



Module name: Computational Intelligence

Academic year: 2016/2017 Code: EIT-2-109-MS-s ECTS credits: 4

Faculty of: Electrical Engineering, Automatics, Computer Science and Engineering in Biomedicine

Field of study: Computer Science Specialty: Systems modelling and data analysis

Study level: Second-cycle studies Form and type of study: Full-time studies

Lecture language: English Profile of education: Academic (A) Semester: 1

Course homepage: <http://home.agh.edu.pl/~horzyk/lectures/ahdydci.php>

Responsible teacher: dr hab. Horzyk Adrian (horzyk@agh.edu.pl)

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Description of learning outcomes for module

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Connections with FLO	Method of learning outcomes verification (form of completion)
Social competence			
M_K001	He can share knowledge, findings, discoveries and achievements. He can work in a team and communicate with other team members. He is able to think creatively and use the tools of creative thinking, e.g. brainstorming technique. He developed the ability to think entrepreneurial about implementation of the computational intelligence solutions in the industry.	IT2A_K01, IT2A_K02	Involvement in teamwork, Execution of laboratory classes, Execution of a project, Project, Presentation
Skills			

M_U001	He can use libraries of computational intelligence methods to solve problems using various learning and adaptation techniques as well as is able to implement these methods using programming languages, choose appropriate parameters and structures in order to optimize them for any given task.	IT2A_U01, IT2A_U03, IT2A_U04, IT2A_U05, IT2A_U06, IT2A_U07, IT2A_U09, IT2A_U10, IT2A_U13	Execution of laboratory classes, Execution of a project, Project, Presentation
Knowledge			
M_W001	He has knowledge in the area of designing, implementation and in the use of methods and techniques in the field of computational intelligence and can apply them to various problems and tasks.	IT2A_W03, IT2A_W04, IT2A_W05, IT2A_W06, IT2A_W07, IT2A_W09	Execution of laboratory classes, Execution of a project, Project, Presentation
M_W002	He knows how to select appropriate methods, architectures and parameters to optimize operations and the quality of generalization of applied methods of computational intelligence.	IT2A_W01, IT2A_W03, IT2A_W04, IT2A_W05, IT2A_W06, IT2A_W07	Project, Presentation, Execution of laboratory classes, Execution of a project

FLO matrix in relation to forms of classes

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Form of classes										
		Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Fieldwork classes	Workshops	Others	E-learning
Social competence												
M_K001	He can share knowledge, findings, discoveries and achievements. He can work in a team and communicate with other team members. He is able to think creatively and use the tools of creative thinking, e.g. brainstorming technique. He developed the ability to think entrepreneurial about implementation of the computational intelligence solutions in the industry.	-	-	+	+	-	-	-	-	-	-	-
Skills												

M_U001	He can use libraries of computational intelligence methods to solve problems using various learning and adaptation techniques as well as is able to implement these methods using programming languages, choose appropriate parameters and structures in order to optimize them for any given task.	-	-	+	+	-	-	-	-	-	-	-
Knowledge												
M_W001	He has knowledge in the area of designing, implementation and in the use of methods and techniques in the field of computational intelligence and can apply them to various problems and tasks.	+	-	-	+	-	-	-	-	-	-	-
M_W002	He knows how to select appropriate methods, architectures and parameters to optimize operations and the quality of generalization of applied methods of computational intelligence.	-	-	-	-	-	-	-	-	-	-	-

Module content

Lectures

Introduction to Computational Intelligence

The variety of models and computational intelligence techniques will be presented. The abilities of contemporary computational intelligence methods, their kinds, limitations, difficulties, pros and cons will be discussed. The biological and historical background will be presented. The contemporary and future trends will be shown. The ability of contemporary computational intelligence methods to abilities of biological creatures, their brains and cognitive properties will be compared. Various kinds of training techniques will be introduced and analysed. Fundamentals of autonomous intelligent systems, motivated learning and embodied intelligence will be discussed.

