MODULE OUTLINE

1. GENERAL INFORMATION

SCHOOL	SCHOOL OF SCIENCE AND TECHNOLOGY			
PROGRAM COURSE	DATA SCIENCE AND MACHINE LEARNING			
LEVEL OF STUDY	POSTGRADUATE			
MODULE CODE	DAMA-50	**YEAR OF STUDY**	1st	
MODULE TITLE	Mathematics for Machine Learning			
INDEPENDENT TEACHING ACTIVITIES *in case credits are awarded for separate components/parts of the course, e.g. in lectures, laboratory exercises, etc. If credits are awarded for the entire course, give the weekly teaching hours and the total credits*			**HOURS**	**CREDITS**
Weekly teaching hours: 21-25 *x 32 weeks			840	30 ECTS
COURSE TYPE Compulsory, Optional, Optional mandatory	Compulsory			
PREREQUISITE MODULES:	The selection of DAMA50 does not require the simultaneous selection or completion of any other DAMA module.			
LANGUAGE OF INSTRUCTION AND EXAMS	ENGLISH			
THE MODULE IS OFFERED TO ERASMUS STUDENTS	No (due to annual duration of the module)			
MODULE WEBSITE (URL)	https://www.eap.gr/education/postgraduate/annual/data-science-and-machine-learning/topics/#dama50 Each module has its own space in the Learning Management System of EAP (http://study.eap.gr), with controlled access (use of code) for students and teaching staff.			

2. LEARNING OUTCOMES

Learning Outcomes
● *The course learning outcomes, specific knowledge, skills and competences of an appropriate (certain) level, which students will acquire upon successful completion of the course, are described in detail. It is necessary to consult:*
• Recognize that the basic mathematical pillars for Machine Learning are Linear Algebra, Vector Calculus as well as Probability and Statistics and apply analytical and computational tools. • Formulate linear equations with many unknowns, detail matrix techniques for their solution. • Summarize basic notions of vector spaces, use linear mappings for basis change. • Use SageMath for solving linear algebra problems.

- Outline the concept of norm of a vector, inner products between two vectors and use it in obtaining the length of a vector.
- Explain what an orthonormal basis is in a vector space and describe the orthogonal complement of a subspace of the vector space.
- Outline the Gram-Schmidt orthogonalization procedure and derive an orthonormal basis for a vector space.
- Use SageMath to perform basic vectror manipulations and perform Gram-Schmidt orthogonalization.
- Recall the definition of the trace and the determinant of a matrix and be able to calculate both by hand for simple matrices; explain the concepts of eigenvalues and eigenvectors of square matrices.
- Describe how a matrix can be decomposed through a Cholesky decomposition and Singular Value Decomposition (SVD), and apply these methods to simple matrices.
- Use SageMath to implement matrix decompositions.
- Outline the concept of the gradient of a function of many variables and describe its geometric significance.
- Summarize the gradient of matrices and its geometric significance and calculate it explicitly in specific cases.
- Summarize the concept of backpropagation and use it in simple models of neural networks.
- Use SageMath for evaluating gradients and derivatives.
- Summarize the properties of single variate and multivariate Gaussian distribution, find marginals and conditionals as well as transformations of the Gaussian function.
- Focus on the binomial Bernoulli distribution and detail the Beta distribution.
- Summarize the conjugate priors connected through Bayes theorem.
- Explain what is sufficient statistics and outline the exponential family of distributions.
- Perform a change of random variables and find the new distribution function.
- Recall how to find minima of a single variable function.
- Summarize the procedure to find the minimum of a multivariate function using the gradient descent algorithm.
- Explain how to perform stochastic gradient descent and what are its advantages and limitations compared to the gradient descent method.
- Describe what are the Lagrange multipliers and explain how they are used in constrained optimization.
- Describe convex optimization.
- Use SageMath to find the minimum of a multivariate function and t to minimize a function with constraints.

General Competences

Taking into consideration the general competences that students/graduates must acquire (as those are described in the Diploma Supplement and are mentioned below), at which of the following does the course attendance aim?

