University of Bremen

– **Faculty 3** –

Courses

Summer Semester 2025

M.Sc. Industrial Mathematics & Data Analysis

M.Sc. Mathematics

M.Sc. Mathematik

M.Sc. Technomathematik

March 2025

This brochure summarizes almost all courses and lectures of the Master's programs Industrial Mathematics & Data Analysis, Mathematics, Mathematik (German-language), and Technomathematik (German-language) for the summer semester 2025. Further information can be found in the Course Catalog of the University of Bremen. There you will find, among other things, the language, the assignments to the individual modules, and the course codes. These information and all details can also be found in Stud.IP.

As you can see in the Course Catalog or in Stud.IP, all courses are usually assigned with an area of focus or specialization. This can also be found for all courses via *Fields of study* in Stud.IP. For the M.Sc. Industrial Mathematics & Data Analysis, these are **Data Analysis** as well as **Industrial Mathematics**. For the M.Sc. Mathematics and the M.Sc. Mathematik, these are **Algebra**, **Analysis**, **Numerical Analysis**, and **Statistics/Stochastics**.

At this point we would like to refer to the Arrival Guide for general questions as well as to Offers for International Students and Living on Campus for answers regarding living, housing, financial help, and scholarships.

Contact

Academic Advisory Office - Mathematics

Place to go for questions on study programs, planning, recognition of credits and exam results, study abroad, and examination regulations. Also responsible for the design of this brochure.

Lars Siemer
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Contents

Lectures

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Reading Courses

Alphabetical ordering and the lecturers are responsible for the content of the descriptions

Advanced Numerical Methods for Partial Differential Equations

Course Code: 03-M-SP-41

Prof. Dr. Andreas Rademacher

Contact: arademac@uni-bremen.de

Description

Finite element methods are a mathematical elegant way to discretize partial differential equations. In this lecture, various special topics are presented and discussed:

- Multigrid methods
- Finite element methods for the wave equation
- Mixed finite element methods
- Methods for nonlinear partial differential equations
- Adaptive finite element methods based on dual weighted error estimators
- Domain decomposition

Prerequisites

You should have previous knowledge of the finite element method, e.g. as acquired in the lecture Numerical Methods for PDEs.

Area of Specialization

- Data Analysis
- Industrial Mathematics
- Numerical Analysis

Structure

There will be two lectures per week and an accompanying tutorial with weekly homework.

Examination and Formalities

The active participation in the exercises is expected. In the end there will be an oral exam.

List of Literature

Will be announced in the lectures.

Algorithmic Game Theory

Course Code: 03-M-SP-6

Prof. Dr. Daniel Schmand

Contact: schmand@uni-bremen.de

Description

Many every-day processes can seen as a game between autonomous interacting players, where each player acts strategically in order to pursue her own objectives. This lecture is an introduction to game-theoretic concepts and techniques, mainly with connections to applications. Use-cases are distributed systems, auctions, online-markets, resource allocation, and traffic networks. The goal of the lecture is to provide an overview over state-of-the-art results in the area of algorithmic game theory. Main topics that we will cover in the course are

- Strategic Games and Efficiency of Equilibria
- Auctions, Truthfulness and VCG-mechanisms
- Cooperative Games
- Social Choice

Prerequisites

The course is designed for Master's students in Mathematics and Industrial Mathematics and Data Analysis. Computer science students are welcome.

Area of Specialization

- Industrial Mathematics
- Numerical Analysis

Structure

- Lectures: Monday, 12.15-13.45 and Tuesday, 10.15-11.45
- Exercise Sessions: Monday, 10.15-11.45
- Room: MZH 2340

Examination and Formalities

oral exam (if not too many participants)

Approximation Theory

Course Code: 03-M-SP-42

Dr. Matthias Beckmann

Contact: matthias.beckmann@uni-bremen.de

Description

This lecture gives an introduction into approximation theory and classical numerical algorithms. We start with the characterization and construction of so-called best approximations in normed spaces from suitable approximation families, like (algebraic or trigonometric) polynomials, rational functions, splines, wavelets or positive definite functions. Thereon, a quantitative analysis of the approximation quality leads to the central notion of asymptotical approximation rate. Finally, we focus on selected advanced topics of approximation theory. The following topics will be covered: - Best approximations - Basic results of approximation theory - Euclidean approximation - Chebychev approximation - Approximation rates - Numerical methods

Prerequisites

Basics from B.Sc. courses in Mathematics (analysis/calculus, linear algebra, numerical analysis) and basic programming skills. All analytical concepts which are needed beyond the three semester course on analysis/calculus of the Bachelor program will be introduced.

