MASTER DEGREE COURSES OFFERED IN ENGLISH IN WINTER SEMESTER 2018-19

- 0104800 **Functional Analysis**
  Instructor: PD Dr. Peer Kunstmann
  Weakly Hours: 4+2

  In this lecture we study Banach and Hilbert spaces and linear operators between them. The focus is on infinite-dimensional spaces and examples include function and sequence spaces. Linear operators on such spaces arise in the formulation and solution of integral and differential equations, and the development of Functional Analysis in the 20th century has been intimately linked to the modern theory of such equations. Functional Analysis as a "common language" is the basis for advanced studies in a number of fields such as partial differential equations, numerical analysis, mathematical physics, and a lot more.
  The topics we shall study in this lecture include metric spaces (notions of topology, compactness), continuous linear operators on Banach spaces, uniform boundedness principle and open, mapping theorem, Hilbert spaces, orthonormal bases, Sobolev spaces, Dual spaces, Hahn-Banach and Banach-Alaoglu theorems, weak convergence, reflexivity, compact linear operators.

  Prerequisites: Analysis 1-3, Linear Algebra 1-2, familiarity with Lebesgue integration.

- 0105100 **Inverse Problems**
  Instructor: Prof. Roland Griesmaier
  Weekly Hours: 4+2

  Following Hadamard, a problem whose solution does not depend continuously on the given data is called ill-posed. Prominent examples are the mathematical problems behind tomographic tools like X-ray tomography, ultrasound tomography or electrical impedance tomography as well as seismic imaging, radar imaging, or inverse scattering. The mathematical models used in this context are typically formulated in terms of integral transforms or differential equations. However the aim is not to evaluate the transform or to solve the differential equation but to invert the transform or to reconstruct parameters of this equation given (part of) its solution, respectively. Therefore these problems are called inverse problems.

Standard methods from numerical mathematics typically fail when they are applied to ill-posed problems - the problem has to be regularized. The course gives an introduction to the functional analytic background of regularization methods for linear ill-posed problems. Results from functional analysis that are needed will be provided during the lecture.

Prerequisites: Linear Algebra 1-2, Analysis 1-3.

This course will be taught in English provided there is a sufficient number of interested students. Please contact the instructor if interested.

- 0105500 **Stochastic Differential Equations**
  Instructor: Prof. Lutz Weis
  Weekly Hours: 4+2

  This course might be taught in English provided there is a sufficient number of interested students. Please contact the instructor if interested.

- 0106000 **Lie groups and Lie algebras**
  Instructor: Prof. Leuzinger
  Weekly Hours: 4+2

  This course provides an introduction to the theory of Lie groups and Lie algebras. This is a beautiful and central topic in modern mathematics and theoretical physics. It had its origins in the nineteenth century in Lie's idea of applying Galois theory to differential equations and in Klein's "Erlanger Programm" of treating symmetry groups as the fundamental objects in geometry. Contents include definition and basic properties of Lie groups and Lie algebras, examples, structure theory, classifiction of complex semisimple Lie algebras, representation theory.

  Prerequisites: Basic concepts of differential geometry and algebra.

- 0106300 **Comparison of numerical integrators for nonlinear dispersive equations**
  Instructor: JProf. Katharina Schratz
  Weakly Hours: 2+2

In this lecture we will compare various numerical methods (e.g., Splitting methods, exponential integrators, Fourier integrators) for nonlinear dispersive equations. We will in particular study their error behavior with respect to the regularity of the solution, the conservation of geometric structures and long time behavior. Our model problems thereby include fundamental models such as the nonlinear Schrdinger and Korteweg-de Vries equation.

Prerequisites: lecture on theoretical and numerical analysis of partial differential equations.

- 0107800 **Numerical methods in mathematical finance**
  Instructor: Prof. Tobias Jahnke
  Weekly Hours: 4+2

  An option is a contract which gives its owner the right to buy or sell an underlying asset at a future time at a fixed price. The underlying asset is often a stock of a company, and since its value varies randomly, computing the fair price of the corresponding option is an important and interesting problem which yields a number of mathematical challenges. This lecture provides an introduction to the most important models for option pricing. The main goal, however, is the construction and analysis of numerical methods which approximate the solution of the corresponding differential equations in a stable, accurate and efficient way. The following topics will be treated: mathematical models for pricing stock options, Itô integral, Itô formula, stochastic differential equations, Black-Scholes equation, binomial methods, Monte-Carlo methods, numerical methods for stochastic differential equations, random number generators, finite difference methods for parabolic partial differential equations, numerical methods for free boundary value problems.