Introduction to Neural Networks

We will focus on various models of neurons and discuss their differences, possibilities and limitations against the possibility of biological neurons and nervous systems. The biological backgrounds of neuron functions, plasticity, development and dynamic adaptability will be explained. The first, fundamental, most popular and promising neuron adaptation methods will be introduced and discussed. Various learning, adaptation and construction strategies will be presented.

MLP Neural Networks

The most popular MLP neural networks will be presented together with various training algorithms and additional techniques that enable us to better adapt this kind of neural networks. Local minima, curse of dimensionality, convergence and overfitting problems will be described and it will be also explained how to tackle with these problems. Various methods for creating, developing or adapting the structure of MLP networks and establishing of their initial parameters will be presented. A few

kinds of computational tasks solvable using MLP networks will be introduced. Validation and testing techniques for optimal adaptation of MLP networks will be shown and data preprocessing techniques (e.g. PCA, ICA) presented.

RBF Neural Networks

The differences between sigmoidal and radial activation functions will be discussed and compared. Various radial activation function will be introduced and examined. Radial Basis Function networks will be presented together with various methods of their creation and training. Methods for adaptation of the number of centers and neurons will be described, compared and discussed due to the generalization problems. Possible and most promising applications of RBF networks will be introduced.

Support Vector Machines

Support Vector Machine idea for optimal discrimination and separation of classes will be explained, proven and analyzed. Nonlinear (polynomial, radial and sigmoidal) SVM and the way of their creation and training will be shown. Various types of SVM for classification and regression (approximation) will be introduced. Techniques of SVM adaptation to the larger number of classes will be presented. Limitations and computational problems of quadratic programming with linear constraints will be discussed.

Competitive Unsupervised Learning and Self Organizing Maps

The concept of self-organization, unsupervised and competitive learning will be explained and compared to biological systems. The training and mapping modes of Self-Organizing Maps (SOM) will be presented. Comparison of unsupervised algorithms and methods will be shown on the sample of the Neural Gas algorithm.

Recurrent Neural Networks

Dynamic convergence to attraction points in recurrent neural networks together with adaptation methods of these kind of networks will be presented and supplemented with introduction of areas of their use. A few kinds of recurrent neural networks, their properties and abilities will be compared. The limitations of these kinds of networks due to their ability to remember training samples will be discussed.

Associative Semantic Memories and Neural Networks

Since associative processes have a great impact on information processes in a human brain some of these processes will be modelled and presented on computational models. The way of working of various kinds of associative memories will be introduced and the substantial differences will be explained. An expanded model of association in neural structures will be introduced to model a kind of semantic and episodic memories. On this background, a few kinds of associative neural networks, their advanced associative features and concluding abilities will be presented. It will be shown how various data relations can be implemented and represented in these associative neural graph structures. This will allow us to substitute the time-consuming search operations on classic data structures with more efficient operations on these associative neural structures.

Deep Learning and Deep Belief Neural Networks

Modern deep learning philosophy as a way of high-level abstractions for optimizing neural structures and results will be presented. Various ways of creation of complex multiple processing layers for hierarchical feature extraction and concept creation will be explained. A few kinds of deep architectures and deep neural networks will be introduced and methods of their creation and training will be presented.

Fuzzy Logic Learning Systems

The main idea of fuzzy logic and fuzzy systems will be introduced. How to handle the concept of partial truth, linguistic variables and fuzzy attributes will be shown. Various kinds of fuzzy logic functions and fuzzy operators will be presented and compared. Fuzzy algebra will be introduced together with computational techniques that enable us to use fuzzy systems to solve various tasks on fuzzy data. Fuzzification and defuzzification processes and methods will be explained. Neuro-fuzzy systems will be also presented and the fuzzy systems will be used to adapt neural systems.

