UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

CONSIGLIO INTERCLASSE IN MATEMATICA

General information	
Academic subject	***Numerical Methods in Data Science***
Degree course	*Mathematics (L35)*
Academic Year	*Third year- second semester*
European Credit Transfer and Accumulation System (ECTS)	7
Language	*Italian*
Academic calendar (starting and ending date)	
Attendance	*Optional*

Professor/ Lecturer	
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Department and address	*Dipartimento di Matematica, piano II, stanza 24*
Virtual headquarters	*Mteams:* ***1n2ti2p***
Tutoring (time and day)	Monday 11:15-12:15 on appointment

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 degree with particular reference to the disciplines of Numerical Analysis I (Calcolo Numerico I) and classical Mathematical Analysis in one and more variables*
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).*
Books and bibliography	*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* *Appunti e riferimenti specifici forniti dal docente*
Additional materials	*Some notes will be available at https://www.dm.uniba.it/members/delbuono*

Work schedule			
Total	Lectures	Hands on (Laboratory, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
Hours			
	52	*8*	*113*
ECTS			
	6.5	*0.5*	

Teaching strategy	
	Classroom lessons and computer lab exercises
Expected learning outcomes	
Knowledge and understanding on:	○ Acquiring the main techniques for treating continuous-optimization problems. ○ Ability to design efficient numerical codes implementing standard optimization techniques. Acquiring basic elements and terminology of Data Science
Applying knowledge and understanding on:	○ Theoretical and practical knowledge acquired would be used on applied mathematical fields and for solving real problems.
Soft skills	• *Making informed judgments and choices* ○ Ability to identify the right numerical techniques which is able to address and solve numerically optimization problems arising in real-life applications using large datasets • *Communicating knowledge and understanding*

	○ Acquiring the advanced mathematical language and formalism required for the consultation and comprehension of technical texts, exposing the acquired knowledge, describing, analyzing, and solving problems in real applications. • *Capacities to continue learning* ○ Learning an appropriate studying methodology, supported by text consultation and implementation of the techniques proposed during the lectures.

Assessment and feedback	
Methods of assessment	*Oral examination on course programm or on an assigned project*
Evaluation criteria	• *Knowledge and understanding* ○ Knowledge of contents and main topics • *Applying knowledge and understanding* • Knowledge of the applications of theoretical concepts • Ability to apply theoretical concepts • *Autonomy of judgment* • Ability to present content and assess the possibilities of application of theoretical concepts • *Communicating knowledge and understanding* ○ Transfer of know-how, know-why, know-what • *Communication skills* ○ Exposition of contents ○ Capacity for analysis and synthesis • *Capacities to continue learning* ○ Ability to make interdisciplinary links
Criteria for assessment and attribution of the final mark	*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, mastery of exposition*
Additional information	