

## Machine Learning and Artificial Intelligence

<b>Course code</b>	<i>IT102</i>
<b>Compulsory in the programmes</b>	<i>Economics and Data Analytics</i>
<b>Level of studies</b>	<i>Undergraduate</i>
<b>Number of credits and</b>	<i>6 ECTS (48 contact hours + 6 consultation hours, 106 individual work hours)</i>
<b>Course coordinator (title and name)</b>	<i>Rokas Bendikas</i>
<b>Prerequisites</b>	<i>Data Mining for Business Intelligence</i>
<b>Language of instruction</b>	<i>English</i>

### THE AIM OF THE COURSE:

In an era where artificial intelligence (AI) and deep learning technologies are reshaping industries, the ability to harness these advanced tools for business and scientific innovation is crucial. This course aims to equip students with a broad understanding of state-of-the-art AI methods and deep learning techniques, enabling them to apply these concepts to specific industry use cases.

The curriculum is structured around four primary areas of focus: (1) Fundamentals of neural networks, such as the universal function approximator theorem, basic neural network architectures, activation functions, and optimization methods; (2) Core deep learning concepts and architectures, focusing on convolutional and recurrent neural networks; (3) Practical application of deep learning models to common real-world tasks, such as image recognition, natural language processing (NLP), time-series forecasting; (4) Advanced topics in AI, exploring transformer-based methods, reinforcement learning, and diffusion models. Emphasizing hands-on experience, the course facilitates project-based learning, predominantly utilizing the PyTorch framework.

This course assumes foundational knowledge in linear algebra, calculus, probability, and programming, preferably in Python.

### MAPPING OF COURSE-LEVEL LEARNING OUTCOMES (OBJECTIVES) WITH DEGREE LEVEL LEARNING OBJECTIVES (See Annex), ASSESSMENT AND TEACHING METHODS

Course level learning outcomes (objectives)	Degree level learning objectives (Number of LO)	Assessment methods	Teaching methods
CLO1. Understand the key components of neural networks and be able to implement simple linear regression and classification neural networks in PyTorch.	ELO1.1 ELO3.1	Final exam, Mid-term exam, group project	Lectures, seminars, independent work
CLO2. Grasp the basic principles of neural network training, including forward/backward passes, automatic differentiation, and the most common optimization algorithms.	ELO1.1 ELO4.2	Final exam, Mid-term exam, group project	Lectures, seminars, independent work
CLO3. Comprehend the distinction between simple neural networks and deep neural networks. Be capable of explaining the motivation behind different specialized layers and activation functions.	ELO4.1 ELO4.2 ELO4.3	Final exam, Mid-term exam, group project	Lectures, seminars, independent work

CLO4. Grasp the principles of the convolution operation and convolutional layers. Be able to implement a simple convolutional neural network in PyTorch.	ELO1.1 ELO3.2	Final exam, Mid-term exam, group project	Lectures, seminars, independent work
CLO5. Understand the curse of dimensionality and be proficient in performing various data augmentation and processing techniques.	ELO1.2 ELO3.2	Final exam, Mid-term exam, group project	Lectures, seminars, independent work
CLO6. Recognize how sequential data differs from tabular data. Develop an intuition for how recurrent neural networks and transformers process sequential data. Be able to discuss the advantages and disadvantages of both approaches.	ELO1.1 ELO1.2 ELO4.2	Final exam, Mid-term exam, group project	Lectures, seminars, independent work
CLO7. Develop a general understanding of generative AI methods, with a focus on diffusion-based approaches. Comprehend the basic principles of diffusion and be able to explain it in general terms.	ELO1.1 ELO1.2	Final exam, Mid-term exam, group project	Lectures, seminars, independent work
CLO8. Understand the distinctions between supervised learning and reinforcement learning methods. Grasp the basics of Markov Decision Processes and their application in formulating RL problems. Develop an intuitive understanding of temporal difference (TD) learning and its role in Q-Learning methods.	ELO4.2 ELO4.1 ELO4.2 ELO4.3	Final exam, Mid-term exam, group project	Lectures, seminars, independent work

#### ACADEMIC HONESTY AND INTEGRITY

The ISM University of Management and Economics Code of Ethics, including cheating and plagiarism, is fully applicable and will be strictly enforced in the course. Academic dishonesty and cheating can and will lead to a report to the ISM Committee of Ethics. With regard to remote learning, ISM reminds students that they are expected to adhere to and maintain the same academic honesty and integrity that they would in a classroom setting.

#### COURSE OUTLINE

Week	Topic	In-class hours	Readings
1.	1. Revision of Linear Algebra and Calculus.	4	Deisenroth et al. (2020), Ch2.1-6, Ch3.1-3, Ch5.1-4
2.	2. Introduction to neural networks.	4	Will be provided during the lectures.
3.	3. Linear neural networks and optimization methods.	4	Zhang et al. (2023), Ch3, Ch4, Ch 12.
4.	4. Introduction to Deep Learning.	4	Zhang et al. (2023), Ch5.
5.	5. Convolutional neural networks.	4	Zhang et al. (2023), Ch7, Ch8.
6.	6. Data augmentation and interpretation.	4	Will be provided during the lectures.
7.	7. Recurrent neural networks.	4	Zhang et al. (2023), Ch9, Ch10.

