MASTER DEGREE COURSES OFFERED IN ENGLISH IN SUMMER SEMESTER 2021

- **0100300 Differential Geometry**

  Instructor: Prof. Enrico Leuzinger

  Weekly Hours: 4+2

  This course provides an introduction to modern differential geometry. This is a central topic in modern mathematics and theoretical physics. It has its origins in the nineteenth century on the work of Gauss and Riemann who used analytic methods to study geometric problems. Contents include definition and basic properties of differentiable manifolds, Riemannian metrics, curvature tensors, Jacobi-fields and the metric structure of Riemannian manifolds.

  Recommended prerequisites: Elementare Geometrie

  Online lectures: Wed 8:00-9:30, Th 10:00-11:00

- **0102000 Sobolev Spaces**

  Instructor: PD Dr. Rainer Mandel

  Weekly Hours: 3+1

  In this course we develop the theory of Sobolev spaces, which is indispensable for the modern theory of Partial Differential Equations. The main idea is to study functions with distributional derivatives given by L^p-functions and to take advantage of the theory of the associated Banach spaces, which are called Sobolev spaces. We will study the most important aspects of these spaces (Trace Theorems, Embedding Theorems) and demonstrate their usefulness in the context of the Calculus of Variations and basic elliptic Partial Differential Equations.

  Prerequisites: Calculus, Basics of Functional Analysis

  Lecture: Tu 12:00-13:30 Problem class: Thu 18:00-19:30

- **0110650 Numerical Linear Algebra for Scientific High Performance Computing**

  Instructor: Dr. Hartwig Anzt

  Weekly Hours: 2

  This course is covers the fundamentals of designing and implementing numerical linear algebra operations and algorithms on modern multi- and manycore architectures. It bridges between mathematical theory on PDEs, discretization, linear solvers, iteration methods, and preconditioning and programming aspects like MPI, OpenMP and GPU programming: We start with an overview about HPC, current trends in high-end computing systems and environments, and continue with an introduction of common architecture designs and programming methodologies. We then take a deeper dive into programming techniques for multi- and manycore. We will learn OpenMP and CUDA programming. Besides that, we will look at performance modeling and tools that allow to assess the efficiency of implementations when running in parallel. We look into direct and iterative solution methods for linear problems: LU, QR, Cholesky, Relaxation Methods, Krylov Methods, Multigrid methods. For the iterative solution methods, we also cover the concept of preconditioning, and the most common techniques like (Block-) Jacobi preconditioning, Incomplete Factorization Preconditioning (ILU), Sparse Approximate Inverses (SAI). The last part of the course is the presentation of the student projects. Each student chooses a topic in agreement with the lecturer, and prepares a presentation along with a project class paper.

Prerequisites: Basic concepts of linear algebra and numerical mathematics, and basic programming skills (C/C++)

Lectures: Mo 8:00-9:30

- **0152800 Convex Geometry**

  Instructor: Prof. Daniel Hug

  Weakly hours: 4+2

  Convexity is a fundamental notion in mathematics which has a combinatorial, an analytic, a geometric and a probabilistic flavour. Basically, a given set in a real vector space is called convex if with any two points of the set also the segment joining the two points is contained in the set. This course provides an introduction to the geometry of convex sets in a finite-dimensional real vector space and to basic properties convex functions. Results and methods of convex geometry are particularly relevant, for instance, in optimization theory and in stochastic geometry. The following topics will be covered: Geometric foundations: combinatorial properties, support and separation theorems, extremal representations Convex functions The Brunn-Minkowski Theory: basic functionals of convex bodies, mixed volumes, geometric (isoperimetric) inequalities Surface area measures and projection functions Integral geometric formulas If time permits, we also consider additional topics such as symmetrization of convex sets.

  Prerequisites: Analysis 1-3, Linear algebra 1+2

  Lectures: Wed 12:00-13:30 and Th 12:00-13:30

Problem Class: Tu 08:00-09:30

- **0153300 Geometric group theory**

  Instructor: JProf. Dr. Claudio Llosa Isenrich

  Weekly hours: 4+2

  This course will provide an introduction to geometric group theory, which studies the interactions between finitely generated groups and geometric spaces, creating connections between algebra and geometry. While a priori groups may seem like purely algebraic objects, they can naturally arise as symmetries of geometric objects. For instance, the symmetries of a regular n-gon form a group (the dihedral group D_n). In fact, every finitely generated group admits a natural action by isometries on a metric space, known as its Cayley graph. For instance the Cayley graph of the integers is the real line with vertices given by the integer points and the group action defined by translation.

  Studying group actions on geometric spaces, allows us to gain insights into "the geometry of groups". Conversely, knowing that a geometric space admits an interesting group action allows us to obtain a better understanding of the space itself. Over the last decades, these interactions between group theory and geometry have led to an array of fundamental results in both areas. This course will provide an introduction to these interactions and their consequences.

  In particular, we will learn about:

  – finitely generated groups and group presentations
  – Cayley graphs and group actions
  – quasi-isometries of metric spaces, quasi-isometry invariants and the Theorem of Schwarz-Milnor
  – explicit examples of infinite groups and their connections to geometry

  Prerequisites: Knowledge of the basic concepts on metric and topological spaces, as well as some familiarity with the basic concepts in group theory are recommended.

