University of Bremen

– Faculty 3 –

Courses

Winter Semester 2025/26

M.Sc. Industrial Mathematics & Data Analysis

M.Sc. Mathematics

M.Sc. Mathematik

M.Sc. Technomathematik

July 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 winter 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
Room / Number: MZH Building / 1302
+49 (0) 421 218 63533
szmathe@uni-bremen.de

www.szmathe.uni-bremen.de

Contents

Lectures

Seminars

Reading Courses

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

Basics of Mathematical Statistics

Statistics I

Course Code: 03-M-SP-2

Prof. Dr. Thorsten Dickhaus

Contact: dickhaus@uni-bremen.de

Description

The specific topics of the course are:

- Decision making under uncertainty, statistical models
- Loss and risk, optimal decision rules
- Point estimation
- Confidence estimation
- Hypothesis tests
- Inferential likelihood theory
- Exponential families
- Bayesian statistics
- The statistics software `R`

The course „Statistics I“ is the entry point for a specialization in the area of (mathematical) statistics. Statistical methods are of utmost importance for all quantitative sciences, and they provide the basis for data science.

Prerequisites

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

Structure

The course consists of four hours of lecture plus two hours exercise class per week. Upon successful completion, 9 ECTS credit points will be awarded for this course.

Examination and Formalities

For the course achievements ("Studienleistungen"), solutions to exercise sheets have to be handed in on a weekly basis, and solutions have to be presented in the exercise class. For the examination achievements ("Prüfungsleistungen"), the final examination will be in written form.

List of Literature

We will mainly follow the exposition in the following textbook (ebook available within the intranet of the University of Bremen) : https://doi.org/10.1007/978-3-642-39909-1

Discrete Mathematics

Course Code: 03-M-SP-45

Dmitry Feichtner-Kozlov

Contact: dfk@math.uni-bremen.de

Description

Main Topics: - Enumerative Combinatorics - Counting techniques - Principle of Inclusion-Exclusion (PIE) - Stirling and other combinatorially defined numbers - The method of generating functions - Asymptotic estimates - Extremal Combinatorics - Sperner theory - Lubell–Yamamoto–Meshalkin inequalities - Turan theorem - Erdos-Ko-Rado theorem - Kruskal-Katona theorem - Discrete structures - Graphs and their structural theory - Posets, lattices, generalization of PIE - Matroids - (non CS part) Algebraic Enumeration - Polya's enumeration theory - Introduction to Algebraic Graph Theory - Further Applications of Linear Algebra

Prerequisites

Structure

4 + 2 (fuer Informatikstudierende nur bis 31.12)

Examination and Formalities

mündliche prüfung

List of Literature

Sample Literature: - Peter Cameron, "Combinatorics: Topics, Techniques, Algorithms" - J.H. van Lint, R.M. Wilson, "A course in Combinatorics" - Norman Biggs, "Discrete Mathematics"

Mathematical Methods for Data Analysis and Image Processing

VAK: 03-M-MDAIP-1

Dirk Lorenz

Contact: d.lorenz@uni-bremen.de

Course Description

This lecture covers several basic methods for standard tasks in data analysis and image processing. A non-exclusive and non-exhaustive list of methods: dimension reduction, clustering, filters, frequency analysis, morphological methods... We will develop the mathematical theory that underlies these methods since this is the basis for thorough understanding and proper execution of the methods. Moreover, we will deal with the practical implementation of the methods and apply them to solve problems such as image denoising, image deblurring, or music identification.
This lecture should enable you to take a deeper dive into image and data analysis and prepares you to follow recent developments in the field. If you want to understand, e.g., the inner working of image compression with JPEG, come to this lecture!

Course Prerequisites

Analysis 1-2 (including limits, integration, differentiation, all multivariate, preferably also Analysis 3, namely basics in measure theory), Linear Algebra 1-2 (including abstract vector spaces, norms and inner product spaces, matrix decompositions), Numerics 1 and the ability to implement mathematical methods in software (we will use Python) are needed. Some background in Functional Analysis would be helpful.
Part I of the book "Mathematics for Machine Learning" from below covers most of the prerequisitives of the course.

Examination and Formalities

??