Area of Specialization

- Analysis
- Data Analysis
- Numerical Analysis

Structure

The course, comprising 4+2 hours per week, is split into a lecture series (two lectures a 2h each week) and accompanying exercise classes (one class a 2h each week). Exercise sheets be assigned for homework and the students are requested to present their solutions during the exercise classes.

Examination and Formalities

It is necessary to solve the provided exercise sheets and actively participate in the exercise classes. The final exam will be in form of an oral exam after the lecture period.

List of Literature

- A. Iske: Approximation Theory and Algorithms from Data Analysis, Springer , 2018 - L.N. Trefethen: Approximation Theory and Approximation Practice, SIAM, 2013 - W. Cheney, W. Light: A Course in Approximation Theory, AMS, 2009 - M.J.D. Powell: Approximation Theory and Methods, Cambridge University Press, 1991

Commutative Algebra

Course Code: 03-M-SP-7

Prof. Dr. Anastasios Stefanou

Contact: stefanou@uni-bremen.de

Description

Commutative algebra is a branch of algebra which studies *commutative rings, ideals* and *modules*. Commutative Algebra has many applications within mathematics, for instance, in *algebraic number theory* and in *algebraic geometry* where commutative algebra is the main technical tool for the study of *varieties* and, more generally, for the study of *schemes*. *Combinatorial commutative algebra* is utilized for the study of *multigraded rings* and *modules* and for their combinatorial presentations. These combinatorial presentations have been quite fundamental for the theory of *multiparameter persistent homology* in *topological data analysis*. In this course we will discuss the theory of *ideals of a polynomial ring*, *graded* and *multigraded modules*, *Gröbner bases*, *presentations* and *resolutions of modules*. Along the way, we will discuss interesting connections between multigraded modules and *multiparameter persistence* in topological data analysis. Topics include:

- Polynomial rings, ideals and varieties
- Gröbner bases and Buchberger's algorithm
- Hilbert's Nullstellensatz
- Multigraded modules and Betti numbers
- Rank invariants
- Presentations and resolutions
- Hilbert's syzygy theorem
- Schreyer's theorem

Prerequisites

The prerequisite is Algebra. The course is also open to interested bachelor students.

Area of Specialization

- Algebra

Structure

The course is a 4+2 lecture, i.e. there are weekly two 2-hour lectures and a 2-hour exercise session. The academic performance consists of a 30 minute oral examination for each participant.

List of Literature

[1] D. A. Cox, J. Little, D. O'Shea. *Ideals, varieties and algorithms*, Springer.

[2] D. S. Dummit, R. M. Foote, *Abstract Algebra*, Wiley.

[3] D. A. Cox, J. Little, D. O'Shea, *Using algebraic geometry*, Springer.

[4] E. Miller, B. Sturmfells, *Combinatorial commutative algebra*, Springer.

[5] G. Carlsson, G. Singh, A. J. Zomorodian, *Computing multidimensional persistence* , Journal of Computational Geometry, 1.1: 72–100, 2010.

[6] E. Miller, *Homological algebra for modules over posets*, https://arxiv.org/abs/2008.00063.

[7] A. L. Thomas, *Invariants and Metrics for Multiparameter Persistent Homology.* PhD Thesis. Duke University, 2019.

[8] W. Kim, F. Mémoli, *Generalized persistence diagrams for persistence modules over posets.* Journal of Applied and Computational Topology, 2021, 5.4: 533-581.

