Academic subject: Optimization methods for Data Science					
Degree Class: LM-40 (Mathematics)		**Degree Course:** Mathematics		**Academic Year:** 2020/2021	
		Kind of class: optional		**Year:** second	**Period:** first semester
				ECTS: 7 divided into **ECTS lessons: 6.5** **ECTS exe/lab/tutor: 0.5**	
Time management, hours, in–class study hours, out–of–class study hours lesson: 52 exe/lab/tutor: 8 in–class study: 60 out–of–class study:113					
Language: Italian	**Compulsory Attendance:** no				
Subject Teacher: Nicoletta Del Buono	**Tel:** +39 0805442711 **e–mail:** nicoletta.delbuono@uniba.it	**Office:** Department of Mathematics Room 24, Floor Second	**Office days and hours:** Monday 10:00-11:00 a.m. Other days: on appointment		
Prerequisites: General knowledges related to first degree in Mathematics (L-35 Mathematics) with particular emphasis to Numerical Methods and Multivariable Mathematical Analysis					
Educational 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					
Expected learning outcomes (according to Dublin Descriptors)	**Knowledge and understanding:** Acquiring the main techniques for treating continuous-optimization problems. Ability to design efficient numerical codes implementing standard optimization techniques. Acquiring basical elements and terminology of Data Science **Applying knowledge and understanding:** Theoretical and practical knowledge acquired would be used on applied mathematical fields and for solving real problems. **Making judgements:** 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 **Communication:** 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. **Lifelong learning skills:** Learning an appropriate studying methodology, supported by text consultation and implementation of the techniques proposed during the course.				

Course program

- Classification of optimization problems. Examples of optimization problems: Steiner problem.
- Nonlinear programming: possible directions, I and II order conditions for local minimum, Convex differentiable functions, their characterizations and sufficient conditions for minimum points. Unimodal functions of R in R: Method of bisections, method of golden section, parabolic interpolation, Newton method, secant method.
- Descent Methods: exact line search, inexact line search methods: rule of Armijo and Wolfe conditions. Steepest descent method applied to the case of quadratic function. Convergence theorems

of steepest descent method. Newton's method in several variables, theorems of convergence in the quadratic case. Trust region methods.

- Conjugate directions method for quadratic functions their properties.
- Quasi-Newton methods, convergence for quadratic functions, modified Newton method, construction of the inverse Hessian. Correction of rank one method. Davidon-Fletcher-Powell (DFP) and BFGS method.
- Constrained optimization: theoretical conditions and KKT conditions. Penalty and barrier methods for constrained problems, convergence theorems, exact penalty functions. Introduction to the gradient projection method.
- Linear programming: definition of a PL in general, canonical and standard forms, Equivalence of these definitions, basic solutions and associated definitions, Matrices E_{rs} and related pivot operation, Simplex method and related entries (test optimality, etc.). Simplex Lemmas Degeneration, method of the two phases, geometric interpretation of a PL by means of convex sets
- Introduction to exploratory data analysis: Data Types, Samples and features. Structured numeric and categorical data. Symbolic, numerical and discrete features. Nominal and Ordinal Scales. Re-processing methods, Missing data classification and their initial treatment. Outliers.
- Optimization and Machine learning: Introduction and mathematical formalization of a learning problem from data. Classification, Clustering and Regression. Quadratic loss functions. Stochastic gradient method, basic algorithm and considerations on its convergence. Mini batch and training epoch concepts. The learning rate problem as a hyperparameter optimization problem. Support Vector Machine: the optimization problem as an example of Penalization. Linear regression solved by the stochastic gradient method.

Teaching methods:
Lectures session and exercises in computer lab

Auxiliary teaching:
Notes available at the web page http://www.dm.uniba.it/~delbuono

Assessment methods:
Oral examination

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