  Prerequisites: Familiarity with ordinary differential equations and the corresponding numerical methods (cf. lecture "Numerische Methoden für Differentialgleichungen"), probability theory (cf. lecture "Wahrscheinlichkeitstheorie"), and programming in Matlab. Knowledge about stocks, options, arbitrage and other aspects from mathematical finance is not required, because the lecture will provide a short introduction to these topics.

- 0109400 **Mathematical modeling and simulation in practice**
  Instructor: PD Dr. Gudrun Thäter

Weakly Hours: 2+1

In this course you learn working on projects in interdisciplinary groups, combining different fields of mathematical and technical knowledge, and develop modeling skills. Topics include game theory, ordinary and partial differential equations, difference equations, modeling of traffic, chaotic behavior, population models, Wiener processes, fluid mechanics. Part of the lecture course is a lecture by a person from industry about their models in December and excursion to one of our industrial partners at the end of the term.

Prerequisites: typical knowledge from any mathematical or engineering bachelor degree like Calculus, introductory knowledge in numerics and numerical methods of ODEs, stochastics.

- 0110650 **Numerical Linear Algebra for Scientific High Performance Computing**
  Instructor: Dr. Hartwig Anzt
  Weakly Hours: 2

  In this course, we learn about scientific high performance computing, method and algorithm development for parallel computing, and how mathematical building blocks are efficiently realized on modern computer architectures. We will cover computer architecture design, BLAS operations, Gaussian elimination, LU/QR/Cholesky factorizations, relaxation methods (Jacobi/Gauss-Seidel/Southwell method), Krylov subspace solvers, incomplete factorization preconditioners, and multigrid methods. In the end, we will also look into machine learning technology.

  Prerequisites: Lectures on Numerics and Linear Algebra, C/Fortran/python programming.

- 0123100 **Forecasting: Theory and Practice**
  Instructor: Prof. Tilmann Gneiting
  Weakly Hours: 2+2

  A common desire of all humankind is to make predictions for the future. As the future is inherently uncertain, forecasts ought to be probabilistic, i.e., they ought to take the form of probability distributions over future quantities or events. In this class, which comprises Part I of a two semester series, we will study the probabilistic and statistical foundations of the science of forecasting.

The goal in probabilistic forecasting is to maximize the sharpness of the predictive distributions subject to calibration, based on the information set at hand. Proper scoring rules such as the logarithmic score and the continuous ranked probability score serve to assess calibration and sharpness simultaneously, and relate to information theory and convex analysis. As a special case, consistent scoring functions provide decision-theoretically coherent tools for evaluating point forecasts. Throughout, concepts and methodologies will be illustrated in data examples and case studies.

Prerequisites: A firm understanding of the contents of module Probability Theory is essential.

- 0155450 **Introduction to Kinetic Theory**
  Instructor: Prof. Martin Frank
  Weakly Hours: 2+1

  Topics of this course include: from Newton's equations to Boltzmann's equation, rigorous derivation of the linear Boltzmann equation, properties of kinetic equations (existence and uniqueness, H theorem), the diffusion limit, from Boltzmann to Euler and Navier-Stokes, method of moments, closure techniques, and selected numerical methods.

  Prerequisites: Partial Differential Equations, Functional Analysis.

- **Selected Topics in Harmonic Analysis**
  Instructor: Dr. Nikolaos Pattakos
  Weakly Hours: 4+2

  In this course we will deal mainly with Calderón-Zygmund and singular integral operators. We will also study the $BMO(\mathbb{R}^d)$ space, weighted norm inequalities, A_∞ weights and the nice interplay between $BMO(\mathbb{R}^d)$ functions and A_∞ class. Other topics we will cover are Reverse Hölder inequalities, the factorisation of A_p weights and the extrapolation theory of Rubio de Francia. If time permits we will also study how the Bellman function technique can be used to pass from dyadic operator estimates to Calderón-Zygmund operator estimates.

Prerequisites: Familiarity with Measure Theory, Lebesgue spaces, Fourier transform, Distributions and Functional Analysis.

See also http://www.math.kit.edu/vvz/seite/vvzkommend