INTERNATIONAL PROGRAM (MASTER)

CLASSES: SUMMER SEMESTER 2016

0150400 Extremal Graph Theory
Lecture: 4 h, 8 credit points
Tue 11:30-13:00 20.30, SR 2.059, Fri 9:45-11:15 20.30, 2.059
Tutorial: 2 h
Thu 14:00-15:30 20.30, SR 3.069
Prof. Axenovich

0152700 Poisson Process
Lecture: 2 h, 4 credit points
Mon 11:30-13:00 20.30, SR 2.58
Tutorial: 2 h
Thu 11:30-13:00 20.30, SR 3.69
Prof. Last

0154100 Geometric Numerical Integration
Lecture: 3 h, 6 credit points
Thu 8:00-9:30 20.30, SR 3.061, Wed 8:00-9:30 20.30, 3.061 (every 2nd week)
Tutorial: 1 h
Wed 8:00-9:30 20.30, SR -1.031 (every 2nd week)
Prof. Jahnke

0156500 Aspects of Nonlinear Wave Equations
Lecture: 4 h, 8 credit points
Mon 9:45-11:15 20.30, SR 3.068, Wed 11:30-13:00 20.30, SR 3.068
Tutorial: 2 h
Wed 14:00-15:30 20.30, SR 3.068
Prof. Reichel

0157400 Algebraic topology
Lecture: 4 h, 8 credit points
Tue 11:30-13:00 20.30, SR 2.058, Thu 11:30-13:00 20.30, 0.014
Tutorial: 2 h
Wed 17:30-19:00 20.30, SR 2.059
Dr. Kammeyer

0157500 Boundary and Eigenvalue problems
Lecture: 4 h, 8 credit points
Mon 8:00-9:30 20.30, SR 3.068, Tue 8:00-9:30 20.30, 3.038
Tutorial: 2 h
Tue 14:00-15:30 20.30, SR 3.069
Dr. Anapolitanos

0161100 Time Series Analysis (Course Syllabus)
Lecture: 2 h, 4 credit points
Tue 14:00-15:30 20.30, SR 2.059
Tutorial: 1 h
Wed 14:00-15:30 20.30, SR 2.058, Fri 14:00-15:30, SCC-PC-Pool L
Prof. Gneiting

0161700 Project-oriented Software Lab on Computational Fluid Mechanics
4 h, 4 credit points
Tue 9:45-11:15 20.30, SR -1.031, Fri 9:45-11:15 20.30, SR -1.031
Dr. Thäter, Dr. Krause

0164500 Time Integration of PDEs
Lecture: 4 h, 8 credit points
Mon 15:45-17:15 20.30 (alternative date), SR 1.067, Tue + Thu 9:45-11:15 20.30, 1.067
Tutorial: 2 h
Tue 15:45-17:15 20.30, SR 3.061 or Wed 9:45-11:15 20.30, SR 3.061 (date of the problem classes will be discussed in the first lecture)
Prof. Hochbruck

0164600 Homotopy Theory
Lecture: 4 h, 8 credit points
Tue 17:30-19:00 20.30, SR 2.59, Thu 15:45-17:15, 20.30, SR 2.059
Tutorial: 2 h
Mon 14:00-15:30 20.30, SR 2.059
Prof. Sauer

Time-table for lectures

	Monday	Tuesday	Wednesday	Thursday	Friday
08:00-09:30	BEPr.	BEPr.	Geo.N.Int.(2nd weakly)	Geo.N.Int.	
09:45-11:15	Asp.NWE.	S.Lab Time Int.		Time Int.	S.Lab ExGr.Theo.
11:30-13:00	Poisson Pr.	Alg.Top. ExGr.Theo.	Asp.NWE.	Alg.Top.	
14:00-15:30		TS Ana.			
15:45-17:15	Al.Top. (Time Int.)			Hom.Theo.	
17:30-19:00		Hom.Theo.			

