UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

CONSIGLIO INTERCLASSE IN MATEMATICA

COURSE OF STUDY TWO-YEAR MASTER OF SCIENCE PROGRAMME IN MATHEMATICS

ACADEMIC YEAR 2023-2024

ACADEMIC SUBJECT OPTIMIZATION METHODS FOR DATA SCIENCE AND ARTIFICIAL INTELLIGENCE

General information	
Programme year	Second
Term	First semester (September 25, 2023 – December 22, 2023)
European Credit Transfer and Accumulation System credits (ECTS)	7
SSD	MAT/08 – Numerical Analysis
Language	Italian
Mode of attendance	Not mandatory

Lecturer	
Name and surname	Nicoletta Del Buono
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Department and office	Department of Mathematics, room 24 second floor
Virtual meeting room	Microsoft Teams: code 1n2ti2p
Web page	https://www.dm.uniba.it/it/members/delbuono
Office hours	Wednesday 11:15-12:15 and by appointment via email

Work schedule	Total	Lectures	Hands-on learning (recitations)	Self-study
Hours	175	48	15	112
ECTS credits	7	6	1	

Learning objectives	
	Acquisition of basic numerical techniques for optimization of nonlinear multivariate functions and for solving linear programming problems. Acquisition of basic knowledge for exploratory Data Analysis and for using optimization mechanisms to deal with problems arising in learning from data

Course prerequisites	
	The knowledge generally acquired in the L-35 Mathematics degree with particular references to the disciplines of Numerical Analysis (Calcolo Numerico I) and classical Mathematical Analysis in one and more variables

Syllabus	
Course contents	-- Classification of an optimisation problem. Examples of optimisation problems: the lifeguard problem, Steiner's problem. -- Nonlinear programming: possible directions, first and second order necessary conditions for local minima, differentiable convex functions, their characterisations and sufficient conditions for minima, unimodal functions of R in R, bisection method, golden section, parabolic interpolation, Newton's

	method, secant. -- Descent methods: exact line search, inexact line search methods: Armijo's rule and Wolfe's conditions in for choice of pitch. Steepest descent method applied to the quadratic case, convergence theorems of the steepest descent method. Newton's method in several variables, convergence theorems in the quadratic case. Trust region methods. -- Method of conjugate directions for quadratic functions, their minimisation properties, method of conjugate gradients for quadratic functions and its properties. -- Quasi-Newton methods, convergence for quadratic functions, modified Newton method, construction of the inverse of Hessian. Rank one correction, Davidon-Fletcher-Powell method (DFP) and BFGS method. -- Constrained optimisation: theoretical background and KKT conditions. Penalty and barrier methods for constrained problems, convergence theorems, exact penalty functions. Introduction to the projected gradient method. -- Linear programming: definition of a PL in general, canonical and standard form, equivalence of these definitions, basic solutions and associated definitions, E_rs matrices and associated Pivot operations, Simplex method, and its lemmas (optimality tests, etc.), degeneracy, two phase method, geometric interpretation of a PL using convex sets. -- Introduction to exploratory data analysis: Data Types, Sample and Feature. Structured data of numerical and categorical type. Symbolic, Numeric and Discrete Features. Nominal and Ordinal Scales. Pre-processing methods. -- Optimisation and Machine learning: Introduction and mathematical formalisation of a data learning problem. Classification, Clustering and Regression. Loss functions of quadratic type. Functional problems of finite sum type. Stochastic Gradient Method, basic algorithm, and convergence considerations. Concepts of mini batch and training epochs. The learning rate problem as a hyperparameter optimisation problem. Support Vector Machine: the optimisation problem as an example of Penalisation. Linear regression line solved with the stochastic gradient method. Introduction to evolutionary optimisation: genetic algorithms. Pattern theorem (constant probability case).
Reference books	D.G.Luenberger, “Linear and nonlinear Programming” (Second Edition) J. Nocedal-S.J. Wright, “Numerical Optimization”, Springer V. De Angelis, “Metodi Matematici di Ottimizzazione”, La Goliardica S. Sra, S Nowozin, S.T. Wright, “Optimization for Machine Learning”, MIT press
Additional course materials	Notes and slides provided by the instructor and available on Microsoft teams
Repository	

Expected learning outcomes	
Knowledge and understanding	Acquisition of the main techniques for solving continuous optimisation problems. Ability to produce efficient numerical codes implementing the acquired techniques. Acquisition of the basic elements and essential terminology used in Data Science contexts
Applying knowledge and understanding	The acquired theoretical and practical knowledge is used in a large part of applied mathematics and in solving real problems
Soft skills	*Making judgements*: Ability to identify the right numerical techniques to address and numerically solve optimisation problems arising from real applications involving big data.
	Communication skills: Students must demonstrate an adequate expository

	capacity of the studied topic and an adequate capacity in analysis and synthesis
	Learning skills: Students must demonstrate a good ability to make interdisciplinary connections

Teaching methods	
	- Lectures conducted with the aid of teaching aids (slides). - Computer-based exercises.

Assessment	
Assessment methods	Oral examination on the syllabus and exercises or project assigned by the lecturer
Evaluation criteria	• *Knowledge and understanding:* Students must demonstrate adequate knowledge of the main topics of the course. • *Applying knowledge and understanding*: Students must demonstrate adequate knowledge of the possible applications of the theoretical concepts and possess adequate ability to implement these applications • *Making judgement*: Students must demonstrate adequate autonomy in selecting the most appropriate theoretical concepts for solving practical problems. • *Communication skills*: Students must demonstrate an adequate expository capacity of the studied topic and an adequate capacity in analysis and synthesis. • *Learning skills*: Students must demonstrate a good ability to make interdisciplinary connections.
Grading policy	The final grade is given in thirtieths. The exam is considered passed when the grade is greater than or equal to 18. The following indicators will be considered in formulating the final grade: degree of knowledge of the content and topics of the teaching, ability, and correctness in applying the fundamental concepts covered during the lectures and exercises, quality of oral exposition. All program topics contribute equally to the formulation of the final grade.

Further information	
	Attendance at lectures and tutorials is strongly recommended.