COURSE OUTLINE

GENERAL

SCHOOL	Sciences and Engineering		
ACADEMIC UNIT	Computer Science		
LEVEL OF STUDIES	1st Cycle		
COURSE CODE	MATH-335	**SEMESTER**	Fall
COURSE TITLE	Optimization Techniques		

INDEPENDENT TEACHING ACTIVITIES *if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits*	**WEEKLY TEACHING HOURS**	**CREDITS**
	2.5	6
Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (d).		

COURSE TYPE *general background, special background, specialised general knowledge, skills development*	Special background
PREREQUISITE COURSES:	MATH-196, MATH-280
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	English
IS THE COURSE OFFERED TO ERASMUS STUDENTS	
COURSE WEBSITE (URL)	

LEARNING OUTCOMES

Learning outcomes

The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.

Consult Appendix A

- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B*
- *Guidelines for writing Learning Outcomes*

After completion of the course students are expected to be able to:

- Visualize concepts from Linear Algebra and Optimization with the aid of Geometry.
- Compute Matrix Factorizations and apply them to dimensionality reduction and Image Compression problems.
- Formulate and solve Least-Squares problems in the context of Linear Regression.
- Compute partial derivatives and gradients of multivariable functions.
- Find the local and global extrema of multivariable functions using the Hessian and relevant derivative criteria.
- Apply Gradient Descent to univariate and multivariate optimization problems.

- Employ Linear Algebra and Mathematical Optimization techniques to Data Science and Machine Learning

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?

Search for, analysis and synthesis of data and information, with the use of the necessary technology	*Project planning and management*
Adapting to new situations	*Respect for difference and multiculturalism*
Decision-making	*Respect for the natural environment*
Working independently	*Showing social, professional and ethical responsibility and sensitivity to gender issues*
Team work	*Criticism and self-criticism*
Working in an international environment	*Production of free, creative and inductive thinking*
Working in an interdisciplinary environment	*……*
Production of new research ideas	*Others…*
	…….

Analysis and synthesis of data with the use of the necessary technology, adapting to new situations, decision-making, working independently, working in an interdisciplinary environment, analytical, critical and quantitative thinking, synthesis of ideas.

SYLLABUS

1.Introduction (Motivation; Some examples of Optimization problems).
2.Review of Matrices and Linear Systems:
   a. Linear Systems (Geometry and matrix representation)
   b. Matrix Fundamentals (Basic operations, Matrices as linear maps, Determinants, Matrices with special structure and properties.
   c. Solution of linear systems using Gaussian elimination.
3.Vector Spaces:
   a. Subspaces and affine sets.
   b. Review: linear independence, basis and dimension, rank of a matrix, the rank and nullity theorem.
   c. Inner products; Vector and Matrix Norms and their geometric interpretation; Orthogonality and Projections; The Gram-Schmidt procedure.
4.Matrix Factorizations:
   a. Eigenvalues and Eigenvectors
   b. Geometric and Algebraic multiplicity, eigenspaces.
   c. The LU and Cholesky decompositions.
   d. Eigendecomposition and Diagonalization
   e. Orthogonal diagonalization of a symmetric matrix. Spectral decomposition and dimensionality reduction.
   f. The SVD. Image compression and other applications.
5.Continuous Optimization Problems and Gradient Descent:
   a. Univariate Optimization (Taylor's Theorem, Univariate Gradient Descent: Convergence and Divergence)
   b. Multivariable functions and partial derivatives. The Gradient vector.
   c. Multivariate Optimization. (Taylor's Theorem, Local and Global Extrema, the Hessian)

d. Convexity. (Convex sets and Convex functions, the First and Second Derivative Conditions)
e. Gradient descent. (Checking with the aid of Finite Differences, Decaying Learning Rates, Line Search, Stochastic Gradient Descent, Typical Objective Functions in Machine Learning)
f. Least squares as an optimization problem. Regression.

TEACHING and LEARNING METHODS - EVALUATION

DELIVERY *Face-to-face, Distance learning, etc.*	Face-to-face
USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY *Use of ICT in teaching, laboratory education, communication with students*	*Use of ICT in teaching / Χρήση ΤΠΕ* *Communication with students / Επικοινωνία με Φοιτητές*
TEACHING METHODS *The manner and methods of teaching are described in detail.* *Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artistic creativity, etc.* *The student's study hours for each learning activity are given as well as the hours of non-directed study according to the principles of the ECTS*	

Activity	***Semester workload***
Lectures	35
Practice problems	46
Written and programming assignments	21
Study of the textbook, lecture notes and online material	48
Course total	***150***

STUDENT PERFORMANCE EVALUATION *Description of the evaluation procedure* *Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open-ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical examination of patient, art interpretation, other* *Specifically-defined evaluation criteria are given, and if and where they are accessible to students.*	- Final Examination - Midterm Examination - Assignments (written and programming) - Participation

ATTACHED BIBLIOGRAPHY

Required Textbooks / Readings:

Title	Author(s)	Publisher	Year	ISBN

Mathematics for Machine Learning	Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong	Free Online Version / Cambridge University Press	2021 2020	https://mml-book.com. 9781108455145 (hardcopy, in library)
Linear Algebra and Optimization for Machine Learning: A Textbook	Charu C. Aggarwal	Springer	2020	9783030403447 (e-book)
Elementary Linear Algebra: Applications Version	Howard Anton, Chris Rorres, Anton Kaul	Wiley 12th Ed.	2019	9781119670766 (e-book)

Recommended Textbooks / Readings:

Title	**Author(s)**	**Publisher**	**Year**	**ISBN**
Introduction to applied linear algebra:Vectors, Matrices and Least Squares	Stephen Boyd, Lieven Vandenberghe	Cambridge University Press	2018	https://web.stanford.edu/~boyd/vmls/ (e-book, available online)
Elementary Linear Algebra	B. Kolman and D. Hill	Pearson 9th Ed.	2017	9780134718538
Optimization for Data Analysis	Stephen Wright and Benjamin Recht	Cambridge University Press	2022	9781009004282 (e-book)