COURSE DESCRIPTION CARD - SYLLABUS

Course name
Spiking neural networks [S1SI1E>PSN]

Course

Field of study
Artificial Intelligence

Year/Semester
4/7

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
english

Form of study
full-time

Requirements
elective

Number of hours

Lecture
15

Laboratory classes
15

Other (e.g. online)
0

Tutorials
0

Projects/seminars
0

Number of credit points

3,00

Coordinators

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Lecturers

Prerequisites

The student starting this course should have knowledge of artificial neural networks and the basics of electronics. They should have the skills of solving basic algorithmic problems, image processing and obtaining information from specified sources. They should understand the need to broaden their competence in modeling real-life decision problems and using IT tools to solve them. In addition, in the field of social competence, the student must present honesty, responsibility, perseverance, cognitive curiosity, creativity, personal culture and respect for other people.

Course objective

The aim of the course is to present the principle of operation of neural networks based on models of human neurons. In particular, the course will cover the following issues: 1. Models of spiking neurons along with an assessment of the computational complexity of the models. 2. Methods of coding information in spiking neural networks and learning of these networks. 3. Comparison of effectiveness of different generations of neural networks. 4. Discussing aspects of hardware implementation of spiking neural networks including the functionality of neuroprocessors.

Course-related learning outcomes

Knowledge:
1. presents ordered, detailed theoretical knowledge about key IT issues in the field of artificial intelligence, including machine learning, data analysis and mining, inductive reasoning, information acquisition and processing, optimization techniques and decision analysis
2. knows and understands the basic techniques, methods, algorithms and tools used in the process of solving IT tasks with particular emphasis on artificial intelligence, including discovering patterns in different types of data and their synthesis to knowledge and conclusions
3. presents basic knowledge of significant directions of development and the most important achievements of artificial intelligence understood as an important field of computer science drawing on the achievements of other scientific disciplines and providing solutions with relevant practical potential

Skills:
1. is able to formulate and solve complex problems in the field of computer science with particular emphasis on artificial intelligence using appropriately selected methods (including analytical, simulation and experimental approaches)
2. is able to perform a critical analysis and assessment of functioning of IT systems and operation of methods of artificial intelligence
3. presents the ability to easily adapt existing and to formulate and implement new algorithms, including algorithms typical for various trends in artificial intelligence, using at least one popular tool
4. is able to use and adapt models of intelligent behaviors and IT tools simulating these behaviors

Social competences:
1. understands that in computer science, with particular emphasis on artificial intelligence, knowledge and skills quickly become obsolete, recognizing the need of continuous training and self-improvement
2. is aware of the importance of knowledge and scientific research related to computer science and artificial intelligence in solving practical problems of key importance for the functioning of individuals, companies, organizations and the whole society
3. is aware of the social role of a technical university graduate and in particular understands the need to formulate and convey to the public, in an accessible form, information and opinions concerning engineering activities, achievements of artificial intelligence and other aspects of work of an IT specialist - an artificial intelligence specialist

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

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The learning outcomes presented above are verified as follows:
Formative assessment:
a) concerning lectures:
- based on answers to questions concerning the material discussed during lectures.
b) concerning laboratory / practical classes:
- based on an assessment of the current progress of implementation of tasks.
Summative assessment:
a) concerning lectures, assumed learning outcomes are verified with:
- assessment of knowledge and skills demonstrated at the written completion assessment with different characteristics of problems to solve: multiple-choice test questions, content to fill in, simple computational or algorithmic tasks and problems of greater complexity; pass with more than half points achieved.
- discussing the completion assessment results.
b) concerning laboratory / practical classes, assumed learning outcomes are verified with:
- assessment of test reports prepared during classes and completed as part of own work after classes; this assessment also includes teamwork skills,
- assessment of skills related to the implementation of laboratory classes.
Getting extra points for activity during classes, especially for:
- discussing additional aspects of an issue,
- effectiveness of applying the acquired knowledge for solving a given problem,
- ability to work as part of a team practically performing a specific task in a laboratory.

Programme content

Lectures will cover the following issues:
1. Different generations of neural networks, spiking neuron operating principle, models of spiking neurons.
2. Methods of data representation in spiking neural networks and network learning methods. Assessment of network processing efficiency.
3. Edge computing using spiking neurons, hardware aspects of semiconductor implementations of spiking neurons, network reconfiguration, synapse plasticity, neuroprocessors.
4. Brain implants on the example of a hippocampal prosthesis. Modeling psychological behaviors based on the cusp catastrophe theory.
5. Methods of solving nonlinear problems, image processing and logical problems using spiking neural networks.
6. eXplainable Artificial Intelligence (XAI) on the example of spiking neural networks.
7. Presenting research works carried out by the department in the field of spiking neural networks.
Laboratories will cover the following issues:
1. Simulating operation of a single spiking neuron using a selected mathematical model.
2. Connecting spiking neurons in multilayer networks and conducting a network learning process.
3. Implementing a network model based on the cusp catastrophe theory. Solving a selected nonlinear problem using a network of neurons.
4. Implementing an explainable network. Implementing a classifier reasoning decisions.

Teaching methods

1. Lecture: multimedia presentation supplemented with examples on a board
2. Laboratory classes: solving tasks, practical exercises, data analysis, simulation, discussion, teamwork, case study, multimedia presentation.

Bibliography

Basic
1. The handbook of brain theory and neural networks / edited by Michael A. Arbib ; editoral advisory board, Shun-Ichi Amari [et al.] ; editoral assistant, Prudence H. Arbib., Cambridge, Mass. ; London : MIT Press, 2003.
Additional
1. Computational neuroanatomy : principles and methods / ed. by Giorgio A. Ascoli, Totowa, N.J. : Humana Press, 2002.
2. S. DeWeerdt, How to map the brain, Nature, 571, pp. 6-8, 2019.
3. A. Chander et al., in Proc. MAKE-Explainable AI, 2018.
4. Spiking Neural Network Based on Cusp Catastrophe Theory, D. Huderek, S. Szczęsny, R. Rato, Foundations of Computing and Decision Sciences, vol. 44, Issue 3, 2018

Breakdown of average student's workload

	Hours	ECTS
Total workload	75	3,00
Classes requiring direct contact with the teacher	30	1,50
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	45	1,50