GERMAN CLASSES

Optional German language classes should be attended in the late afternoon and evening.

CLASSES: SUMMER SEMESTER 2016

0150400 Extremal Graph Theory

Lecture: 4 h, 8 credit points
Tue 11:30-13:00 20.30, SR 2.059, Fri 9:45-11:15 20.30, 2.059
Tutorial: 2 h
Thu 14:00-15:30 20.30, SR 3.069
Prof. Axenovich

Contents

The extremal function $\mathrm{ex}(n, H)$ for a graph H is the largest number of edges in a graph on n vertices that does not contain H as a subgraph. The Ramsey function $r(H)$ for a graph H is the smallest integer n such that in any 2-coloring of the edges of a complete graph K_n on n vertices there is a monochromatic copy of H.
In this course the properties of these functions and their generalizations are considered. In addition, other extremal results are discussed.
Specific topics include: Turan's theorem for $\mathrm{ex}(n, K_t)$, classical theorems on matchings and cycles, Regularity lemma and applications, Erdös-Stone-Simonovits' theorem for $\mathrm{ex}(n, H)$, $\mathrm{ex}(n, K_{s,t})$, $\mathrm{ex}(n, C_k)$, extremal numbers for hypergraphs, $r(K_t)$, $r(K_3, K_t)$, hypergraph Ramsey numbers, Ramsey numbers for graphs of bounded maximum degree and arrangeable graphs, size and online Ramsey numbers.

Prerequisites:

Knowledge of basic graph theory and linear algebra.

References:

The main source of this course are lecture notes from David Conlon (University of Oxford) for courses in extremal graph theory and Ramsey theory.
Other sources include the books:
R. Diestel: Graph Theory (free onlone edition available on http://diestel-graph-theory.com).
B. Bollobas: Extremal Graph Theory.

0152700 Poisson Process

Lecture: 2 h, 4 credit points
Mon 11:30-13:00 20.30, SR 2.58
Tutorial: 2 h
Thu 11:30-13:00 20.30, SR 3.69
Prof. Last

Contents

These lectures give an introduction into the Poisson process, one of the most fundamental objects in modern probability theory. While many of its applications involve the Euclidean space or other specific settings, it is both possible and natural to develop much of the theory in the abstract setting of a general measurable space. As applications we discuss Cox and permanental processes, compound Poisson processes, and the Gilbert graph of stochastic geometry.

Prerequisites:

The lectures require a sound knowledge of measure-theoretic probability theory but no specific knowledge of stochastic processes.

References:

J.F. Kingman: Poisson Processes. Oxford Studies in Probability, 1993.
G. Last and M.D. Penrose: Lectures on the Poisson process. To be published by Cambridge University Press.
http://www.math.kit.edu/stoch/∼last/seite/lehrbuch_poissonp/de

0154100 Geometric Numerical Integration

Lecture: 3 h, 6 credit points
Wed 8:00-9:30 20.30, 3.061 (every 2nd week), Thu 8:00-9:30 20.30, SR 3.061.
Tutorial: 1 h
Wed 8:00-9:30 20.30, SR -1.031 (every 2nd week)
Prof. Jahnke

Contents

The numerical simulation of time-dependent processes in science and technology often leads to the problem to solve a system of ordinary differential equations (ODEs) with a suitable method. In many applications it can be shown that the exact flow exhibits certain qualitative or "geometric" properties. For example, it is well-known that the flow of a Hamiltonian system is symplectic, and that the energy remains constant along the solution although the solution itself changes in time.
When the solution or the flow is approximated by a numerical integrator, it is desirable to preserve these geometric properties (at least approximately), because reproducing the correct qualitative behavior is important in most applications. It turns out, however, that many numerical schemes destroy the structure of the solution, and that only selected methods respect the geometric properties of the dynamics. These methods are called geometric numerical integrators. In this lecture we will investigate
why certain methods are (or are not) geometric numerical integrators,
how to construct geometric numerical integrators,
which properties are conserved, and in which sense,
how structure conservation is related to the long-time error behavior of the method.