8.	Midterm exam	2	
9.	8. Attention is all you need!	4	Zhang et al. (2023), Ch11.
10.	9. Transformers in action.	4	Will be provided during the lectures.
10.	10. Introduction to Diffusion models.	4	Will be provided during the lectures.
11.	11. Introduction to Reinforcement Learning.	4	Sutton et al. (2018), Ch1, Ch3, Ch4, Ch6.
13.	Course review	2	
		<b>Total: 48 hours</b>	
	CONSULTATIONS	6	
	FINAL EXAM	2	

#### FINAL GRADE COMPOSITION

Type of assignment	%
<i>Group Components 30%</i>	
Group project	30%
<i>Individual Components, 70%</i>	
Homework	20%
Mid-term exam	25%
Final exam	25%
<b>Total:</b>	<b>100</b>

#### DESCRIPTION AND GRADING CRITERIA OF EACH ASSIGNMENT

**Group project.** In the group project, students will work together (in groups of 3-4) to develop the best AI solution they can for a given problem. During the project, students will be expected to identify the most appropriate method to use and develop a solution that achieves as high a performance as possible. The grading will be based on the performance of the method, normalized across the class. Details on the group project will be provided later in the course. There will be one such project, worth 30% of the final grade.

**Homework.** Students will be assigned homework tasks to be completed in Python. The homework tasks will include applying the theoretical knowledge gained during the class in the Jupyter Notebook environment. This will involve completing tasks such as performing data processing and augmentation, assembling the building blocks of deep neural networks, training the networks on the provided datasets, evaluating their performance, and determining their failure modes. It counts towards 20%

of the final grade. There may be up to 5 homework assignments. Intermediate grades for the homework might not be released by the instructor.

**Mid-term exam.** The mid-term exam will be held during the midterm exam session. It counts towards 25% of the final grade. The midterm will be based on topics 1-7. The midterm will consist of multiple-choice and open-ended questions. The students will not be expected to code during the exam.

**Final exam.** The final exam counts towards 25% of the final grade. The final exam will be based on topics 8-11. The final exam includes multiple-choice as well as open-ended questions. It tests the theoretical and practical understanding of all the material covered. The students will not be expected to code during the exam. The final examination will take place during the final examination session.

**Retake exam.** Students who receive a failing final grade shall have the right to the retake exam, which will comprise 50% of the final grade and cover all topics of the course. Midterm exam and final exam results will be annulled.

### SUGGESTED READINGS BEFORE THE START OF THE COURSE

Deisenroth, M. P., Faisal, A. A., & Ong, C. S. (2020). *Mathematics for machine learning*. Cambridge University Press.

### REQUIRED READINGS

Zhang, A., Lipton, Z. C., Li, M., & Smola, A. J. (2023). *Dive into deep learning*. Cambridge University Press.

Sutton, R. S., & Barto, A. G. (2018). *Reinforcement learning: An introduction*. MIT press.

### ADDITIONAL READINGS

He, K., Zhang, X., Ren, S., & Sun, J. (2016). Deep residual learning for image recognition. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 770-778).

Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., ... & Polosukhin, I. (2017). Attention is all you need. *Advances in neural information processing systems*, 30.

Ho, J., Jain, A., & Abbeel, P. (2020). Denoising diffusion probabilistic models. *Advances in neural information processing systems*, 33, 6840-6851.

Mnih, V., Kavukcuoglu, K., Silver, D., Rusu, A. A., Veness, J., Bellemare, M. G., ... & Hassabis, D. (2015). Human-level control through deep reinforcement learning. *Nature*, 518(7540), 529-533.

**ANNEX**

**DEGREE LEVEL LEARNING OBJECTIVES**

**Learning objectives for the Bachelor of Business Management**

*Programmes:*  
*International Business and Communication,*  
*Business Management and Marketing,*  
*Finance,*  
*Industrial Technology Management,*  
*Entrepreneurship and Innovation*

Learning Goals	Learning Objectives
Students will be critical thinkers	BLO1.1. Students will be able to understand core concepts and methods in the business disciplines
	BLO1.2. Students will be able to conduct a contextual analysis to identify a problem associated with their discipline, to generate managerial options and propose viable solutions
Students will be socially responsible in their related discipline	BLO2.1. Students will be knowledgeable about ethics and social responsibility
Students will be technology agile	BLO3.1. Students will demonstrate proficiency in common business software packages
	BLO3.2. Students will be able to make decisions using appropriate IT tools
Students will be effective communicators	BLO4.1. Students will be able to communicate reasonably in different settings according to target audience tasks and situations
	BLO4.2. Students will be able to convey their ideas effectively through an oral presentation
	BLO4.3. Students will be able to convey their ideas effectively in a written paper

**Learning objectives for the Bachelor of Social Science**

*Programmes:*  
*Economics and Data Analytics,*  
*Economics and Politics*

Learning Goals	Learning Objectives
Students will be critical thinkers	ELO1.1. Students will be able to understand core concepts and methods in the key economics disciplines
	ELO1.2. Students will be able to identify underlying assumptions and logical consistency of causal statements
Students will have skills to employ economic thought for the common good	ELO2.1. Students will have a keen sense of ethical criteria for practical problem-solving
Students will be technology agile	ELO3.1. Students will demonstrate proficiency in common business software packages
	ELO3.2. Students will be able to make decisions using appropriate IT tools
Students will be effective communicators	ELO4.1. Students will be able to communicate reasonably in different settings according to target audience tasks and situations
	ELO4.2. Students will be able to convey their ideas effectively through an oral presentation
	ELO4.3. Students will be able to convey their ideas effectively in a written paper