List of Literature

- Mathematical Image Processing; Kristian Bredies and Dirk Lorenz, Birkhäuser, 2018, https://link.springer.com/book/10.1007/978-3-030-01458-2
- Mathematics for Machine Learning; Marc Peter Deisenroth, A. Aldo Faisal, and, Cheng Soon Ong, Cambridge University Press, 2020, https://mml-book.com.
- Foundations of Data Science; Avrim Blum, John Hopcroft, Ravindran Kannan, Cambride University Press, 2020, https://doi.org/10.1017/9781108755528 and https://home.ttic.edu/~avrim/book.pdf

Numerical Methods for Partial Differential Equations

Course Code: 03-M-NPDE-1

Prof. Dr. Andreas Rademacher

Contact: arademac@uni-bremen.de

Description

Partial differential equations are a main component in the modelling of physical, chemical or biological phenomena in several spatial dimensions or in space and time. They also often occur in mathematical problems in geometry or calculus of variations. The lecture deals with the discretisation of partial differential equations and the estimation of the error between continuous and discrete solution. In particular, the finite difference and the finite element method are introduced and investigated. We first discuss the application of the methods to stationary elliptic problems. Later also time-dependent problems are considered. The connection of theory, numerical analysis and implementation is particularly important.

Prerequisites

Knowledge of matrices (regularity, eigenvalues, positive definiteness) and of the numerical solution of linear systems of equations is assumed in the course. Furthermore, knowledge in the field of analysis (multidimensional differential and integral calculus, in particular Lebesgue integration, Taylor series, Gauss' theorem) is mandatory. Previous knowledge of Sobolev spaces and in the field of weak solution theory of partial differential equations is helpful. Basic knowledge of mathematical software is expected.

Structure

There are two lectures and one exercise per week. Every week an exercise sheet is published with theoretical and, if applicable, practical tasks.

Examination and Formalities

At the end of the course, depending on the number of participants, there will be an oral exam or a written exam as module examination. The course credits are awarded with the help of tests. These tests are written over the

course of the lecture period in line with the thematic progress of the lectur. The exact dates are set at the beginning of the lecture.

List of Literature

Braess, D.; Schumaker, L. L.: Finite elements - theory, fast solvers, and applications in elasticity theory, Cambridge University Press, Cambridge, third edition, 2010 Knabner, P.; Angermann, L.: Numerical Methods for Elliptic and Parabolic Partial Differential Equations, Springer, Cham, second edition, 2021 Johnson, C.: Numerical solution of partial differential equations by the finite element method, University Press, Cambridge, 1987

Online Optimization

Course Code: 03-M-SP-43

Prof. Dr. Daniel Schmand

Contact: schmand@uni-bremen.de

Description

Classical offline optimization problems consider problems where we are given input data and aim to find a feasible solution that minimizes or maximizes a certain objective function. For many application areas, this is too restrictive. For example, consider the problem of finding a route that minimizes the travel time from Bremen to another city. When starting the trip we have to decide on a mode of transport and the first parts of our route while information about congestion, and road or train track blockages becomes available over time. In online optimization, we address problems where input information is revealed step by step while some parts of the solution are already fixed. The main topics that we will cover are

- Paging
- k-server Problem
- Online Bipartite Matching
- Secretary Problems
- Various Prophet Inequalities
- Pandora's Box

Prerequisites

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

Structure

4 hours lectures + 2 hours exercise sessions per week

Examination and Formalities

oral exam (if not too many participants)

Simultaneous Statistical Inference

Course Code: 03-M-SP-46

Nabaneet Das

Contact: nabaneet@uni-bremen.de

Description

In scientific research, hypothesis testing is fundamental to drawing reliable conclusions. However, as data sets become larger and more complex, researchers often face the challenge of testing multiple hypotheses at once. Fields like astronomy and genomics, for example, often involve testing thousands, or even millions, of hypotheses simultaneously. These hypotheses may involve various parameters from high-dimensional data with complex and unknown relationships between variables. Traditional statistical methods, however, struggle to address the issues that arise from testing so many hypotheses at once. This lecture will explore the challenges of simultaneous statistical inference and review current research on the topic. We will also discuss the less-explored issue of dependence between observations, which adds an additional layer of complexity to statistical analysis.

Prerequisites

No formal prerequisites, but a solid understanding of statistics and probability theory is required to understand the material.

Structure

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

Examination and Formalities

Will be communicated later

List of Literature

Will be announced in the lectures

Algorithmic Game Theory

Course Code: 03-M-AC-35

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 seminar covers various 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 seminar 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

No formal prerequisites. We highly recommend knowledge in Algorithmic Game Theory, e.g., from the lecture in summer 2025.

Structure

Block course in February or March.

Examination and Formalities

Students are allocated a paper and we expect them to understand the topic, give a talk and write an extended abstract on the chosen topic. Additionally, we assume active participation in the discussions of the other presentations.