The course consists of a lecture (Wednesday and Thursday, 8:00-9:30, SR 3.61) and exercise classes (Wednesday, 8:00-9:30, computer pool -1.031, alternating with lecture).
Both the lecture and the exercise classes will be given in English.

In the exercise class, students will be asked to write Matlab programs which illustrate the theoretical results presented in the lecture. The exercises can be solved in pairs or alone, at home or in class, and with the assistance of the tutor. Participants are expected to be familiar with Matlab. As KIT has a Campus License for MATLAB, all students can download and install the software.

The exams (oral, 25 mins) will take place on 24 August 2016.

Prerequisites:

The lecture will be suited for students in mathematics, physics and other sciences with a basic knowledge in ordinary differential equations and Runge-Kutta methods. In particular, students should be familiar with concepts such as, e.g., order, consistency, convergence, A-stability, and so on. The course "Numerische Methoden für Differentialgleichungen" provides a good basis.

References:

Ernst Hairer, Christian Lubich, and Gerhard Wanner: *Geometric numerical integration. Structure-preserving algorithms for ordinary differential equations.* 2nd ed., Springer, 2006.
Ernst Hairer, Christian Lubich, and Gerhard Wanner: *Geometric numerical integration illustrated by the Störmer-Verlet method.* Acta Numerica 12, 399-450, 2003.
Sebastian Reich and Benedict Leimkuhler: *Simulating Hamiltonian dynamics.* Cambridge monographs on applied and computational mathematics 14. Cambridge University Press (Cambridge), 2004.
Jesus Maria Sanz-Serna and Mari Paz Calvo: *Numerical Hamiltonian problems.* Number 7 in Applied Mathematics and Mathematical Computation. Chapman & Hall (London), 1994.

0156500 Aspects of Nonlinear Wave Equations

Lecture: 4 h, 8 credit points
Mon 9:45-11:15 20.30, SR 3.068, Wed 11:30-13:00 20.30, SR 3.068
Tutorial: 2 h
Wed 14:00-15:30 20.30, SR 3.068
Prof. Reichel

Contents

Nonlinear wave equations occur in many mechanical and electromagnetic models. This course is meant to describe some typical phenomena in nonlinear wave equations like the formation of stable traveling or standing waves. The course will be more of exemplary nature rather than of comprehensive nature. I will use many tools and notions from linear and nonlinear analysis, e.g., Sobolev spaces, spectral theory, variational techniques, notions from nonlinear functional analysis like Frechet-differentiablity, implicit function theorem. They will be

mostly introduced and explained during the course.
The questions that I will address are:
Existence of traveling waves for $u_{tt} - u_{xx} = f(u)$
Existence of traveling waves in a suspension bridge model $u_{tt} + u_{xxxx} = f(u)$
Variational approach to standing, time-periodic waves for $u_{tt} - u_{xx} = -|u|^{p-1}u$
Stability questions for nonlinear wave equations
The examination will be via an oral exam.

Prerequisites:

The course is meant for advanced Master students. Familiarity with partial differential equations and some functional analysis is indispensable.

References:

Among others I will use the following sources (the list will be completed during the course):
Adams, Fournier: Sobolev spaces (Elsevier, 2002).
Struwe: Variational Methods (Springer, 1996), Chapter I.6.
Grillakis, Shatah, Strauss: Stability Theory of Solitary Waves in the Presence of Symmetry, Journal of Functional Analysis 74, 160–197 (1987).

