UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

CONSIGLIO INTERCLASSE IN MATEMATICA

General information		Academic year 2022-2023
Academic subject	**Optimization Methods for Data Science**	
Degree programme	Mathematics (LM-40)	
Programme year	Second year	
Term	First semester (September 26, 2022 – December 22, 2022)	
European Credit Transfer and Accumulation System credits (ECTS)		7
Language	Italian	
Attendance	Not compulsory	

Lecturers		
Name and surname	Nicoletta Del Buono (instructor of record)	Luciano Lopez
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Department and office	Department of Mathematics, room 23 second floor	Department of Mathematics, room 15 second floor
Virtual meeting room	Microsoft Teams, access code p4os1fa	
Web page	https://www.dm.uniba.it/members/delbuono	
Office hours	Wednesday 11:15-12:15 and by appointment via email	

Syllabus	
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 I (Calcolo Numerico I) and classical Mathematical Analysis in one and more variables
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

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

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

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

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	Acquisition of the language and advanced mathematical formalism necessary for the consultation and comprehension of texts, the exposition of acquired knowledge, the description, analysis and resolution of applied and Data Science problems
Learning skills	Acquisition of an adequate study method, supported by the consultation of texts and the computer implementation of the numerical techniques exposed during the course.

Assessment and feedback	
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 judgements*: 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 evaluation of the oral examination and the awarding of the final mark will be based on the following learning assessment scale: – Insufficient grade (<18): Fragmentary and superficial knowledge of the contents, errors in the application of the concepts, poor exposition – Grade 18-20: Sufficient but general knowledge of content, simple exposition, uncertainties in the application of theoretical concepts – Grade 21-23: Appropriate but not extensive knowledge of content, ability to apply theoretical concepts, ability to present content in a simple manner – Grade 24-25: Appropriate and extensive knowledge of the content, fair ability to apply the knowledge, ability to present the content in an articulate manner. – Grade 26-27: Accurate and comprehensive knowledge of the content, good ability to apply the knowledge, ability to analyse, clear and correct presentation. – Grade 28-29: Extensive, complete, and thorough knowledge of the content, good application of the content, good analytical and synthesising skills, secure and correct presentation. – Grade 30 and 30 with distinction: very broad, complete, and in-depth knowledge of the content, well-established ability to apply the content, excellent ability to analyse, summarise and make interdisciplinary connections, very good exposition

Additional information	
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