Computational Physics III

Winter semester 2024/2025

Lecture Topics (Prof. Sebastiano Bernuzzi)

- **Introduction**
  - Partial differential equations (PDEs)
  - PDEs classification
  - Boundary value problems (BVPs) and initial value problems (IVPs)
  - Well-posedness
  - Standard physics problems
- **Discrete representation**
  - Discretization of functions and derivatives
  - Finite differencing
  - Spectral and Fourier representation
  - Consistency, Stability and Convergence
- **Elliptic BVP**
  - BVP with the Laplace equation and Dirichlet boundaries in 1D
  - BVP with the Laplace equation and Dirichlet boundaries in 2D
  - Matrix inversion: direct and iterative methods
  - Multigrid method
  - Spectral methods
- **Parabolic boundary-initial-value problems**
  - IBVP with the heat equation in 2D
  - Time integration: explicit and implicit methods
  - Von Neumann stability analysis
- **Hyperbolic initial-value problems**
  - IVP: hyperbolicity and well-posedness
  - Characteristics
  - IVP with the wave equation in 1D
  - Dissipation and dispersion
  - Method of lines
  - Open boundary conditions

Tutorials (Aurora Capobianco)

- **Session 1**
  - Introduction to git
  - Ssh keys, remote versus local version of the code
  - Creating repositories
  - Git commands
  - Testing merge conflicts
- **Session 2**
  - Introduction to python and Jupyter Notebook
  - Plotting with matplotlib
  - Arrays and matrices with numpy
  - Exercise: Matrix multiplication and the power method for eigenvalues
  - LU decomposition methods and their performance
- **Session 3**
  - The finite difference method
  - Exercises: Implementation with/without loops
  - The importance of vectorization
  - Introduction to python classes
- **Session 3**
  - BV problem with Poisson equation in 1D
  - Dirichlet boundary conditions
  - Using finite differencing, shooting method, Fourier method
- **Session 4**
  - Poisson equation in 2D
  - Using direct finite differencing and Jacobi iteration
- **Session 5**
  - Heat equation in 2D
  - Using implicit finite differencing
- **Session 6**
  - Wave equation in 1D
  - Flux conservative finite difference
- **Session 7**
  - Wave equation in 2D