0157400 Algebraic topology

Lecture: 4 h, 8 credit points
Tue 11:30-13:00 20.30, SR 2.058, Thu 11:30-13:00 20.30, 0.014
Tutorial: 2 h
Wed 17:30-19:00 20.30, SR 2.059
Dr. Kammeyer

Contents

Algebraic topology is the study of spaces by algebraic methods. In modern terms it is concerned with constructing *functors* from the *category of spaces* to algebraic categories, most notably *abelian groups*. Developing the necessary machinery is intriguing but instructive because it touches upon various interwoven mathematical fields. The results are rewarding: at the end of the course we have tools at our disposal to distinguish spaces and to predict that certain maps have fixed points. This has some striking and even somewhat amusing consequences: while it is always possible to cut a ham sandwhich, whatsoever shaped, into fair parts with a single slice, it is impossible to comb a hairy ball without leaving a cowlick. Categories, functors, adjunction and limits, The fundamental groupoid and van Kampen's theorem, Chain complexes and singular homology, Cell complexes and cellular homology.

Prerequisites:

Participants should have taken the course "Introduction to Geometry and Topology" beforehand.

References:

A. Hatcher: Algebraic Topology, Cambridge University Press, 2002.
G. E. Bredon: Topology and Geometry, GTM Volume 139, Springer, 1993.
T. tom Dieck: Algebraic Topology, EMS Textbooks in Mathematics, 2008.
W. Lück: Algebraische Topologie: Homologie und Mannigfaltigkeiten, Aufbaukurs Mathematik, Vieweg, 2005.

0157500 Boundary and Eigenvalue problems

Lecture: 4 h, 8 credit points
Mon 8:00-9:30 20.30, SR 3.068, Tue 8:00-9:30 20.30, 3.038
Tutorial: 2 h
Tue 14:00-15:30 20.30, SR 3.069
Dr. Anapolitanos

Contents

Examples of boundary and eigenvalue problems, Maximum Principles for Equations of second order, Sobolev spaces, weak formulation of elliptic equations of second order, existence and regularity theory for elliptic equations, weak formulated eigenvalue problems.
Understanding of the meaning and the importance of boundary and eigenvalue problems in Mathamatics and Physics, and illustration with examples. Description of qualitative properties of their solutions. Proving existence and uniqueness of solutions of boundary value problems with methods of functional analysis. Knowledge of statements regarding existence of eigenvalues and eigenfunctions of elliptic differential operators and description of their properties.

Prerequisites:

Linear algebra 1+2, Analysis 1-3, Differential Equations and Hilbert spaces or Functional Analysis.

References:

L. C. Evans: Partial Differential Equations, American Mathematical Society 1998.
R. A. Adams, J. F. Fournier: Sobolev spaces, Academic Press 2003.
Gilbarg and Trudinger: Elliptic Partial Differential Equations of Second Order, Springer 1998.
W. Strauss: Partial differential equations. An introduction. Second edition.

0161100 Time Series Analysis (Course Syllabus)

Lecture: 2 h, 8 credit points
Tue 14:00-15:30 20.30, SR 2.059
Tutorial: 1 h
Wed 14:00-15:30 20.30, SR 2.058, Fri 14:00-15:30, SCC-PC-Pool L
Prof. Gneiting

Contents

A time series is a set of data $\{x_t\}$ in which the subscript t indicates the time at which the datum x_t was observed. The course provides an introduction to the theory and practice of statistical time series analysis. Topics covered include stationary and non-stationary stochastic processes, autoregressive and moving average (ARMA) models, state-space models and Kalman filter, model selection and estimation, forecasting and forecast assessment, and an outline of spectral techniques.
Tentative Weekly Schedule

April 19	Introduction
April 26	Stationary processes
May 3	Trend and seasonality
May 10	Forecasting
May 17	Forecasting
May 24	ARMA models
May 31	ARMA models
June 7	Identification and estimation for ARMA processes
June 14	Identification and estimation for ARMA processes
June 21	(S)ARIMA models
June 28	Multivariate time series models
July 5	State-space models and the Kalman filter
July 12	Non-Gaussian time series models
July 19	Spectral analysis

This schedule is tentative and subject to revision. Exercise sessions will be offered every other week, beginning April 27.
Statistical Software for Time Series Data
The problem sets will frequently require the use of a suitable statistical programming language. Any code discussed in class meetings will be written in the R language, and you are encouraged to use R, or your standard language if it is suitable.