Search for, analysis and synthesis of data and information by the use of appropriate technologies,
Adapting to new situations
Decision-making
Project planning and management
Respect for diversity and multiculturalism
Environmental awareness
Social, professional and ethical responsibility and sensitivity to gender issues

Individual/Independent work *Group/Team work* *Working in an international environment* *Working in an interdisciplinary environment* *Introduction of innovative research*	*Critical thinking* *Development of free, creative and inductive thinking* *……* *(Other…….citizenship, spiritual freedom, social awareness, altruism etc.) …….*
Search for, analysis and synthesis of data and information by the use of appropriate technologies, Adapting to new situations Decision-making Individual/Independent work Project planning and management Critical thinking Development of free, creative and inductive thinking	

3. MODULE CONTENT

The students will learn the basic mathematical tools necessary for Machine Learning (ML). These include basic concepts from linear algebra such as vectors, matrices, measures and operations with vectors and matrices. From calculus, students will be exposed to functions of many real variables and the basic concept of the gradient and directional derivative to be applied in backpropagation ML algorithms. Very basic tools of probability, statistics and optimisation will be also introduced. Overall, a student without prior knowledge of these mathematical areas will be able to form a background in order to understand the ML techniques while and student with prior mathematical knowledge will be able to go much deeper in application of mathematics in ML. The mathematical study will be supplemented by computational software that will enable both analytical and numerical evaluations.
The key subjects of the module are:
A. “Linear Algebra”
B. “Calculus”
C. ”Statistics and Probabilities”

4. TEACHING METHODS--ASSESSMENT

MODES OF DELIVERY *Face-to-face, in-class lecturing, distance teaching and distance learning etc.*	Distance education with five Group Counseling Meetings (OSS) during the academic year on weekends.
USE OF INFORMATION AND COMMUNICATION TECHNOLOGY *Use of ICT in teaching, Laboratory Education, Communication with students*	We use : Remote meetings tools (cisco webex), Presentation software (e.g. power point), Specialized software in the subjects under study (SageMath, etc.).

<table>
<tr><td></td><td>Additionally, the students use office automation tools, web browsers and e-reader for digital books.</td></tr>
<tr><td>MODULE DESIGN
Description of teaching techniques, practices and methods: Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, Internship, Art Workshop, Interactive teaching, Educational visits, projects, Essay writing, Artistic creativity, etc

The study hours for each learning activity as well as the hours of selfdirected study are given following the principles of the ECTS.</td><td><table>
<tr><th>Activity</th><th>Annual Workload</th></tr>
<tr><td>5 Tutorial Meetings (x 4 hours)</td><td>20</td></tr>
<tr><td>Preparation of Assignments (6 assignments x 10 hours)</td><td>60</td></tr>
<tr><td>Examination</td><td>3</td></tr>
<tr><td>Individual study</td><td>672-800</td></tr>
<tr><td>Total module workload (hours)</td><td>755-883</td></tr>
</table></td></tr>
<tr><td>STUDENT PERFORMANCE EVALUATION/ASSESSMENT METHODS
Detailed description of the evaluation procedures.

Language of evaluation, assessment methods, formative or summative (conclusive), multiple choice tests, short- answer questions, open-ended questions, problem solving, written work, essay/report, oral exam, presentation, laboratory work, other……etc.

Specifically defined evaluation criteria are stated, as well as if and where they are accessible by the students</td><td>Elaboration of written assignments during the academic year, the average of the grades of which participates in the formation of the final grade of module by 30%, if there is a passable in the final or repetitive examinations. In the final written exams the grade of the written assignments participates in the formation of the final grade of module by 70%.

All the criteria are posted, both in each written assignment (in the LMS study.eap.gr), as well as in the general regulation of HOU at:
https://www.eap.gr/education/study-regulations/</td></tr>
</table>

(5) SUGGESTED BIBLIOGRAPHY

- *Suggested bibliography:*

- Marc Peter Deisenroth, A. Aldo Faisal, and Cheng Soon Ong. *Mathematics for Machine Learning*. Cambridge University Press, 2020 (https://mml-book.com/)
    - o Accompanying Study Guide

- Paul Zimmermann, Alexandre Casamayou, Nathann Cohen, Guillaume Connan, Thierry Dumont, Laurent Fousse, François Maltey, Matthias Meulien, Marc Mezzarobba, Clément Pernet, Nicolas M. Thiéry, Erik Bray, John Cremona, Marcelo Forets, Alexandru Ghitza, Hugh Thomas. *Computational Mathematics with SageMath*. SIAM, 2018
    - o Accompanying Study Guide

- Related scientific Journals: