

## **NUMERICAL METHODS**

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### **Program:**

#### **Iterative methods for large linear and nonlinear systems.**

Sparse matrices. Preliminaries on iterative methods. The method of the steepest descent. The Conjugate Gradient method. Convergence theory. Acceleration of iterative methods by preconditioning. Krylov subspace methods. The GMRES method. Practical implementations.

Iterative solution of large systems of nonlinear equations: The Newton method and its variants. Local convergence, hints to global convergence. Inexact Newton methods. Quasi-Newton methods.

#### **Introduction to Finite Elements for elliptic and parabolic equations.**

Remarks of functional analysis. Second order partial differential equations (PDEs): elliptic, parabolic, and hyperbolic equations. Boundary and initial conditions. Variational methods: Galerkin methods and weak formulations. Time integration for parabolic PDEs. Finite elements: 1D Lagrangian elements, extensions to 2D and 3D, triangular finite elements. Finite element solution of Poisson's equation and diffusion equation.

### **References:**

- Y. Saad: *Iterative methods for sparse linear systems*, SIAM, 2003
- C.T. Kelley: *Iterative methods for linear and nonlinear equations*, SIAM, 1987
- A. Quarteroni: *Numerical models for differential problems*, Springer (2014).
- O.C. Zienkiewicz, R.L. Taylor, J.Z. Zhu: *The finite element method: its basis and fundamentals*, Butterworth-Heinemann (2005).

### **Examination and grading: the student can choose one of the following**

- Solution of a number of linear algebra exercises with implementation of the iterative methods described in the course and solution of numerical tests given by the teachers;
- Implementation of a finite elements code - which makes use of an iterative solver - to solve a model PDE, which can be proposed either by the student or provided by the teachers.

The final grading is based on the evaluation of a written report describing the obtained results and discussing the methodologies employed.

### **Course details:**

The course will be offered in-person.