Main information on the course	
Academic subject	**MATHEMATICAL FOUNDATIONS FOR DATA SCIENCE**
Degree course	Data Science (second-level degree in Data Science)
Academic year	2023-2024
European Credit Transfer and Accumulation System (ECTS), in Italian Crediti Formativi Universitari (CFU)	6 CFU (each CFU corresponds to 25 hours (h) of student's time); CFU are of type T1, T2 or T3 T1 = 8 h lecture + 17 h individual study T2 = 15 h practice + 10 h individual study T3 = 25 h individual study
S.S.D.	MAT-05
Course language	Italian
Year	First
Academic calendar	First Semester
Attendance	Not mandatory but strongly recommended
Web page	https://www.uniba.it/it/ricerca/dipartimenti/informatica/didattica/corsi-di-laurea/data-science/data-science

Professor(s)	
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Office hours	Students may send an email to the teacher to require an appointment
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Office hours	Students may send an email to the teacher to require an appointment

Syllabus	
Learning Objectives	The course provides the basic mathematical skills necessary for the management, processing and analysis of large amounts of data. Furthermore, it helps to stimulate in students not only the basic cognitive tools necessary to think analytically, creatively, critically and in an inquiring way, but also the abstraction and problem-solving skills necessary to deal with complex systems.
Course prerequisites	To understand and know how to apply most of the techniques, it is necessary to master the basic tools of Differential and Integral Calculus in one variable and to know the basic notions of Linear Algebra e of Analytical Geometry in Euclidean spaces.

Contents	**Part I: Mathematical Analysis** **Metric spaces, normed spaces, Hilbert spaces (6 h.)** Metric spaces. Vector spaces. Normed spaces. Metric structure of a normed space; distance deduced from the norm. Convergent and Cauchy sequences in a metric space. Complete metric spaces. Banach Spaces. Scalar product in a vector space. Examples. Norm associated with a scalar product. Examples. Hilbert spaces. Topology in **R**^n. **Differential calculus in R^n (16 h).** Scalar and vector functions on **R**^n. Definition of limit and its properties for scalar and vector functions. Continuity. Weierstrass theorem. Bolzano theorem. Partial derivatives. Gradient. Differentiable functions and their properties. Tangent plane. Curves and their derivative. Derivability of the composed function. Lagrange's theorem. Jacobian matrix. Differentiability of the composite function. Second partial derivatives and Hessian matrix. Local maxima and minima points of a scalar function. Critical points. Saddle points. Convex and strictly convex functions in **R**^n and their properties. Finding the global maximum and minimum of a continuous function. Lagrange multipliers. **Integral calculus in R^n (10 h.)** Integrable functions in **R**. Partitions in **R**^2. Measurable sets. Integrable functions. Integrability of continuous functions. Reduction formulas for double integrals. Change of variables for double integrals. Particular case: polar coordinates. Improper integrals. **Part II: Linear Algebra** **Matrices and linear systems (9 h.)** Matrices. Square matrices. Row matrices. Column matrices. Submatrices. Block matrices. Sum between matrices. Multiplication of a matrix by a scalar. Transpose and conjugated transpose of a matrix. Symmetric and Hermitian matrices. Product between matrices. Powers of a matrix. Trace of a matrix. Non-singular matrices and inverse matrices. Determinant of a matrix and methods for the calculation. Triangular and diagonal matrices. Linear systems and Gaussian elimination method for square and rectangular systems. Gauss-Jordan method. Rank of a matrix. Homogeneous and non-homogeneous linear systems and their general solution. Linear systems and non-singular matrices. Invertibility of square matrices. LU and LDU factorizations of square matrices. Determinant formula for pivots. Cholesky factorization for symmetric matrices. **Vector spaces and linear functions (5 h.)** Vector spaces. Subspaces. Subspace generated by a finite set of elements of a vector space. Linearly independent sets in vector spaces. Linearly independent sets of **R**^m. Bases of a vector space. Dimension of a vector space. Dimension of subspaces. Direct sum of subspaces. Linear maps between vector spaces. Rotations, reflections and projections and associated matrices. Matrices and linear applications. Change of bases. Fundamental subspaces of a linear application. Fundamental subspaces of a matrix, their dimensions and their bases. **Normed spaces and spaces with scalar product (3 h)** Normed spaces. Euclidean norm. Matrix norms. Spaces with scalar product. Norm induced by a scalar product. Cauchy-Schwarz inequality. Angle between two vectors. **Orthogonality (5 h):** Orthogonal vectors. Orthonormal sets. Linear independence of orthonormal sets. Orthonormal bases. Coordinates of a vector with respect to an orthonormal basis. Gram-Schmidt orthogonalization. QR factorization. Orthogonal matrices. Unitary matrices. Orthogonal subspace. Decomposition theorem. Orthogonal subspaces of the fundamental subspaces of a matrix. **Eigenvalues and eigenvectors of a matrix (4 h)** Eigenvalues and their characterization. Eigenvectors and eigenspaces. Characteristic polynomial of a matrix. Spectral ray and its properties. Algebraic and geometric multiplicity. Simple and semi-simple eigenvalues. Linear independence of eigenvectors corresponding to distinct eigenvalues. Similar matrices, similarity transformations. Eigenvalues of similar matrices. Diagonalizable matrices. Necessary and sufficient condition for