Laboratory classes

Computational Intelligence tools and experiments

We will learn how to use RapidMiner to solve a few computational intelligence problems on sample data. We will try to build a few classifiers and compare their results and discuss various learning strategies on the samples.

MLP and RBF network construction, optimization and supervised learning

MLP and RBF networks will be implemented and selected methods for their training will be used to adapt them to sample data. Next, we will estimate their quality of generalization and compare it for various networks and training algorithms.

SOM network construction and unsupervised competitive learning

SOM and Neural Gas networks will be implemented and trained to adapt to sample data. Various kinds of competitions will be used to adapt the networks. Training results and their efficiency will be compared.

Recurrent neural network implementation, construction and learning

Recurrent neural network will be implemented and adapted for some image recognition tasks. We will see how this network is attracted to local minima representing training samples and their combinations that cannot be usually treated as correct answers.

Fuzzy systems implementation and learning

We will construct a fuzzy system for representation of some fuzzy linguistic data in order to automatically draw some conclusions about them and use them to control an external process. We also try to fuzzify data and defuzzify results.

Project classes

Associative structures, neural graph and memories implementation and adaptation

We will use associative graph data structures and associative systems to represent sample data in an associative form where horizontal and vertical data relations are represented and can be easily used for concluding about them, e.g. their similarities, differences, correlations, classes and other attributes. We will automatically draw conclusions about these data, find classes and mine some interesting information. Parallel implementation using GPU will be an advantage.

Deep learning and neural networks.

We will use deep learning strategy to develop and adapt neural networks to sample data in order to compare results to other previously obtained ones by other methods to conclude about their efficiency, adaptability and generalization properties. We will try to achieve better training and generalization results than using more simple or basic models.

Method of calculating the final grade

The course grade is the average of laboratory and project grades. In case of a correction exam, grades of all terms are taken into consideration when computing the average grade of the course.

Prerequisites and additional requirements

Each student who will take a part in this course should have a good background in computational techniques, object programming languages. Every student should be able to use these languages to create computer applications and use complex data structures, e.g. inhomogeneous graphs or trees of classes representing neurons. It is also necessary to have sufficient skills and knowledge of the English language to take a part in lectures and classes.

Recommended literature and teaching resources

1. Cruse, Holk; Neural Networks as Cybernetic Systems, 2nd and revised edition, file:///C:/Users/Adrian/Downloads/bmm615.pdf
2. Schwenker, Friedhelm; Kestler, Hans A.; Palm, Günther (2001). "Three learning phases for radial-basis-function networks". *Neural Networks* 14: 439–458. doi:10.1016/s0893-6080(01)00027-2.
3. Martin D. Buhmann (2003). *Radial Basis Functions: Theory and Implementations*. Cambridge University. ISBN 0-521-63338-9.
4. Bengio, Yoshua (2009). "Learning deep architectures for AI". *Foundations and Trends in Machine Learning* 2 (1): 1–127. doi:10.1561/22000000006.
5. Larochelle, Hugo; Bengio, Yoshua; Louradour, Jerdme; Lamblin, Pascal (2009). "Exploring Strategies for Training Deep Neural Networks". *The Journal of Machine Learning Research* 10: 1–40.
6. Hinton, G. (2009). "Deep belief networks". *Scholarpedia* 4 (5): 5947. doi:10.4249/scholarpedia.5947.
7. B. Ploj (2014). *Advances in Machine Learning Research (chapter 3)*. Nova Science Publishers. ISBN 978-1-63321-214-5.
8. Horzyk, A., Innovative types and abilities of neural networks based on associative mechanisms and a new associative model of neurons – the invited talk and paper at the International Conference ICAISC 2015,
9. Horzyk, A., How Does Generalization and Creativity Come into Being in Neural Associative Systems and How Does It Form Human-Like Knowledge?, Elsevier, *Neurocomputing*, 2014, pp. 238-257, DOI: 10.1016/j.neucom.2014.04.046.
10. Kohonen, Teuvo (1982). "Self-Organized Formation of Topologically Correct Feature Maps". *Biological Cybernetics* 43 (1): 59–69. doi:10.1007/bf00337288.
11. Fernando Canales and Max Chacon (2007). "Modification of the growing neural gas algorithm for cluster analysis". In Luis Rueda, Domingo Mery, Josef Kittler, *International Association for Pattern Recognition. Progress in pattern recognition, image analysis and applications: 12th Iberoamerican Congress on Pattern Recognition, CIARP 2007, Viña del Mar-Valparaiso, Chile, November 13–16, 2007; proceedings*. Springer. pp. 684–693. doi:10.1007/978-3-540-76725-1_71. ISBN 978-3-540-76724-4.
12. Jürgen Schmidhuber. Learning complex, extended sequences using the principle of history compression. *Neural Computation*, 4(2):234–242.

