General information

Course name	**Numerical Calculus**
Degree	Three-year bachelor programme in Computer Science
Academic year	2023/24
European Credit Transfer and Accumulation System (ECTS), in Italian Crediti Formativi Universitari (CFU)	6 CFU
SSD	MAT/08
Course language	Italian
Programme year	Second
Term	Second semester, (March 01, 2024 – June 07, 2024)
Mode of attendance	Attendance is not mandatory, though strongly suggested
Course of study web page	https://www.uniba.it/it/ricerca/dipartimenti/informatica/didattica/corsi-di-laurea/informatica-270/laurea-triennale-in-informatica-d.m.-270-1

Lecturer(s)

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e-learning platform	https://elearning.uniba.it/course/index.php?categoryid=104
Web page	https://www.dm.uniba.it/members/iavernaro
Office hours	Students may send an email to the teacher to ask for an appointment

Syllabus

Learning objectives	Introducing the fundamental methods for numerically solving some basic mathematical problems, the course serves as a constructive link between Mathematics and Computer Science, providing students with specific basic tools to solve applied problems using a computer. It highlights the computational and implementation aspects of problem-solving.
Prerequisites/requirements	○ Mastery of all topics covered in the Mathematical Analysis course. ○ Basic linear algebra covered in the Discrete Mathematics course. ○ Fundamental programming knowledge covered in the Programming and Computer Science Laboratory course
Course contents	The program includes the study of machine arithmetic and error analysis, iterative methods for nonlinear equations, direct methods for linear systems, interpolation, and approximation. Below is the detailed list of topics that will be covered during the lectures. 1. ERROR ANALYSIS. (12 hours) Real and machine numbers representation. IEEE single and double precision standards. Truncation and rounding. Machine precision. Absolute and relative errors. Operations with machine numbers. Significant digit cancellation. Error propagation. Conditioning of a problem. Stability of an algorithm. 2. NUMERICAL SOLUTION OF NONLINEAR EQUATIONS. (15 hours) Method of successive bisections. Functional iteration. Analysis of local and global convergence. Stopping criteria and error estimates. Order of convergence. Method of constant direction. Newton's method and modified Newton's method. Secant Method. Comparisons between methods. 3. ELEMENTS OF LINEAR ALGEBRA - PART I. (6 hours) Vector operations. Matrices. Matrix operations. Trace and determinant of a matrix. Computation of the determinant using Laplace's and Sarrus' rules. Special matrices. Matrix-vector and matrix-matrix products. Inverse of a matrix, existence theorem. Cramer's linear systems: existence and uniqueness theorem. Cramer's method for determining the solution of a linear system. 4. ALGORITMS FOR THE SOLUTION OF LINEAR SYSTEMS. (12 hours) Lower and upper triangular systems. Permutation matrices and related properties. Gauss elimination algorithm. Stability issues. Existence theorem of LU factorization with pivot. Generic linear systems. Matrix rank. Echelon reduction of a matrix and generalization of LU factorization to rectangular matrices. Rouché-Capelli theorem. Applications. 5. ELEMENTS OF LINEAR ALGEBRA - PART II. (9 hours) Definition of vector spaces. System of generators. Linearly independent vectors. Basis of a vector space. Linear transformations and matrices. Vector subspaces. Vector space generated by a given set of vectors. Kernel and image of a linear transformation. Orthogonal subspace. Decomposition of a vector space as the direct sum of two subspaces. Vector and matrix norms. Study of the conditioning of linear systems. Brief overview of eigenvalues and eigenvectors. Applications to the calculation of google's pagerank. 6. INTERPOLATION AND APPROXIMATION. (8 hours) Power basis. Interpolation with Lagrange basis. Error in polynomial interpolation. Runge's phenomenon. The linear least squares problem. Data fitting: polynomial of best approximation in the least squares sense. Linear regression line. 7. PROGRAMMING ENVIRONMENT: Python/Matlab The working environments used for the development of algorithms related to the studied methods are Python and Matlab. Among others, the following topics will be analyzed: predefined functions for solving the problems studied during the lectures,

	some elements related to the programming language, and the graphic routines that allow, where required, the visualization of results that have a geometric interpretation.
Reference books	○ Notes in PDF format distributed through the University e-learning paltform (https://elearning.uniba.it/) ○ **Atkinson, Kendall E.** . An introduction to numerical analysis / Kendall E. Atkinson. - New York [etc.] : John Wiley & sons, 1978. (Capitoli 1,2,3,4,7,8) ○ L. Brugnano, C. Magherini, A. Sestini, Calcolo numerico, seconda edizione, Master, Università & Professioni, Firenze 2010. The interested students can borrow the texts from the Library. It may be convenient to check their availability through the University Library System at https://opac.uniba.it/easyweb/w8018/index.php and contact the library to arrange for the loan.
Additional notes on the course materials	The material shared with students on the e-learning platform covers the entire program and includes preparation exercises for the exam. Therefore, for exam preparation purposes, the shared material is considered exhaustive. The student may, if desired, delve into specific topics by consulting alternative sources, including the recommended texts. The index provides an easy reference to the relevant sections of the course.