Ergodic Theory

Course Code: 03-M-SP-13

Prof. Dr. Marc Keßeböhmer

Contact: mhk@uni-bremen.de

Description

In this course we will delve into the fascinating world of Ergodic Theory, a branch of mathematics that studies the asymptotic properties of transformations on topological and measurable spaces. From the origins of the ergodic hypothesis, which laid the foundation for classical statistical mechanics, to modern applications such as hyperbolic geometry or metric number theory, we will uncover the intricate relationships between measure-preserving systems, recurrence, entropy, and stochastic characterisations of dynamical systems. Through a combination of theoretical foundations and illuminating examples, we will explore the fundamental concepts of ergodic theory, including Measure-preserving systems and their properties Several ergodic theorems and their implications Recurrence and its role in understanding the behaviour of dynamical systems Dynamical spectra and their connections to number theory Entropy and its role in the study of dynamical systems Ergodic theory has far-reaching implications in many different fields outside mathematics, including physics, biology, economics and computer science (machine learning). The study of dynamical systems and ergodic theory has led to numerous breakthroughs in mathematics and has been recognised by several Fields Medals in recent years. By studying ergodic theory, you will gain a deeper understanding of the underlying mathematical structures and principles that govern complex systems. This course is an excellent starting point for further research in the field of dynamical systems, leading to exciting topics for master theses in the areas of the analysis/stochastics group. Join us on this journey into the fascinating world of Ergodic Theory!

Prerequisites

While there are no strict prerequisites for this course, a good understanding of analysis, linear algebra, basic topology and measure theory will be beneficial. However, the course is designed to be accessible to students with a strong mathematical background and a willingness to learn.

Area of Specialization

- Analysis
- Data Analysis
- Statistics/Stochastics

Structure

There will be four hours of lectures and two hour of tutorials each week to discuss the weekly exercises. Lecture notes will be provided.

Examination and Formalities

Take an active part in the tutorials. You must pass the oral examination at the end of the course.

List of Literature

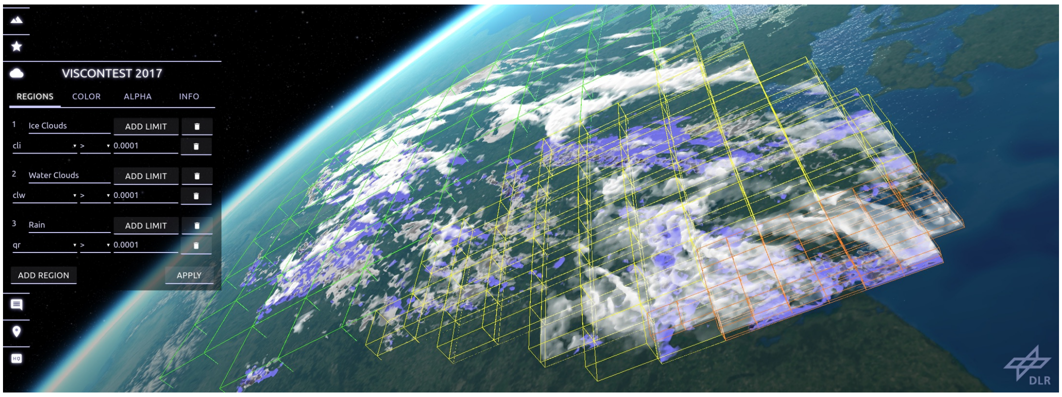
Lecture notes provided on StudIP during the lecture. Various books and online lecture notes with "ergodic theory" in the title.

High-Performance Visualization

Course Code: 03-M-SP-12

Prof. Dr. Andreas Gerndt

Contact: gerndt@uni-bremen.de



Description

In this lecture, the mathematical basics of scientific visualization are taught. It aims at methods for parallel post-processing of very large-scale scientific datasets. Such data occurs in plenty of scientific applications. It is created by simulations on high-performance supercomputers (e.g. to support climate research or analysis of flow fields at airfoils). It can also be the outcome of measurements as it occurs in Earth observation missions. To get any insight into the scientific results, first of all, a huge amount of raw data has to be processed to extract meaningful features. Those features can eventually be explored in interactive working environments. To enable real-time exploration at the end of the processing pipeline, again highly parallel and efficient methods are required. They have to be optimized for the execution on distributed computing clusters and high-end graphics cards. This lecture addresses foundational approaches of feature extraction, data processing, and efficient 3D visualization. Application examples are demonstrated with the Open Source software ParaView.

Prerequisites

Students from Mathematics, Computer Science, and other relevant application domains (like Geoscience or Aerodynamics) can participate at the lecture. Background knowledge in Computer Graphics or High-Performance Computing is useful but not required. Programming skills e.g. in Python are also useful.

Area of Specialization

- Data Analysis
- Industrial Mathematics
- Numerical Analysis

Structure

The weekly lecture is given in English. The slides are in English as well and can be used as references. In the lectures, several topics are presented: Computer Graphics Primer, HighPerformance Computing Primer, Visualization Pipeline, Data Representation and Reconstruction, Scalar Visualization, Color Mapping, Scalar Topology Extraction, Vector Field Processing, Particle Integration, Vector Field Topology, Tensor Field Visualization, Direct Volume Rendering, Parallel and Distributed Postprocessing, Multi-Resolution and Data Streaming, In-situ Co-processing, Terrain Rendering, Atmosphere Visualization, Flow Visualization, Vortex Extraction, Multivariate Data Queries.