Eventually Positive Semigroups

Course Code: 03-M-AC-38

Hendrik Vogt

Contact: hendrik.vogt@uni-bremen.de

Description

The seminar is based on the so-called "29th Internet Seminar 2025/26", see https://www.fan.uni-wuppertal.de/de/lehre/29th-internet-seminar/ On that website, new material will be provided each week, starting mid October. This material shall be presented by the participants. It is also possible to prepare your presentation during the summer: I will be able to make some of the material available on Stud.IP in advance, presumably in mid July. The seminar is devoted to the study of eventually positive resolvents and semigroups, first in finite dimensional spaces and then in Banach spaces - or to be more precise in Banach lattices, which is a convenient setting for the study of (eventual) positivity. A continuation in the summer semester is possible: there will be a project phase where you can work in small international groups of 3-4 students and a workshop in Wuppertal (June 8 to June 12, 2026), where participants meet together with leading experts in the field.

Prerequisites

Solid knowledge of Analysis and Linear Algebra on the level of a bachelor's degree in mathematics is strongly recommended. Moreover, basic knowledge of Functional Analysis (Banach spaces, dual spaces, bounded linear operators) is highly recommended, but there will be a few topics that do not require any knowledge of Functional Analysis.

Structure

The seminar takes place weekly, with presentations of the material by the participants. Apart from registering on Stud.IP, please also register via the homepage of the 29th Internet Seminar to get access to the seminar material.

Examination and Formalities

The exam consists of a presentation (with subsequent discussion) along with a written report on the presented topic. Students are expected to actively

participate in the discussion of the presentations.

List of Literature

Will be published on the website https://www.fan.uni-wuppertal.de/de/lehre/29th-internet-seminar/

Introduction to Robust Control

Course Code: 03-M-AC-31

Dr. Chathura Wanigasekara

Contact: chathura@uni-bremen.de

Description

In this course Robust control is introduced. Robust control is an approach to design controllers to deal with uncertainty. The aim is to achieve robust performance (or stability) in the presence of bounded modelling errors.

Prerequisites

Basic knowledge of control systems; Basic knowledge of optimisation.

Structure

Seminar (Once a week, 2 hours)

Examination and Formalities

Type of Course: Seminar Form of Examinations: Assignment (Continuous Assessment) and Oral Examination (Final Exam)

List of Literature

1. B. Francis, A course in H∞ control theory, Springer-Verlag, 1987. 2. J. Doyle, B. Francis, A. Tannenbaum, Feedback Control Theory, Macmillan Publishing Company, 1990. 3. S. Skogestad, I. Postlethwaite, Multivariable Feedback Control, Analysis and Design, John Wiley & Sons, 1996. 4. K. Zhou, J.C. Doyle, K. Glover, Robust and Optimal Control, Prentice-Hall, 1996. 6. G.E. Dullerud, F. Paganini, A Course in Robust Control, Springer-Verlag, 1999. 7. S. P. Bhattacharya, H. Chapellat, L. H. Keel. Robust Control-The Parametric Approach, Prentice Hall, 2000.

High-Performance Visualization

Ausgewählte Publikationen aus dem Bereich der Visualisierung großer wissenschaftlicher Datensätze

VAK: 03-M-AC-2

Prof. Dr. Andreas Gerndt

Kontakt: gerndt@uni-bremen.de

Veranstaltungsbeschreibung

In der Einführungsveranstaltung werden ausgewählte Publikationen aus dem Bereich der wissenschaftlichen Visualiserung vorgestellt. Die Studierenden können sich dann für eine der Arbeiten entscheiden. Bis Weihnachten soll die zugrunde liegende Basisliteratur recherchiert werden. Im weiteren Verlauf des Semesters soll sodann das Thema aufbereitet und eine Seminararbeit im Umfang von circa 20 Seiten ausgearbeitet werden. Zum Ende des Semesters werden die Ausarbeitungen in Form von Vorträgen präsentiert. Abhängig von der Anzahl der Teilnehmenden erfolgen die Vorträge in Einzel- oder Blockveranstaltungen. Es wird dabei erwartet, dass die Studierenden die ausgearbeiteten Themen in Rahmen von 45-minütigen Vorträgen vorstellen. Vortrag und Ausarbeitung sollten bevorzugt in Englisch erfolgen. Ausarbeitung und Vortrag werden für eine Leistungsbewertung herangezogen. Für Fragen und Unterstützung stehen über den Verlauf des Semesters Ansprechpartner für die jeweiligen Themenbereiche zur Verfügung. Der Austausch findet im Wesentlichen online statt.