Work schedule

Hours

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 ○ Exercise sessions

Expected learning outcomes

Knowledge and understanding	○ Acquiring knowledge of techniques and methods for numerical programming aimed at solving problems in the field of mathematical and related disciplines, with particular emphasis on the fundamental problems in linear algebra.

	○ Understanding and being able to illustrate the issues related to the use of the computer for solving mathematical problems.
Applying knowledge and understanding	○ Ability to solve mathematical problems using algorithms optimized in terms of computational cost and stability. ○ Development of the ability to program, document, and test numerical algorithms, correctly interpreting their results.
Soft skills	**Making judgements:** Being able to detect a proper numerical method for solving a given mathematical problem among those analyzed during the lectures. **Communication skills** Being able to provide rigorous definitions of the analyzed mathematical problems and to discuss the related numerical methods, outlining their most prominent features. **Learning skills** Capability of studying and solving problems similar, but not necessarily equivalent, to those faced during the teaching activities.

Assessment	
Modalità di verifica dell'apprendimento	The exam consists of an oral test that will cover all the topics discussed in class, including theoretical aspects (definitions, theorems, and proofs) and related exercises. The exam also includes the discussion of programs, in Python/Matlab environment, related to the algorithms covered in class. Throughout the lessons, various questions and exercises similar in type to those commonly given during exams will be discussed in a participatory manner. The aim is twofold: to monitor in real-time the preparation of attending students, refining their preparation for the exam or exemptions; to facilitate ongoing study of the practical aspects of the discipline, concretely motivating participants to take the exam promptly, possibly taking advantage of the exemption option. Two exemptions are planned: the first during the mid-course break, the second at the end of the course. Both dates are agreed upon, within the allowed limits, with attending students. Passing both tests with a grade of at least 15/30 and an overall average not lower than 18/30 will exempt students from the final exam. Additional Il superamento di un solo esonero consentirà allo studente di recuperare in sede di esame unicamente la parte mancante, la cui valutazione verrà poi mediata con il voto conseguito nella prova di esonero superata. ○ A student who passes both exemptions can still choose to waive the grade obtained in one of the two tests, recovering the corresponding part during the exam (useful if there is a significant discrepancy in the grades obtained in the two tests). ○ Students who pass both exemptions, can potentially present and discuss, during the exam, an applied project on the computer to enhance their final evaluation. ○ The validity of passed exemption is extended until the end of the current academic year.

Evaluation criteria	**Knowledge and understanding** ○ Identification of the fundamental properties of the methods, with particular reference to the hypothesis of applicability and computational efficiency. Ability to compare methods that solve the same problem. ○ Understanding and being able to illustrate the issues related to the use of the computer for scientific computing. **Applying knowledge and understanding** ○ Ability to solve mathematical problems using algorithms optimized in terms of computational cost and stability. ○ Discussion of the codes and examples performed; correct interpretation of the results obtained. **Making judgement** ○ Being able to identify the most suitable numerical method to solve a mathematical problem among those covered in the course. **Communication skills** ○ Clarity, also in terms of formalism, in the description and coding of the numerical methods, as well as ability to effectively present the numerical tests carried out. **Learning skills** ○ Ability to study and solve numerical problems that are similar but not necessarily identical to those addressed during the lessons.
Grading policy	The oral assessment is based on the achievement of the expected learning objectives.
Further information	Students are invited to rely exclusively on information and communications provided on the official websites of the Department of Computer Science, or on social groups only if established and administered exclusively by the instructors of the respective courses: ● https://www.uniba.it/it/ricerca/dipartimenti/informatica/didattica/corsi-di-laurea/corsi-di-laurea ● https://www.uniba.it/it/ricerca/dipartimenti/informatica ● https://elearning.uniba.it/ Courses contents are available at the url: ● https://elearning.uniba.it/course/index.php?categoryid=284 Official documentation pertaining the organization of the course of study is available at the url: ● https://www.uniba.it/it/ricerca/dipartimenti/informatica/didattica/corsi-di-laurea/corsi-di-laurea Students are advised to be cautious of information and materials circulating on unofficial websites or social groups, as they often prove to be unreliable, incorrect, or incomplete. In case of any doubts, it is recommended to request a meeting with the teacher following the specified procedures for office hours. _____ The course material is available through the University e-learning platform - https://elearning.uniba.it/