Examination and Formalities

Application exercises and example datasets are provided to repeat the presented topics. Programming exercises can also be carried out as homework. The programming results should be submitted within two weeks after an exercise has been dispatched. They would then become part of the evaluation. The lecture eventually ends with an individual oral exam. An oral exam is also possible without programming exercises. The achievable amount of credit points would then be reduced. Consultation hours can be agreed on personal need.

List of Literature

- A. C. Telea, "Data Visualization – Principles and Practice", 2. Edition, CRC Press, 2015 - E. W. Bethel, H. Childs, C. Hansen, "High Performance Visualization", CRC Press, 2013 - W. Schroeder, K. Martin, B. Lorensen, "The Visualization Toolkit", 4. Edition, Kitware, 2006 - C. Hansen, C. Johnson, "The Visualization Handbook", Elsevier Academic Press, 2005

Inverse Problems

Course Code: 03-M-SP-1

Prof. Dr. Dirk Lorenz

Contact: d.lorenz@uni-bremen.de

Description

Inverse problems are problems where one would like to find an unknown cause for which one can only measure observed effects. This situation occurs, for example, if one can only make indirect measurements of the quantity of interest. Two simple examples:

- We measure the position of an object, but would like to know the speed.
- In tomography we measure several projections (X-ray images) of an object, but would like to know the absorption spectrum of said object.

Inverse problems usually suffer from ill-posedness: Solutions may not be unique, they may not exist (for example due to measurement noise), and, most drastically, their solution is unstable in the sense that it does not depend continuously on the data. We will analyze the phenomenon on ill-posedness for linear inverse problems (modeled as linear and continuous maps between Hilbert spaces) to understand the reason for instability. A central goal of the course is to establish the notion of regularization of ill-posed problems (which roughly means the approximate solution by stable methods) and to derive and analyze regularization methods such as Tikhonov regularization, or the Landweber method with early stopping. We will also treat the numerical solution of inverse problems in the lecture and the exercises.

Prerequisites

Analyis, Linear Algebra, Functional Analysis

Area of Specialization

- Data Analysis
- Industrial Mathematics
- Numerical Analysis

Structure

Lectures:
Thursday 12:00 - 14:00, MZH 2340
Friday 12:00 - 14:00, MZH 2340
Exercise classes:
Friday 14:00 - 16:00, MZH 2340
First Lecture: Friday, 11.04.2025

Examination and Formalities

Weekly homework assignments and oral exams

List of Literature

- Engl, H. W., Hanke, M., & Neubauer, A. (1996). Regularization of inverse problems (Vol. 375). Springer.
- Hanke, Martin, and Otmar Scherzer. "Inverse problems light: numerical differentiation." The American Mathematical Monthly 108.6 (2001): 512-521.
- Kirsch, A. (2011). An introduction to the mathematical theory of inverse problems (Vol. 120). New York: Springer.

Mathematics of Quantum Computing

Course Code: 03-M-SP-19

Dr. Matthias Knauer

Contact: knauer@uni-bremen.de

Description

The need to process ever larger amounts of data means that the development of ever smaller circuits and ever more compact physical memory is constantly being promoted. At the latest at the sub-atomic level, the effects of quantum mechanics must be taken into account in order to be able to describe calculation rules and data storage. This is what the young discipline of „quantum computing" deals with. In addition to discussing physical principles, we need mathematical foundations from many different areas: analysis, linear algebra, functional analysis, group and number theory, and stochastics.
The aim of this course is to create an understanding of which algorithms are suitable for implementation on quantum computers and which problems can be solved with them. To do this, we study the basic terms of quantum mechanics and introduce the concept of quantum bits (qubits) as the smallest unit to store data (instead of classical bits). Here we encounter the curious property of entanglement, and illustrate this with the Einstein-Podolski-Rosen paradox and Bell's inequality. We need quantum gates to represent arithmetic operations and can use them to build quantum circuits. Using various algorithms (e.g. Deutsch-Jozsa algorithm, Shor's algorithm) and tasks (detection of attacks on communication) we discuss the differences between classical computing and quantum computing. We close the lecture with contributions