Scientific publications of module course instructors related to the topic of the module

1. Horzyk, A., Human-Like Knowledge Engineering, Generalization and Creativity in Artificial Neural Associative Systems, Springer Verlag, AISC 11156, ISSN 2194-5357, ISBN 978-3-319-19089-1, ISBN 978-3-319-19090-7 (eBook), DOI 10.1007/978-3-319-19090-7, Springer, Switzerland, 2016, pp. 39-51.
2. Horzyk, A., Innovative types and abilities of neural networks based on associative mechanisms and a new associative model of neurons – the invited talk and paper at the International Conference ICAISC 2015, Springer Verlag, LNAI 9119, 2015, pp. 26-38, DOI 10.1007/978-3-319-19324-3_3.
3. Tadeusiewicz, R., Horzyk, A., Man-Machine Interaction Improvement by Means of Automatic Human Personality Identification, Springer-Verlag, LNCS 8838, 2014, pp. 278-289.
4. Horzyk, A., How Does Generalization and Creativity Come into Being in Neural Associative Systems and How Does It Form Human-Like Knowledge?, Elsevier, *Neurocomputing*, 2014, pp. 238-257, DOI: 10.1016/j.neucom.2014.04.046.
5. Horzyk, A., How Does Human-Like Knowledge Come into Being in Artificial Associative Systems, Proc. of the 8-th International Conference on Knowledge, Information and Creativity Support Systems, ISBN 978-83-912831-8-9, Krakow, Poland, 2013, pp. 189-200.
6. Horzyk, A., *Artificial Associative Systems and Associative Artificial Intelligence*, Academic Publishing House EXIT, Warsaw, 2013, postdoctoral monograph, pp. 1-280.
7. Horzyk, A., Gadamer, M., *Associative Text Representation and Correction*, Springer Verlag Berlin

Heidelberg, LNAI 7894, 2013, pp. 76-87.

8.Horzyk, A., Information Freedom and Associative Artificial Intelligence, Springer Verlag Berlin Heidelberg, LNAI 7267, ISBN 978-3-642-29346-7, 2012, pp. 81-89.

9.Horzyk, A., Self-Optimizing Neural Network 3, L. Franco, D. Elizondo, J.M. Jerez (eds.), Constructive Neural Networks, Springer, Series: Studies in Computational Intelligence, ISBN 978-3-642-04511-0, Vol. 258, 2009, pp. 83-101.

Additional information

The course language is English, so the students should know this language enough to understand lectures, learn from English written materials and use it to communicate with a teacher and other students to solve tasks and take an active part in laboratory and project classes.

Student workload (ECTS credits balance)

Student activity form	Student workload
Participation in lectures	28 h
Participation in laboratory classes	14 h
Participation in project classes	14 h
Preparation for classes	6 h
Preparation of a report, presentation, written work, etc.	10 h
Completion of a project	40 h
Realization of independently performed tasks	6 h
Contact hours	2 h
Summary student workload	120 h
Module ECTS credits	4 ECTS