Universität Münster

Specialization Scientific Computing and Applied Analysis WS 24/25

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living.knowledge

Mathematics Münster

Lectures in Scientific Computing in the WS 24/25

- Christian Engwer: Scientific Computing
- Frank Wübbeling: Inverse Problems
- Carsten Wolters: Modern Appl.Math. in Bioelectromagnetism

All lectures are usable as Type I/Type II. Related seminars.

Lectures in Scientific Computing in the SS 25

- Mario Ohlberger/Stephan Rave: Numerics of PDE II
- Christian Engwer: Numerical Optimization and Machine Learning
- Carsten Wolters: Modern Appl. Math. in Bioelectromagnetism II

All lectures are usable as Type I/Type II. Related seminars.

Lectures in Applied Analysis in the WS 24/25

- Theresa Simon: Calculus of Variations

All lectures are usable as Type I/Type II. Related seminars.

Lectures in Applied Analysis in the SS 25

- Hendrik Weber: Harmonic Analysis
- Angela Stevens: Dynamical Systems
- André Schlichting: Nonlinear PDE

All lectures are usable as Type I/Type II. Related seminars.

General Required knowledge

- Infinite-dimensional function spaces, Sobolev spaces
- Partial Differential Equations (weak formulations)
- Numerical Analysis / NPDE (finite elements, not finite differences)
- Fundamentals of Programming
- List is on the Master Mathematics/Applied Math web page.
- Note: These are soft requirements.
- Note: Consider taking the Bachelor PDE I or NPDE I course.

Scientific Computing

- Prerequisite/Useful: Numerics of PDE, Mathematical Modeling
- Useful: Programming in C++ (Python)
- Contents: Treat concrete practical problems.
  - **Modeling**
  - **Numerical Simulation**
  - **Using PDE libraries (DUNE, pyMOR)**

Inverse Problems

- Definition: Recover cause from observations. Typically ill-posed, the process is discontinuous. Reverse modeling.
    - **Imaging:**
      Recover image from tomographic measurement (medicine)
      Recover ground layout from seismic measurements (geophysics)
      Recover source location from acoustic measurement (acoustics)
- More theoretically oriented, can be used in AA and SC
- Borrows lots of stuff from Functional Analysis, PDE, Stochastics

Bioelectromagnetism

- Lecture given at the University Hospital
- Very practically oriented towards MEG (MagnetoEncephaloGraphy)
- Map brain activity by measuring the (weak) brain‘s magnetic fields
- Treats both challenges:
  - **Modeling problem: Simulate the field generated by a brain activity**
  - **Inverse problem: Recover the activity map from field measurements**

Numerical Optimization and Machine Learning

- We start with basic questions of what are optimization problems and their mathematical properties.
- Within the lecture a central question is how to solve different types of optimization problems numerically.
- Starting from classical optimization (simplex method, convex optimization), we will see that machine learning is a particular type of (non-linear) optimization problem.
- We will learn how neural networks lead to non-linear optimization problems and what adequate numerical methods look like.

Numerics of PDE II

- (Example, many more subjects like Model Order Reduction are possible)
- Scalar conservation laws in 1D
- Scalar conservation laws in nD
- Systems of conservation laws
- Boundary conditions for nonlinear scalar equations

Calculus of Variations

- minimization on infinite dimensional function spaces
- necessary and sufficient conditions for minimizers
- Euler-Lagrange equations
- direct method
- Gamma-Konvergenz

Harmonic Analysis

- Fourier transformation
- Fourier series
- Distributions
- singular integrals
- interpolation theory
- maximal functions
- Calderon-Zygmund theory

Dynamical Systems

- general methods
- stability of equilibria
- qualitative properties of solutions
- real world applications

Nonlinear PDE

- fixed point methods
- self-similar solutions
- large-time dynamics
- blow-up solutions