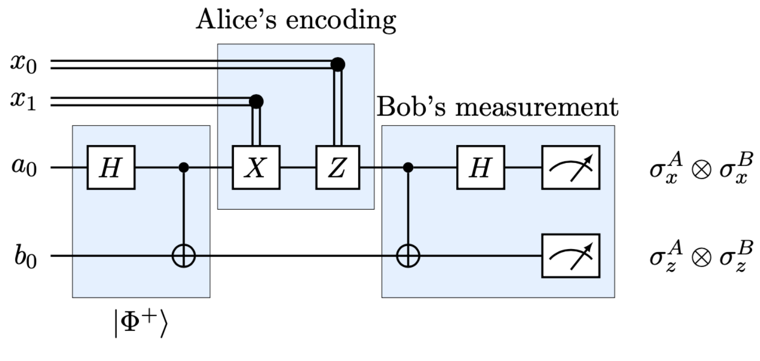


Figure 1: Alice sends two classical bits x_0 and x_1 to Bob using one qubit a_0.

on error correction (which plays an important role to actually build quantum computers) and on adiabatic quantum algorithms (which use quantum mechanical states directly and are no longer based on circuit concepts). In addition to the mathematical part, we will also build quantum circuits in the Python-based programming language Qiskit and simulate resp. execute them on the IBM Quantum Lab computers.

Prerequisites

Functional analysis

Area of Specialization

- Industrial Mathematics
- Numerical Analysis

Structure

The course consists of a 4-hour lecture and a 2-hour exercise and is held in English. The lecture notes with the current material will be provided to the students each week. The students' solutions of the weekly homework has to be submitted as PDF. The solutions to the tasks are discussed in the exercise sessions.

Examination and Formalities

- Requirement #1: 50% of the points of the exercise sheets
- Requirement #2: 2× successful presentation of own solution in exercise session
- Oral exam. Several selection dates by arrangement.

List of Literature

- Wolfgang Scherer: Mathematics of Quantum Computing. Springer, 2019.
- Matthias Homeister: Quantum Computing verstehen. Springer, 2018.
- Abraham Asfaw et al.: Learn Quantum Computation using Qiskit, 2020.

Advanced Communication Analysis

Course Code: 03-M-AC-22

Dr. Maxim Kirsebom

Contact: kirsebom@uni-bremen.de

Description

"AC: Analytic methods with applications in ergodic theory" is a seminar for Master's students which consists of a collections of stand-alone topics each covering a central method, concept or application in the analysis of ergodic theory.

Ergodic theory is considered a subfield of dynamical systems which is the theory of systems that change over time. More precisely, by a dynamical system we will mean a space X and a map T from X to itself. Iterations of the map T will represent discrete time instances of the system. Adding the concept of a (probability) measure to this setup brings us into the world of ergodic theory. Dynamical systems and ergodic theory is a modern mathematical field with a very lively research activity. It interacts with many other fields and makes extensive use methods and results from almost every other field. In this seminar we will focus on methods from analysis and their implementation in ergodic theory.

In dynamical systems, a very important concept is that of recurrence, i.e. loosely speaking the property that a systems returns (close) to a state in which it has already been. Going beyond recurrence one can ask more accurate questions about the rate and frequency with which recurrence takes place, also know as quantitative recurrence. In short, this seminar will focus on understanding methods from analysis as well as their implementation in ergodic theory to understand quantitative recurrence properties of certain classes of systems.

The list of possible topics will include more basic background theory that will enable everyone to have a solid foundation in the field as well as more advanced topics that might be based on advanced textbooks or even research papers.

A few examples of possible directions of topics.

- Operator theory, functional analysis and Fourier series: Ergodic theory enjoys a close relationship with these fields which often have the advantage of giving a "birds view" of a dynamical system. More concretely, these methods are for example used to prove mixing properties of dynamical systems, a property which is stronger than ergodicity.

- Fractal geometry: In many quantitative recurrence questions a certain set of interest turns out to have measure zero. However, there are techniques to distinguish the sizes of various zero measure sets which normally resides in the field of fractal geometry where the concept of non-integer dimensions are developed for this purpose.
- Number theory: Dynamical systems often have applications to number theory, for example to continued fraction expansions through the dynamics of the so-called Gauss-map. But also methods of analytic number theory are sometimes used to prove properties in dynamical systems such as the dynamics of circle rotations for which the so-called Diophantine properties of the rotation number plays an important role.
- Stochastics: An alternative way to understanding quantitative recurrence properties is through distributional results. This includes understanding and proving statistical limit theorems such as extreme value laws, hitting time statistics and the like for the given dynamical system.

