COURSE DESCRIPTION CARD - SYLLABUS

Course name

ARTIFICIAL NEURAL NETWORKS IN THE DESIGN OF CONTROL SYSTEMS

Course

Proposed by Discipline

Automation, electronic, electrical engineering and space technologies

Type of studies

Doctoral School

Form of study

full-time

Year/Semester

III/6

Course offered in

English

Requirements

elective

Number of hours

Lecture	Tutorials	Projects/seminars
4		

Number of credit points

1

Lecturers

Responsible for the course/lecturer:

dr hab. Stefan Brock, prof. PUT

email: stefan.brock@put.poznan.pl

phone: +48 61 665 2627

Faculty of Automatic Control, Robotics and Electrical Engineering

Poznan University of Technology

ul. Piotrowo 3a, 60-965 Poznan, Poland

Responsible for the course/lecturer:

Prerequisites

Knowledge: knows and understands in enhanced level the selected areas of mathematics: linear algebra, has an background knowledge of methods of analysis and design of control systems.

Skills: has the ability to self-educate in order to improve and update one's professional competences, can design control systems using selected engineering tools (e.g. Matlab).

Social competencies: is aware of responsibility for own work and willingness to conform to the principles of teamwork and taking responsibility for jointly implemented tasks.

Course objective

The purpose of this lecture series is to provide a quick overview of neural networks and to explain how they can be used in control systems. We introduce the multilayer perceptron neural network and describe how it can be used for function approximation. The popular algorithms for training multilayer perceptrons are briefly described. Care must be taken, when training perceptron networks, to ensure that they do not overfit the training data and then fail to generalize well in new situations. Some techniques for improving generalization are discussed. The lecture also presents the feedback linearization control and model reference adaptive control. We demonstrate the practical implementation of this controller, using the Matlab/Simulink environment.

Course-related learning outcomes

Knowledge

A PhD student who graduated from doctoral school knows and understands:
1) key developmental trends of science disciplines in which education takes place at the doctoral school, [P8S_WG/SzD_W02]
2) scientific research methodology in disciplines represented at the doctoral school. [P8S_WG/SzD_W03]

Skills

A PhD student who graduated from doctoral school can:
1) use the knowledge from different branches of science to creatively identify, formulate and to innovatively solve complex problems, [P8S_UW/SzD_U01]
2) critically analyze and asses scientific research results, work of experts and other creative activities together with their contribution into knowledge development. [P8S_UW/SzD_U02]

Social competences

A PhD student who graduated from doctoral school is ready to:
1) critically evaluate their own contribution to the development of a given scientific discipline, [P8S_KK/SzD_K02]
2) acknowledge the importance of knowledge in solving cognitive and practical problems. [P8S_KK/SzD_K03]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

PQF code	Methods for verification of learning outcomes	Assessment criteria
W02, W03	Written report, prepared in a group of 2-3 students or individually. The report should contain results of neural control system tests. Models will be provided by the instructor or developed individually	Grade F (2.0): Failure to design. No method given or completely incorrect method Grade E (3.0): The design incorrect; the learners will show evidence of ability to make the

		calculations correctly but the demonstration of how the calculation was done is poor, incoherent or not sufficiently detailed Grade range C-D (3.5-4.0): The learners show evidence of the ability to design the control system correctly but the demonstration of how it was done insufficient Grade range A-B (4.5-5.0): The learners will show evidence of the ability to make the design of control system correctly; the demonstration of how it was done is excellent, coherent, detailed and very well explained, showing great command and understanding of the methods involved
U01, U02	as above	as above
K02, K03	as above	as above

Programme content

1. Multilayer perceptron architecture (Neural networks have been applied successfully in the identification and control of dynamic systems. The universal approximation capabilities of the multilayer perceptron make it a popular choice for modeling nonlinear systems and for implementing general purpose nonlinear controllers).
2. Approximation capabilities and training of multilayer networks (Multilayer networks, with sigmoid transfer functions in the hidden layers and linear transfer functions in the output layer, are universal approximators, can approximate virtually any function of interest to any degree of accuracy, provided sufficiently many hidden units are available. The procedure for selecting the parameters for a given problem is called training the network. There are many optimization algorithms that can use the

backpropagation procedure, in which derivatives are processed from the last layer of the network to the first. For example, conjugate gradient and quasi-Newton algorithms are generally more efficient than steepest descent algorithms, and yet they can use the same backpropagation procedure to compute the necessary derivatives. The Levenberg-Marquardt algorithm is very efficient for training small to medium-size networks).
3. Control systems applications – Feedback linearization control (There are typically two steps involved when using neural networks for control: system identification and control design. In the system identification stage, we develop a neural network model of the plant that we want to control. In the control design stage, we use the neural network plant model to design (or train) the controller. The central idea of feedback linearization control is to transform nonlinear system dynamics into linear dynamics by canceling the nonlinearities. This section begins by presenting the companion form system model and showing how we can use a neural network to identify this model. Then it describes how the identified neural network model can be used to develop a controller).
4. Control systems applications - Model reference control (Model reference control architecture uses two neural networks: a controller network and a plant model network. The plant model is identified first, and then the controller is trained so that the plant output follows the reference model output).

Teaching methods

Lecture: multimedia presentation including illustrations and examples.

Bibliography

Basic

1. Liu J.: Radial Basis Function (RBF) Neural Network Control for Mechanical Systems, Springer 2013.

2. Lewis F. L., Shuzhi Sam Ge: Neural Networks in Feedback Control Systems, in: Mechanical Engineers' Handbook, Wiley 2006.

Additional

1. Mathworks documentation: Neural Network Control Systems, 2019.

2. Perez, C.: Neural networks control systems with Matlab. radial basis and LVQ neural network, CreateSpace 2017.

3. Sarangapani J.: Neural Network Control of Nonlinear Discrete-Time Systems, CRC 2006.

Breakdown of average student's workload

	Hours	ECTS
Total workload	11	1.0
Classes requiring direct contact with the teacher	5	0.5
Student's own work (literature studies, preparation for tutorials, project preparation) [1]	6	0.5

[1] delete or add other activities as appropriate