Prerequisites:

Knowledge of the contents of modules MATHBAST01 (Introduction to Stochastics) and MATHBAST02 (Probability Theory) is essential. Module MATHBAST05 (Statistics) is strongly recommended.

References:

Textbooks on time series analysis include Brockwell and Davis (2006, 2010), Chatfield (2004), Diggle (2004), Wei (2006) and Zivot and Wang (2006). Hyndman and Athanasopoulos (2016), Shumway and Stoffer (2011), Venables and Ripley (2003) and Zivot and Wang (2006) discuss the use of the S-PLUS and R languages for the analysis of time series data.
Brockwell, P. J. and Davis, A. (2006): *Time Series, Theory and Methods*, second edition. New York: Springer.
Brockwell, P. J. and Davis, A. (2010). *Introduction to Time Series and Forecasting*, second edition. New York: Springer.
Chatfield, C. (2004). *The Analysis of Time Series, an Introduction*, sixth edition. London:

Chapman & Hall/CRC.
Diggle, P. J. (2004). *Time Series, a Biostatistical Introduction*. Oxford: Clarendon Press.
Hyndman, R. J. and Athanasopoulos, G. (2016). *Forecasting: Principles and Practice*. Available online at https://www.otexts.org/book/fpp.
Shumway, R. H. and Stoffer, D. S. (2011). *Time Series Analysis and Its Applications: With R Examples*, third edition. New York: Springer.
Venables, W. N. and Ripley, B. D. (2004). *Modern Applied Statistics with S-PLUS*, fourth edition. New York: Springer.
Wei, W. W. S. (2006). *Time Series Analysis, Univariate and Multivariate Methods*, second edition. Boston: Pearson Addison Wesley.
Zivot, E. and Wang, J. (2006). *Modeling Financial Time Series With S-Plus*, second edition. New York: Springer.

0161700 Project-oriented Software Lab on Computational Fluid Mechanics

4 h, 4 credit points
Tue 9:45-11:15 20.30, SR -1.031, Fri 9:45-11:15 20.30, SR -1.031
Dr. Thäter, Dr. Krause

Contents

The software lab is be focused on mathematical applications in computational fluid mechanics. In this context main teaching goals are:
mathematical modeling, numerical simulation with Lattice Boltzmann Methods, presentation of results, interpretation of results.
During the lab, a flow problem is to be formulated, simulated and analyzed under guidance. Therefore we provide the open source library OpenLB. The lab is composed of three phases, the first phase is lecture like and provides a theoretical foundation. It is followed by two simulation projects. The first is an introduction to the used software and the same for everybody. The second is more complex and may vary between groups. The projects are to be solved in groups of two and a written report is expected. Proposals for the second project on your part are always welcome.
Attendance is compulsory for the first two meetings, on April 19th and April 22nd as well as during the presentations by the end of the semester.

Start:	Tue, 04/19/2016
Dates:	Tue + Fri 9:45am–11:15am, Bldg. 20.30, Room -1.031
Credits:	4SWS / 4ECTS

The lab is limited to 30 students. **Reservations are required.**
Please sign up by email. For questions, please contact: **thomas.henn@kit.edu**

Prerequisites:

The course has an introductory character and only requires knowledge in C/C++ or similar. It is particularly aimed at master students in chemical engineering and mathematics.

References:

OpenLB, http://www.openlb.net
OpenLB User Guide, http://openlb.net/wp-content/uploads/2016/03/olb_ug-1.0r0.pdf

Erlend Viggen: The Lattice Boltzmann Method with Applications in Acoustics, PhD Thesis, http://www.diva-portal.org/smash/get/diva2:697490/FULLTEXT01.pdf
Mohamad, Abdulmajeed A.: Lattice Boltzmann method: fundamentals and engineering applications with computer codes, Springer Science & Business Media, 2011.
Chen, Shiyi, and Gary D. Doolen: Lattice Boltzmann method for fluid flows. Annual review of fluid mechanics 30.1 (1998): 329-364.