This list is incomplete and could be extended to include hyperbolic geometry, differential geometry and much more. Suggestions are welcome!

The structure of the seminar offers you the opportunity to prepare your contribution during the summer if you want. The course can serve as a basis for master theses.

Please sign in into the Stud.IP group early on to facilitate organization. You can deregister at any time.

Prerequisites

Solid mathematical knowledge to the extent of a bachelor's degree in mathematics.

Area of Specialization

- Analysis

Structure

Weekly presentations of material by participants. Check in Stud.IP for date and time of first meeting.

Examination and Formalities

Presentation (ca. 70 min) of a subtopic and written report/exposition. Presentation and report are graded separately. You need to obtained passing grades in both parts. The course grade is the arithmetic mean of these two grades.

List of Literature

References will be provided via Stud.IP.

Game-Theoretic Statistics

Course Code: 03-M-AC-33

Prof. Dr. Thorsten Dickhaus

Contact: dickhaus@uni-bremen.de

Description

This is a seminar in the specialization area „Stochastics / Statistics“. The seminar deals with statistics based on game-theoretic probability. This approach towards statistical inference differs from what is usually taught in introductory statistics courses, and it has become quite popular over recent years.

The specific topics of the seminar are:

- Game-theoretic probability
- Game-theoretic statistical modelling
- (Super-) martingale theory
- Testing by betting
- Betting scores, e-values
- Classes of e-values
- Bayes factors and e-values
- Multiple testing with e-values
- Miscellaneous further topics

Prerequisites

No formal prerequisites, but solid knowledge in measure-theoretic probability theory is required to understand the material.

Area of Specialization

- Data Analysis
- Statistics/Stochastics

Structure

The seminar consists of one session (of 90 minutes length) per week.

Upon successful completion, 4.5 to six ECTS credit points will be awarded for this seminar. The exact number of credit points depends on the study program in which the candidates are enrolled.

Examination and Formalities

Students are expected to work themselves into a topic, to give a talk and to write a term paper on that topic, and to participate actively in the discussions of the other presentations.

List of Literature

A list of relevant literature will be provided electronically via Stud.IP.

Homological Algebra

Course Code: 03-M-AC-10

Prof. Dr. Dmitry Feichtner-Kozlov

Contact: dfk@math.uni-bremen.de

Description

Introduction to cohomology theory and homological algebra. The students will learn to read and understand higher level textbook material and present it in class.

Prerequisites

Algebraische Topologie

Area of Specialization

- Algebra
- Data Analysis
- Industrial Mathematics

Structure

Seminar, wöchentliche Treffen mit Studierendevorträge

Examination and Formalities

Vortrag und schriftliche Ausarbeitung

List of Literature

Elements of Algebraic Topology, James R. Munkres, Chapters 5-7

Large Scale Convex Optimization

Course Code: 03-M-AC-35

Prof. Dr. Dirk Lorenz

Contact: d.lorenz@uni-bremen.de

Description

This seminar will treat methods of convex optimization that are suitable for large problems with millions of variables (the size is basically restricted that the computer memory can hold a small finite number of vectors). The guiding principle of these methods is to exploit suitable additive *splitting* of the objective function and then use simple building blocks for the splitted parts to assemble an algorithm. Recently there has been much progress in this areas and in this seminar we will explore the following directions, for example:

- Stochastic optimization (stochastic gradient descent, stochastic proximal gradient method), [Chapter 7, 1]
- Accelerated methods (Accelerated gradient descent, accelerated proximal point methods), [Chapter 12, 1]
- Degenerate preconditioned proximal point methods [2]
- Kaczmarz (row-action) methods with mismatched adjoint [3]

Prerequisites

Convex Analysis

Area of Specialization

- Data Analysis
- Industrial Mathematics
- Numerical Analysis

Structure

The first meeting for the seminar will be on Tuesday, April 1, 10:00-12:00 in MZH 5450. Interested students enroll in Stud.IP and can contact me before if they have a specific interested for a topic.

Examination and Formalities

Presentation and written report.