Books and bibliography	1. Part I: Any textbook of Calculus 2, such as • M. Bramanti – C. D. Pagani – S. Salsa, Analisi Matematica Due, Zanichelli Ed., 2009 2. Part II: C.D. Meyer, Matrix Analysis and Applied Linear Algebra SIAM, 2000. Students can borrow the texts from the library. It may be convenient to check availability via the University Library System https://opac.uniba.it/easyweb/w8018/index.php?
Additional materials	Lecture notes available on the e-learning platform.

Organization of the didactic activities

Work schedule

Total	Lectures	Practice sessions	Individual study
150 hours	32 hours	30 hours	88 hours
CFU/ETCS			
6 CFU	4 CFU	2 CFU	

Teaching methods

Lectures in class, accompanied by carrying out exercises whose aim is to acquire the ability to apply theoretical concepts.

Expected learning outcomes

Knowledge and understanding	Acquisition of the fundamental concepts of Linear Algebra and Differential and Integral Calculus for functions in several variables, their related theorems and their application to the study of eigenvalues and eigenvectors of a matrix, to the description of the fundamental properties of a function in several real variables and the calculation of multiple integrals
Applying knowledge and understanding	The mathematical tools acquired during the course will be applied in other teachings, particularly in Automatic Learning, Data Mining, Numerical Methods for Data Science, Statistical Modeling.

Soft skills	*Making informed judgments and choices:* At the end of the course, students should be able to evaluate the coherence of logical reasoning used and to identify the best mathematical tools and techniques to address different Data Science problems. *Communicating knowledge and understanding: A*t the end of the course, students should have acquired the language and the advanced mathematical formalism necessary for the consultation and understanding of texts, exposition of the acquired knowledge, the description, analysis and resolution of problems of Linear Algebra and Differential and Integral Calculus for functions in several real variables. *Capacities to continue learning:* At the end of the course, students should have acquired an adequate study method, supported by consultation of texts e by problem solving abilities.

Assessment	
Methods of assessment	The final exam includes: • A written exam with open answers, lasting a minimum of two hours, • an oral exam. The evaluations of both parties will contribute to determining the final grade. The result of the written exam, which is preparatory to the oral exam, will be communicated via e-mail either directly by the teacher or through the ESSE3 platform. The written axame, where its score is greater than or equal to 18/30, can be maintained for the whole academic year.
Evaluation criteria	Students should be able to: • undertake Linear Algebra exercises, • study the properties of matrices, • study any real function in several real variables, recognizing its main properties • calculate multiple integrals. Furthermore, they should be able to state and prove theorems using the correct mathematical language and proving mastery of the main concepts and coherence in logical reasoning.
Criteria for assessment and attribution of the final grade	The final grade, determined by both the written and oral exams, is awarded out of thirty. The exam is considered passed when the final grade is greater than or equal to 18/30. To access the oral test, student must have passed the written exam with a minimum grade of 18/30.

Additional information	Students are advised to rely exclusively on information/communications provided on the official websites of the Computer Science Department, or on social groups only if administered exclusively by the teachers of the relevant courses: • https://www.uniba.it/it/ricerca/dipartimenti/informatica/teaching/degree-courses/degree-courses • https://www.uniba.it/it/ricerca/dipartimenti/informatica • https://elearning.uniba.it/ The teaching programs are available here: • https://elearning.uniba.it/ For further official information see https://www.uniba.it/it/ricerca/dipartimenti/informatica/teaching/degree-courses/degree-courses Students are advised to be wary of information and materials circulating on unofficial sites or social groups, as they were often found to be unreliable, incorrect or incomplete. If in doubt, ask the teacher for a meeting.