0154100 Time Integration of PDEs

Lecture: 4 h, 8 credit points
Mon 15:45-17:15 20.30 (alternative date), SR 1.067, Tue + Thu 9:45-11:15 20.30, 1.067
Tutorial: 2 h
Tue 15:45-17:15 20.30, SR 3.061 or Wed 9:45-11:15 20.30, SR 3.061 (date of the problem classes will be discussed in the first lecture)
Prof. Hochbruck

Contents

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.
Lecture dates: Please note that the dates for the lectures and problem classes may vary from week to week. The dates for the next weeks are listed below. If changes to already announced dates are required, please see webpage of the lecture.
cw 16: Tuesday 19.4. and Thursday 21.4.
cw 17: Tuesday 26.4. and Thursday 28.4.
cw 18: Monday 2.5. and Thursday 5.5.
Exam: The format of the exams will be the following: Until the end of the semester, we will provide you with a list of possible questions for each chapter of the lecture. You randomly draw three questions from this list, each from another chapter. One question can be redrawn from the same chapter with the possibility to answer the original question. Then you are given 20 minutes for preparation (without any aid). Any notes that you prepare during this time can be used in the oral exam. The actual oral exam will last additional 20 minutes during which you have to answer the questions. This leaves approximatly 7 minutes for each question. If the answer is too short we expect you to present further details of the topic. In order to assure that you understand all aspects of the topic in question, you can always be asked further questions. The final grade will be the mean of the grades (1-6) from the three answered questions.

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.

References:

M. Hochbruck: lecture notes.
M. Hochbruck: lecture notes "Numerik I, Numerik II and Numerische Methoden für Differentialgleichungen".
S. Brenner, R. Scott: The Mathematical Theory of Finite Element Methods, Springer Texts in Appl. Mathematics, Vol 15, Springer, 3rd ed., 2008.
D. Braess: Finite Elements, Cambridge University Press, 3rd ed., 2007.
Further literature will be provided in the lecture .

0164600 Homotopy Theory

Lecture: 4 h, 8 credit points
Tue 17:30-19:00 20.30, SR 2.59, Thu 15:45-17:15, 20.30, SR 2.059
Tutorial: 2 h
Mon 14:00-15:30 20.30, SR 2.059
Prof. Sauer

Contents

The course covers the fundamentals of homotopy theory: Cofibrations, fibrations, Puppe sequences, Blakers-Massey excisions theorems, higher Hurewicz isomorphisms, spectral sequences. An emphasis is put on geometric applications of the abstract homotopy-theoretic machinery.
There will be oral exams of about 25 min after the end of the course.

Prerequisites:

Students are expected to be familiar with the contents of the course *Algebraic Topology* and *Algebraic Topology II*, i.e. with computations of fundamental groups via van-Kampen's theorem, axiomatic homology theory, CW complexes, and the computation of homology via cellular homology, product structures on cohomology and Poincare duality.

Active participation is of utmost importance. We also offer an accompanying seminar that might be interesting to attend to deepen the understanding of the lecture. However, the lecture course and the seminar will be independent.

References:

Bredon, Glen E.: Topology and geometry, Graduate Texts in Mathematics, 139, Springer, 1997, xiv+557.
tom Dieck, Tammo: Algebraic topology, EMS Textbooks in Mathematics, EMS Zürich, 2008.
Hatcher, Allen: Algebraic topology, Cambridge University Press, 2002, xii+544, available under `http://www.math.cornell.edu/ hatcher/AT/ATpage.html`.
May, J. P.: A concise course in algebraic topology, Chicago Lectures in Mathematics, University of Chicago Press, x+243, 1999.