List of Literature

1. Large Scale Convex Optimization. Ernest Ryu, Wotau Yin, Cambridge University Press, 2022, https://large-scale-book.mathopt.com/

2. Bredies, K., Chenchene, E., Lorenz, D. A., & Naldi, E. (2022). Degenerate preconditioned proximal point algorithms. SIAM Journal on Optimization, 32(3), 2376-2401.

3. Lorenz, D. A., Rose, S., & Schöpfer, F. (2018). The randomized Kaczmarz method with mismatched adjoint. BIT Numerical Mathematics, 58, 1079-1098.

Numerical Methods for Nonlinear Partial Differential Equation

Course Code: 03-M-AC-34

Prof. Dr. Andreas Rademacher

Contact: arademac@uni-bremen.de

Description

The possible topics in this seminar include finite differences and finite element methods for nonlinear PDEs. The Newton method and its analysis play an important role in this context. Other topics are free boundary value and non-smooth problems. Data-based techniques will also be discussed.

Prerequisites

You should have previous knowledge of numerical methods for solving PDEs, e.g. as acquired in the lecture Numerical Methods for PDEs

Area of Specialization

- Data Analysis
- Industrial Mathematics
- Numerical Analysis

Structure

At the beginning of the semester, lecture topics are assigned from various subject areas in the field of numerical solution of PDEs. The topics will be presented by the students in the course of the semester in talks of approx. 1 hour in length.

Examination and Formalities

All participants are required to give a presentation of approximately 60 minutes on a previously agreed topic. The presentation must also be accompanied by a paper.

List of Literature

The literature will be announced when the topics are assigned.

Modeling Project (Part 1)

Course Code: 03-M-MP-1

Dr. Matthias Knauer

Contact: knauer@uni-bremen.de

Description

The Modeling Project is a two-semester course designed to bridge the gap between academic mathematics and its practical applications in industry and research. Participants work in teams of two students to solve real-world problems, gaining experience in mathematical modeling, programming, and project management. In addition to technical skills, the course emphasizes professional communication, cultural awareness, and practical tools for collaborative work. The course begins with a **skills update phase** during the first month, where participants refine and expand their expertise in areas such as:

- Advanced data analysis techniques.
- Working with legacy codebases.
- Identifying and resolving algorithmic bottlenecks.
- Organizing project workflows and managing detailed coding tasks.
- Visualizing results.

This phase ensures all participants are prepared for the challenges ahead. Following this, **projects will be assigned to individual teams**, tailored to their interests and strengths. Each team will collaborate with a project partner, addressing tasks in industrial mathematics or applied research. We are currently contacting possible project partners, covering diverse industrial and research applications.

Learning Objectives

Throughout the course, students will:

- Enhance Technical and Mathematical Skills
  - Apply advanced mathematical concepts to solve practical problems.
  - Improve programming and data analysis capabilities in realistic settings.

  - Gain experience optimizing code performance and integrating existing systems.

- Develop Professional and Social Competencies
  - Understand the expectations of industrial and research partners.
  - Prepare for and lead productive meetings, including structured note-taking for later use.
  - Tailor presentations for diverse audiences, from technical experts to non-specialists.
  - Cultivate cultural sensitivity, especially for working in a German professional context.

- Master Practical Tools and Strategies
  - Use professional communication tools and avoid common pitfalls. (e.g., sending large email attachments).
  - Collaborate effectively with lecturers, peers, and external partners.
  - Organize and present project deliverables using industry-standard methods.

Prerequisites

This course is open to students enrolled in the **Master's programme in Industrial Mathematics and Data Analysis.**

- Basic understanding of programming (e.g. in MATLAB, Python, C++, or similar)
- Numerical analysis
- Depending on the individually assigned projects, mathematical skills are needed in e.g. optimization, AI, image processing, PDEs, ...

Structure

The course includes weekly meetings, consisting of presentations, status updates, and collaborative work sessions.

Examination and Formalities

Assessment, conducted in spring 2026 after Modeling Project (Part 2), will be based on:

- **Mathematical Presentation** (internal) and **User-Oriented Presentation** (public).
- **Comprehensive Written Report** ($\approx$ 30 pages).
- **Individual Project Deliverables** such as a poster, video, software demonstration, or interactive tool.

