, Skip-grams, and Continuous Bag of Words (CBOW). Global vectors (GloVe) and fastText. Visualizing word relationships and document similarity.	**2**

Syllabus of teaching activities	Number of hours
	Full-time education
T3. **Artificial Neural Networks (ANN).** Biological neuron and perceptron. Inputs, weights, and outputs. Activation function with threshold. Example of perceptron prediction calculation. Sigmoid activation function. Hyperbolic tangent activation function. Rectifier activation function. Example of real estate price prediction with ANN. Backpropagation. Gradient Descent and Stochastic Gradient Descent. Choosing the cost function. Regularization. Weight initialization. Choosing the learning rate.	**4**
T4. **Convolutional Neural Networks (CNNs).** Representation of digital image data. Convolution layer. Convolution filters or feature detectors. Feature map. Convolution formula. Convolution – cross-correlation and cosine similarity. Loss of information in convolution and padding. Convolution for color images (3D tensors). Spatial invariance and pooling layer (Max and Mean Pooling). Fully connected layer. Example of training CNN on images.	**4**
T5. **Recurrent Neural Networks (RNNs).** The vanishing gradient problem. The exploding gradient problem. Simple RNN or Elman Network. Example of word classification with RNN. Hidden states. Types of tasks and RNN architectures. Tanh activation function. Gated Recurrent Units (GRUs). Update gate vector and reset gate vector. Long Short-Term Memory Networks (LSTMs). Cell state. Forget gate, input/update gate, and output gate. Bidirectional RNNs.	**4**
T6. **Transformers.** Seq2Seq architecture and Attention Mechanism. Basic self-attention and Context Vector. Encoders (e.g., BERT) and Decoders (e.g., GPT). Queries, Keys, and Values. Example of calculating attention scores (similarity).	**2**
Total course:	**20**
Practical work topics	
Practical work no. 1. Predicting the unsubscribe rate using an ANN. Adjusting the hyperparameters of the feedforward neural network.	**6**
Practical work no. 2. Image classification using CNN.	**4**
Practical work no. 3. Text mining using the NLTK library in the Python programming language.	**6**
Practical work no. 4. Fine-tuning BERT for sentiment analysis in movie reviews using the Hugging Face's Transformers library.	**4**
Total practical work:	**20**

8. Using generative AI

Permission to use	The use of generative AI in assignments and projects is permitted, provided that students adhere to the following rules: • Generative AI may be used to generate ideas, text structures, or code, but all generated materials must be reviewed and adjusted by the student to ensure that they meet academic requirements. • Any use of generative AI must be declared in the appendix section of each paper, using the phrase: "During the preparation of this paper, the author used [NAME OF TOOL / SERVICE] for the purpose of [REASON]. After using this tool / service, the author reviewed and edited the content as necessary and assumes full responsibility for the content of the paper."
Restrictions to use	Students ***MUSTN'T consider generative AI as a reliable source of information***, as it does not provide clear references or documented sources. • ***Direct citation of AI-generated content*** in academic papers as if it were a primary source ***isn't permitted.*** • Activities in which the use of **generative AI is prohibited** are specified by the teacher and are usually ***intermediate and final assessments*** or that don't involve professional competence development activities.

9. Bibliographic references

Main	1. Michael Nielsen, Neural Networks and Deep Learning, 2019, http://neuralnetworksanddeeplearning.com 2. Ian Goodfellow, Yoshua Bengio and Aaron Courville, Deep Learning, 2016, MIT Press, http://www.deeplearningbook.org 3. Nithin Buduma, Nikhil Buduma and Joe Papa, 2022 Fundamentals of Deep Learning: Designing Next-Generation Machine Learning Algorithms, 2nd Edition, OReilly Media Inc. 4. Educational materials and bibliographic sources on FCIM's ELSE Platform: https://else.fcim.utm.md/course/view.php?id=703
Supplementary	Lewis Tunstall, Leandro von Werra, and Thomas Wolf, Natural Language Processing with Transformers. Building Language Applications with Hugging Face, O'Reilly Media, 2022.

10. Evaluation

Periodic		**Current**	**Individual study**	**Project/thesis**	**Exam**
PE 1	**PE 2**				
Full-time education					
15%	15%	15%	15%		40%
Minimum performance standards Attendance at lectures; activity and quality of preparation for lectures and laboratory work; Achieving the minimum grade of "5" in each of the assessments and laboratory works; Demonstrating knowledge of the theoretical content and practical skills in the final examination paper.					

11. Evaluation criteria

Activity	**Evaluation components**	**Evaluation method, Evaluation criteria**	**Weight in the final grade of the activity**	**Weight in the course evaluation**
Full-time education				
Periodic evaluation I	Theoretical content, topics 1-4	Test on MOODLE	100%	**15%**
Periodic evaluation II	Theoretical content, topics 6-8	Test on MOODLE	100%	**15%**
Current evaluation	Practical activity	Discussions during seminars	50%	**15%**
		File completed with Reports for each Case Study under discussion	50%	
Individual study	Research on the topic	Presentation/public speech	100%	**15%**
Final evaluation	Theoretical and practical content	Oral exam. Grading according to grading scale	100%	**40%**