UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Computational Physics Laboratory

2425-3-E3001Q066

Aims

Learn the basis of scientific numerical calculus and how to study physical problems with the computer.

Contents

Introduction and basic concepts of computer programming. Methods to numerically solve integrals, ordinary differential equations, linear systems of equations, and their applications, as well as an introduction to Monte Carlo methods.

Detailed program

Introduction and basic concepts

- Representation of Numbers on a Computer, round-off errors and Floating-Point Arithmetic
- Error Propagation, Condition Numbers, and Stability

Interpolation/Optimization

- Interpolations by Polynomials, (optional) Interpolation by Rational Functions
- (optional) Trigonometric Interpolation: Fast Fourier Transforms

Topics in Integration

- The Integration Formulas of Newton and Cotes: Trapezoidal rule, Simpson’s rule, Composite rules, etc.

- Gaussian Integration Methods. Error Analysis
- Applications to simple integrals

Systems of Linear Equations

- Techniques and Algorithms for solving Linear Systems
- Data Fitting: Linear Least Squares and the Normal Equation

Finding Zeros and Minimum Points by Iterative Methods

- Development of Iterative Methods and their Convergence
- Basic Methods and Algorithms: Bisection, Newton-Raphson, etc.
- Applications: Roots of Polynomials, (optional) Nonlinear Least-Squares

Eigenvalue Problems

- Introduction and basic facts on Eigenvalues
- Methods for Determining the Eigenvalues and Eigenvectors of a Matrix
- (optional) Computation of the Singular Values of a Matrix and Singular Value Decomposition

Ordinary Differential Equations

- Some Theorems from the Theory of Ordinary Differential Equations
- Techniques for the numerical solution of a differential equation: Euler, Runge-Kutta, (optional) symplectic integrators
- Applications: Classical dynamics, Schroedinger equation, etc.

Monte Carlo methods

- Foundations of Monte Carlo methods. Random number generators
- Importance sampling. Metropolis-Hastings algorithm
- Applications to simple integrals

Prerequisites

Teachings of previous years. No particular coding skills are required other than very basic concepts of the C programming language, like the general structure of a code and the definition of a variable, of an array, of a function and of a loop.

Teaching form

Activity is carried out in the computer lab "Marco Comi" (room 2026, 2nd floor, building U2). The numerical techniques useful for solving the exercises are presented in a few theoretical lectures; each student works individually with the support of the teacher in case of need.

Textbook and teaching resource

The lecture notes by the teachers will be uploaded on the course webape.

In addition, we recommend the students to consult the following books:

Title: Numerical Recipes
Authors: William H. Press, Saul A. Teukolsky, William T. Vetterling, Brian P. Flannery
Editor: CAMBRIDGE UNIVERSITY PRESS

Title: Introduction to Numerical Analysis 3rd Edition
Authors: J. Stoer, R. Bulirsch
Editor: Springer

Title: Numerical Methods in Scientific Computing: Volume 1 & 2
Authors: Germund Dahlquist, Åke Björck
Editor: Society for Industrial and Applied Mathematics

Semester

The first instance of the course will take place during the first semester (under the supervision of Prof. Mattia Bruno and Dr. Marco Ce'), while a second instance will take place during the second semester (under the supervision of Prof. Mattia Dalla Brida). Students will be split up in the two instances by the teachers.

Assessment method

1. In the computer lab the student has to solve numerically a number of execises by writing computer codes.
2. Every student collects the results of the study in a written report. The report (in pdf format) as well as the codes and the results of the numerical study have to be sent to the teacher by email at least two weeks before the exam.
3. The exam, oral, consists in the discussion of the report and the solutions of the exercises.

The overall evaluation takes into account the oral exam, the lab activity and the final report. If desired, (Erasmus) students can give the exam in English (both the oral part and the written report).

The students that will attend the course during the first semester will be evaluated by the corresponding teachers, Prof. Mattia Bruno and Dr. Marco Ce', while those attending it during the second semester will be evaluated by Prof. Mattia Dalla Brida.

Office hours

For the students attending the course during the first semester, by fixing an appointment with the teachers via e-mail: *mattia.bruno@unimib.it* and *marco.ce@unimib.it*.

For the students attending the course during the second semester by fixing an appointment with the teacher via e-mail: *mattia.dallabrida@unimib.it*.

Sustainable Development Goals

QUALITY EDUCATION