  Lectures: Mo 12:00-13:30, Tu 10:00-11:30

  Problem class: Fr 12:00 - 13:30 (Class tutor: M.Sc. Jerónimo García Mejía)

- **0156400 Harmonic Analysis**

  Instructor: Prof. Dr. Dorothee Frey

  Weekly hours: 4+2

  This course gives an introduction to Fourier analysis and real harmonic analysis. Harmonic analysis has its origin in Fourier's work, which provides explicit solutions for e.g. heat and wave equations. Nowadays, it provides important tools in tackling a large variety of problems coming from partial differential equation, in particular for boundary value problems on L^p spaces. Topics of the course include summability of Fourier series, the Fourier transform on R^n, interpolation methods, singular integral operators, and Fourier multipliers.

Prerequisites: Functional analysis

Lectures: Mo 10:00-11:30, Wed 8:00-9:30

Problem class: Fr 10:00-11:30

- **0163700 Spectral Theory**

  Instructor: Prof. Dirk Hundertmark

  No description is available.

- **0164400 Uncertainty Quantification**

  Instructor: Dr. Jonas Kusch

  Weekly Hours: 2+1

  There are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns ? there are things we do not know we don't know." (Donald Rumsfeld)

  In this class, we learn to deal with the "known unknowns", a field called Uncertainty Quantification (UQ). More specifically, we focus on methods to propagate uncertain input parameters through differential equation models. Given uncertain input, how uncertain is the output? The first part of the course ("how to do it") gives an overview on techniques that are used. Among these are: Sensitivity analysis, Monte-Carlo methods, Spectral expansions, Stochastic Galerkin method, Collocation methods and sparse grids. The second part of the course ("why to do it like this") deals with the theoretical foundations of these methods. The so-called "curse of dimensionality" leads us to questions from approximation theory. We look back at the very standard numerical algorithms of interpolation and quadrature, and ask how they perform in many dimensions.

  Prerequisites: Basic concepts of partial differential equations are helpful.

  Lectures: Th 8:00-9:30

  Problem Class: Th 16:00-17:30

- **0165300 Applications of Topological Data Analysis**

  Instructor: PD Dr. Andreas Ott

  Weekly hours: 2+2

This course explores applications of topological data analysis in the natural sciences. A prominent example will be the evolution of viruses. We will learn about methods (persistent homology and the Mapper algorithm), study the mathematical background, and design and implement computer algorithms in concrete examples.

Prerequisites: Basic linear algebra and calculus, basic algebraic topology (as taught in the course "Topological Data Analysis" in WS 2020/21, available on ILIAS), basic computer programming skills.

Lecture: Wed 10:00-11:30

Problem class: Thu 14:00-15:30

- **0165700 Analytical and numerical homogenization**

  Instructors: Dr. Fatima Z. Goffi, Dr. Barbara Verfürth

  Weekly hours: 3+1

  The lecture deals with analytical and numerical homogenization for multiscale problems, which will be illustrated for elliptic diffusion problems. Multiscale problems are partial differential equations where the coefficients vary rapidly on small spatial scales. Such problems arise in various applications in science and engineering, where materials with fine structures of different components play an important role. Analytical and numerical homogenization provide tools to describe and simulate the so-called macroscopic behavior of the materials. Contents include classical analytical homogenization theory (multiscale expansions, energy method, two-scale convergence) and numerical methods to approximate the homogenized as well as the multiscale solution.

  Prerequisites: Basics on partial differential equations and numerics for differential equations

  Lectures/ Problem class: Mo 14:00-15:30, Tu 18:00-19:30 (Tuesday alternating between lecture and problem class).

- **0165900 Time Integration of PDEs**

  Instructor: Prof. Marlis Hochbruck

  Weekly hours: 4+2

  The aim of this lecture is to construct, analyze and discuss the efficient implementation of numerical methods for time-dependent partial differential equations (pdes). We will consider traditional methods and techniques as well as very recent research.

  Prerequisites: The students are expected to be familiar with the basics of the numerical analysis of the time integration of ordinary differential equations (Runge-Kutta and multistep methods) and of finite element methods for elliptic boundary element methods. The lecture starts with a review on Runge-Kutta and multistep methods. Some basic knowledge in functional analysis and the analysis of boundary value problem is helpful but the main results will be repeated in the lecture.

Lectures: online, Tu 16:00-17:30 (every week), Th 10:00-11:30
Problem class: Fr 8:00-9:30

- **0178000 Forecasting: Theory and Practice II**

  Instructor: Prof. Tilmann Gneiting
  Weekly Hours: 2+1

  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 constitutes Part II of a two-semester sequence, we will focus attention on tests of predictive performance, distributional regression techniques, and methods for combining predictive distributions. Throughout, concepts and methodologies will be illustrated in data examples and case studies.

  Prerequisites: A firm understanding of the contents of Part I is essential.
  Lecture: Tu 14:00-15:30
  Problem class: Wed 16:00-17:30

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