Reading Course Analysis

Analytic Methods with Applications in Ergodic Theory

Course Code: 03-M-RC-ANA

Dr. Maxim Kirsebom

Contact: kirsebom@uni-bremen.de

Description

This reading course will be concerned with the fundamental theory underpinning the analysis of ergodic theory, general analytic methods and tools from which ergodic theory borrows and the application of said tools and methods to problems in the ergodic theory of quantitative recurrence.
Ergodic theory is considered a subfield of dynamical systems which is the theory of systems that change over time. More precisely, by a dynamical system we will mean a space X and a map T from X to itself. Iterations of the map T will represent discrete time instances of the system. Adding the concept of a (probability) measure to this setup brings us into the world of ergodic theory. Dynamical systems and ergodic theory is a modern mathematical field with a very lively research activity. It interacts with many other fields and makes extensive use methods and results from almost every other field. In this reading course we will focus on methods from analysis and their implementation in ergodic theory.
In dynamical systems, a very important concept is that of recurrence, i.e. loosely speaking the property that a systems returns (close) to a state in which it has already been. Going beyond recurrence one can ask more accurate questions about the rate and frequency with which recurrence takes place, also know as quantitative recurrence. In short, this reading course will focus on understanding methods from analysis as well as their implementation in ergodic theory to understand quantitative recurrence properties of certain classes of systems.
The list of possible topics will include more basic background theory that will enable everyone to have a solid foundation in the field as well as more advanced topics that might be based on advanced textbooks or even research papers.
A few examples of possible directions of topics.
- Operator theory, functional analysis and Fourier series: Ergodic theory

enjoys a close relationship with these fields which often have the advantage of giving a “birds view” of a dynamical system. More concretely, these methods are for example used to prove mixing properties of dynamical systems, a property which is stronger than ergodicity.
- Fractal geometry: In many quantitative recurrence questions a certain set of interest turns out to have measure zero. However, there are techniques to distinguish the sizes of various zero measure sets which normally resides in the field of fractal geometry where the concept of non-integer dimensions are developed for this purpose.
- Number theory: Dynamical systems often have applications to number theory, for example to continued fraction expansions through the dynamics of the so-called Gauss-map. But also methods of analytic number theory are sometimes used to prove properties in dynamical systems such as the dynamics of circle rotations for which the so-called Diophantine properties of the rotation number plays an important role.
- Stochastics: An alternative way to understanding quantitative recurrence properties is through distributional results. This includes understanding and proving statistical limit theorems such as extreme value laws, hitting time statistics and the like for the given dynamical system.
This list is incomplete and could be extended to include hyperbolic geometry, differential geometry and much more. Suggestions are welcome!
The reading course can serve as a basis for master theses.
Please sign in into the Stud.IP group early on if you are interested in this reading course in order to contribute to the discussion on the topic. You can deregister at any time.

Prerequisites

Solid mathematical knowledge to the extent of a bachelor's degree in mathematics. Choice of material and level of discussion of background material will be adapted to the previous knowledge of the participants.

Area of Specialization

- Analysis

Structure

Weekly assignments of reading material, weekly meetings for discussions and presentations of material by participants. Check in Stud.IP for date and time of first meeting.

Examination and Formalities

Active participation (reading material, presentations and discussions), written exposition ("report") of selected material

List of Literature

References will be provided via Stud.IP.

Reading Course Numerical Analysis

Course Code: 03-M-RC-NUM

Prof. Dr. Christof Büskens

Contact: bueskens@uni-bremen.de

Description

Students study special topics of numerical mathematics in this reading course. The aim is a self-study of selected topics on the basis of textbooks, scientific articles or other monographs. The course may also include an introduction into other associated topics or to special software (e.g. Alberta, WORHP). In addition, aspects of scientific work will b e discussed, e .g. obtaining relevant literature, correct citation, or structure of a scientific a rticle. A ll t his is done under the supervision of a lecturer from the ZeTeM. In addition to the self-study, there will be regular meetings with the supervisor to discuss the topics in an informal or formal way and also written reports on a regular basis are mandatory. The topic will be discussed with the supervisor and, ideally, it is already into the direction of a future Master's thesis.

Prerequisites

Basic knowledge from a mathematical Bachelor's degree, in particular from the modules Algebra, Analysis 1 + 2, Linear Algebra, Numerical Mathematics 1, Numerical Mathematics 2, and also programming skills can be beneficial.

Area of Specialization

- Numerical Analysis

Structure

Will be communicated during the lecture. Language: English Appointment by arrangement in the NEOS building.

List of Literature

Will be announced in the lecture.