Voraussetzungen

Das Seminar steht Studierenden aus den Fachbereichen Mathemathik, Informatik oder aus einem relevanten Anwendungsfach (wie Geowissenschaften oder Aerodynamik) offen. Hilfreich wäre die vorherige Teilnahme an der Vorlesung "High-Performance Visualization". Dies stellt aber keine Voraussetzung dar. Kenntnisse in Computer Graphics oder High-Performance Computing (HPC) könnten ebenfalls hilfreich sein.

Ablauf und Format

In der Einführungsveranstaltung werden ausgewählte Publikationen aus dem Bereich der wissenschaftlichen Visualiserung vorgestellt. Die Studierenden

können sich dann für eine der Arbeiten entscheiden. Bis Weihnachten soll die zugrunde liegende Basisliteratur recherchiert werden. Im weiteren Verlauf des Semesters soll sodann das Thema aufbereitet und eine Seminararbeit im Umfang von circa 20 Seiten ausgearbeitet werden. Zum Ende des Semesters werden die Ausarbeitungen in Form von Vorträgen präsentiert. Abhängig von der Anzahl der Teilnehmenden erfolgen die Vorträge in Einzel- oder Blockveranstaltungen. Es wird dabei erwartet, dass die Studierenden die ausgearbeiteten Themen in Rahmen von 45-minütigen Vorträgen vorstellen. Vortrag und Ausarbeitung sollten bevorzugt in Englisch erfolgen.

Leistung und Prüfungsform

Ausarbeitung und Vortrag werden für eine Leistungsbewertung herangezogen. Für Fragen und Unterstützung stehen über den Verlauf des Semesters Ansprechpartner für die jeweiligen Themenbereiche zur Verfügung. Der Austausch findet im Wesentlichen online statt.

Literatur

- Ausgewählte Konferenz-Veröffentlichungen und Journal-Artikel aus den verschiedenen Bereichen der High-Performance-Visualisierung; diese werden in der Einführungsveranstaltung präsentiert. - 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

Seminar on Numerics of PDEs

Course Code: 03-M-AC-36

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

Successful completion of the lecutre "Numerics of PDEs" is a prerequisite.

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.

Stochastic-statistical dependencies

Course Code: 03-M-AC-37

Prof. Dr. Thorsten Dickhaus

Contact: dickhaus@uni-bremen.de

Description

Some specific topics of the seminar are:

- Correlation coefficients
- Empirical likelihood ratio tests for the population correlation coefficient
- The Rearrangement Algorithm
- Covariances of order statistics
- Equi-correlation matrices
- Skew-normal distributions
- The weighted bootstrap

Prerequisites

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

Structure

The seminar consists of one session (of 90 minutes length) per week. During the first two sessions, the schedule for the students' presentations will be made.

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. These three criteria determine the grading.

List of Literature

We will mainly follow the exposition in the following textbook (ebook available within the intranet of the University of Bremen): https://doi.org/10.1007/978-3-030-96932-5

Topology

VAK: 03-M-AC-32

Prof. Dr. Eva-Maria Feichtner

Kontakt: emf@math.uni-bremen.de

Veranstaltungsbeschreibung

This seminar is mainly aimed at Bachelor students who followed my lecture on Topology in spring 2025. However, we can find suitable topics for Master level, please do contact me ahead of time if you are interested.

Voraussetzungen

Solid background in point set and basic algebraic topology (fundamental group, covering spaces).

Ablauf und Format

Seminar format

Leistung und Prüfungsform

Seminar talk and write-up

Literatur

Will be provided during the first session in the beginning of the term.

Reading Course Analysis

Course Code: 03-M-RC-ANA

Hendrik Vogt

Contact: hendrik.vogt@uni-bremen.de

Description

The aim of the course is self-study of an advanced selected topic in the area of analysis. On the one hand, the participants are expected to work independently, with the advice of a supervisor. On the other hand, they shall give small talks on the topic and engage in discussion with the other participants. The Reading Course can serve as a basis for a Master's thesis. Please sign in on Stud.IP for the Reading Course in order to obtain up-to-date information on the course.

Prerequisites

Solid knowledge of Analysis and Linear Algebra on the level of a bachelor's degree in mathematics is strongly recommended. Moreover, basic knowledge of Functional Analysis (Banach spaces, dual spaces, bounded linear operators) is highly recommended.

Structure

There will be weekly assignments of reading material as well as weekly meetings for discussions and for presentations of the material by the participants. The date and time for the first meeting will be announced via Stud.IP.

Examination and Formalities

Successful participation will be certified upon active participation in weekly meetings (including small presentations) and a written exposition of selected material.

List of Literature

Will be provided via Stud.IP.