GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Machine learning, PG_00063394		
Field of study	Nanotechnology		
Date of commencement of studies	October 2024	Academic year of realisation of subject	2026/2027
Education level	first-cycle studies	Subject group	Obligatory subject group in the field of study Subject group related to scientific research in the field of study
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	3	Language of instruction	Polish
Semester of study	5	ECTS credits	4.0
Learning profile	general academic profile	Assessment form	assessment
Conducting unit	Division of Theoretical Physics and Quantum Informaton -> Institute of Physics and Applied Computer Science -> Faculty of Applied Physics and Mathematics -> Wydziały Politechniki Gdańskiej		
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Paweł Syty	
	Teachers		

Lesson types and methods of instruction

Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	15.0	0.0	30.0	0.0	0.0	45

E-learning hours included: 0.0

Learning activity and number of study hours

Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
Number of study hours	45	5.0	50.0	100

Subject objectives

The aim of the course is to familiarise students with machine learning issues (algorithms, tools, techniques), including elements of deep learning, mainly using neural networks (including convolutional networks), as well as with methods of programming selected methods and the practical use of ready-made tools.

Learning outcomes

Course outcome	Subject outcome	Method of verification
[K6_U03] has programming skills in a selected language, and is able to use basic software packages.	The student is able to implement basic machine learning algorithms in Python. The student is able to use ready-made programming libraries and computational packages to perform advanced calculations in the field of machine learning.	[SU1] Assessment of task fulfilment [SU4] Assessment of ability to use methods and tools [SU5] Assessment of ability to present the results of task
[K6_W02] has systematic knowledge of higher mathematics, including calculus, linear algebra with elements of geometry, numerical methods, the basics of probability theory.	The student knows and understands the basic algorithms of machine learning. The student is able to select the appropriate algorithm for a given task.	[SW1] Assessment of factual knowledge [SW3] Assessment of knowledge contained in written work and projects
[K6_W04] Has knowledge of IT tools (word processors, spreadsheets, etc.), preparing multimedia presentations, programming and computer graphics	The student knows and understands the basic applications of selected machine learning tools.	[SW1] Assessment of factual knowledge

Subject contents	**Lecture** 1. History and definition of machine learning. Overview of machine learning applications. Classification of machine learning methods. The role of data and its quality in machine learning. Preparing data for the learning process. Introduction to Python. 2. Imperfect knowledge in machine learning. Methods for dealing with imperfect knowledge. Bayesian inference. Fuzzy logic. 3. Biological foundations of artificial neural networks. The nervous system of animals and humans classification and functions. Reception and processing of stimuli by the brain. Neurons structure, classification. Life manifestations of neurons. Memory. Discussion of the possibilities and limitations of mapping biological systems in the form of artificial systems. 4. History and basics of neural networks. Basic model of a nerve cell simple perceptron and its properties. Simple perceptron as a generalisation of linear regression. Basic methods of perceptron learning. Limitations of a single perceptron. Combining perceptrons into larger structures. Basic classification of artificial neural network architectures. Preliminary classification of neural network applications. Features of artificial neural networks that predestine them for applications in the modern world. 5. Single-layer feedforward networks. Structure, learning methods, applications, limitations. Weight map. Hyperparameters. Metrics. Data encoding. 6. Multilayer feedforward networks. Structure, learning methods, applications, limitations. More about network learning methods backpropagation method, momentum method (including Nesterov's method). Discussion of selected optimisers (SGD, RMSprop, Adam). Model initialisation. Activation functions. 7. Generalisation ability of neural networks. Measures of generalisation ability. Kolmogorov's theorem. Training, validation and test sets. Overfitting and underfitting of networks. Regularisation methods. Selection of optimal network architecture. Network dimension reduction process. Dropout layers. 8. Convolutional networks. Structure, learning methods, applications, limitations. Convolution operation. Pooling layers. Filters. OpenCV library. Neural network methods and architectures for image recognition. Lenet and VGGNet networks. Multi-label classification. Data augmentation. 9. Autoassociative networks. Transfer learning. Cross-validation. Elements of explainable artificial intelligence. 10. Recurrent networks. Structure, learning methods, applications, limitations. Associative memories. LSTM and GRU cells. 11. Two-player game strategies. MINIMAX algorithm. Heuristic function. Alpha-beta pruning. The idea of self-play. 12. Cellular automata with particular emphasis on their application in machine learning. 13. Other machine learning methods: k-nearest neighbours, support vector machine (SVM), decision tree, random forest, evolutionary algorithms, linear mixed models. Ensemble methods. 14. Elements of unsupervised learning. Cluster analysis. Centroid algorithm (k-means). Time series analysis. K-shape algorithm and DTW (Dynamic Time Warping). 15. Elements of the Prolog language. Predicate notation. Backward and forward reasoning. **Laboratory** During the classes, students complete a series of programming tasks related to the topics discussed in the lecture. In addition, they carry out one larger project related to a topic of their choice related to machine learning.

<table>
<tr><td>Prerequisites and co-requisites</td><td colspan="3">Knowledge of the basics of mathematical analysis and algebra. Knowledge of the basics of programming.</td></tr>
<tr><td>Assessment methods and criteria</td><td colspan="3"><table>
<tr><th>Subject passing criteria</th><th>Passing threshold</th><th>Percentage of the final grade</th></tr>
<tr><td>assessment of programming tasks</td><td>50.0%</td><td>50.0%</td></tr>
<tr><td>final examination</td><td>50.0%</td><td>50.0%</td></tr>
</table></td></tr>
<tr><td rowspan="3">Recommended reading</td><td>Basic literature</td><td colspan="2">Daniel T. Larose, Data Mining and Predictive Analytics (2nd edition), Wiley John&Sons, 2015

Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, 3rd Edition, OReilly, 2022

Aileen Nielsen,Practical Time Series Analysis: Prediction with Statistics and Machine Learning, Helion 2019</td></tr>
<tr><td>Supplementary literature</td><td colspan="2">Joel Grus, Practical Time Series Analysis: Prediction with Statistics and Machine Learning, OReilly 2019

Keras and Tensorflow package documentation</td></tr>
<tr><td>eResources addresses</td><td colspan="2"></td></tr>
<tr><td>Example issues/ example questions/ tasks being completed</td><td colspan="3">Overview of data preparation methods for machine learning.

Implementation of a neural network for automatic classification of SEM images.</td></tr>
<tr><td>Work placement</td><td colspan="3">Not applicable</td></tr>
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