OTH REGENSBURG

Module handbook

Mathematics for Business and Industry (M.Sc.)

Master programme

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Faculty of Computer Science and Mathematics

Preliminary Remarks

The introduction to this module handbook follows the annex to the study and examination regulations for the Master's degree program **Mathematics for Business and Industry (MBI)** at **OTH Regensburg**, in the version dated **09.07.2024**.

This module handbook outlines the learning objectives of the individual modules based on the competencies to be acquired. These are categorized into **professional competence** (knowledge, skills) and **personal competence** (social competence, independence).

Each competence is assigned a level, indicated by one of the numbers **"1" to "3"** in brackets. The three levels are:

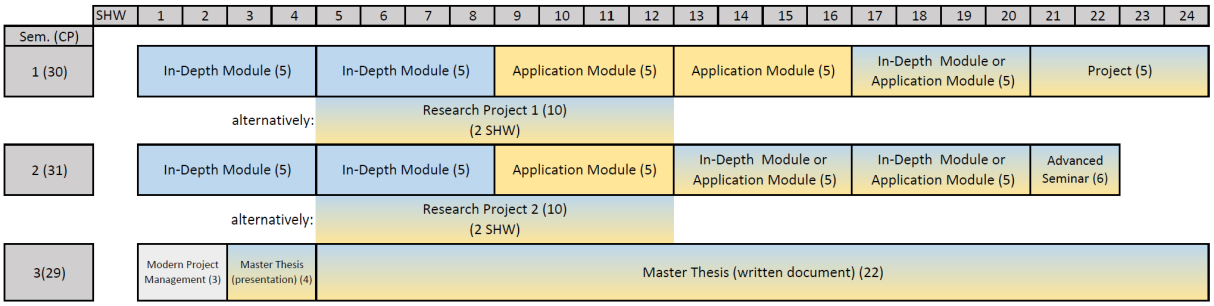
- **Level 1:** Knowledge
- **Level 2:** Skills
- **Level 3:** Understanding and applying

In addition to subject-specific skills, the development of personal skills is an integral part of every course and university studies in general. If personal skills are not explicitly stated for a module, students—after successfully completing the module—are able to:

- Analyze their own learning progress and learning needs **(3)** and, if necessary, derive courses of action from this **(3)**.
- Work together with others in a goal-oriented manner **(2)**, understand their interests and social situations **(2)**, deal with them rationally and responsibly, communicate effectively **(2)**, and help shape their working and living environment **(3)**.
- Work scientifically in accordance with the *guidelines of good scientific practice* **(2)**, present subject-specific content **(2)**, and explain it to an audience using correct technical language **(2)**.

Study Plan

Semester Overview



Legend:

	mathematics
	applications
CP	credit point
SHW	semester hour per week

Modules Overview

- **Compulsory Modules**
  - *Advanced Seminar* (6 CP)
  - *Modern Project Management* (3 CP)
  - *Project* (5 CP)
- **Elective compulsory modules**
  - *In-depth Modules* (5 CP): Provide a strong mathematical foundation across various fields of mathematics.
  - *Application Modules* (5 CP): Combine theory and practice, allowing students to deepen their knowledge in high-demand areas that drive innovation in industry.
  - *Research Project* (10 CP): Students may complete one or two research projects, each worth 10 CP.
- **Master Thesis**
  - *Written Document* (22 CP)
  - *Presentation* (4 CP)

Remarks

A **research project** counts as **one in-depth module** and **one application module**.

For each semester, the **faculty board** decides on the course offerings based on academic and industry relevance.

In case of doubt, the valid legal norms published by **OTH Regensburg** always apply.

Module list

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Specialisation: 3. Module catalogue - Application and In-depth. Choices here can be made from modules within both the Application and In-depth module catalogue

Module title	Module code
Advanced Seminar	1

Person responsible for the module	Faculty
Faculty IM Dean	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1	1	mandatory	6

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Advanced Seminar	2 SWS	6

Submodule	Submodule abbreviation
Advanced Seminar	

Responsible person	Faculty
Faculty IM Dean	Informatik und Mathematik
Lecturer	Availablilty of module
Faculty IM Dean	
Teaching method	
Seminar	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1	2 SWS	english	6

Study hours required

Hours in attendance/lectures	Hours for self-study

Method of assessment
Presentation: 45 minutes

Literature
More information about the course
The language of instruction and examination is English. Exceptions to this, i.e., German instead of English, are regulated by the study plan.

Module title	Module code
Master's Thesis	7

Person responsible for the module	Faculty
Chair of the examination board	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
3	1	mandatory	26

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Oral presentation	2 SWS	4
2.	Written document		22

Notes on the assignment requirement or options
The individual modules of the master's thesis can be conducted in either English or German.

Submodule	Submodule abbreviation
Oral presentation	

Responsible person	Faculty
Chair of the examination board	Computer Science and Mathematics
Lecturer	Availablilty of module
All IM Professors	
Teaching method	
Seminar	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
3	2 SWS	german/english	4

Study hours required

Hours in attendance/lectures	Hours for self-study

Method of assessment
Presentation: 30 minutes

Literature
More information about the course
Admission Requirements: Written report submitted on time in accordance with section 7.1.

Submodule	Submodule abbreviation
Written document	

Responsible person	Faculty
Chair of the examination board	Computer Science and Mathematics
Lecturer	Availablilty of module
All IM Professors	
Teaching method	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
3		german/english	22

Study hours required

Hours in attendance/lectures	Hours for self-study

Method of assessment
Master's Thesis

Literature

Module title	Module code
Modern Project Management	2

Person responsible for the module	Faculty
Prof. Dr. Markus Westner	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1	1/2	mandatory	3

Recommended previous knowledge
n/a

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Modern Project Management	2 SWS	3

Submodule	Submodule abbreviation
Modern Project Management	**MPM**

Responsible person	Faculty
Prof. Dr. Markus Westner	Informatik und Mathematik
Lecturer	**Availablilty of module**
Werner Schiekofer	**every year

Teaching method
Seminar-based lecture

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1	2 SWS	english	3

Study hours required

Hours in attendance/lectures	Hours for self-study
30 h	30 h

Method of assessment
Project report with presentation

Content

- Basic Concepts: Projects, processes, dependencies, phases, milestones, resources, budgets, project organization.
- Project Charter: Definitions, creation, and goal-setting.
- Project Planning: Work breakdown structures, scheduling, methods for project planning, and critical path calculation.
- Project Execution: Monitoring and control of projects.
- Human Resource Management: Team dynamics, roles, conflict management, and time management.
- Methodologies: Phase models, waterfall model vs. agile methods (e.g., Scrum).

Learning objectives: Subject competence

After successful completion of the submodule, students are able to,

- explain basic concepts, methods, frameworks, and standards in project management, including their interrelations.
- identify opportunities and risks within project organization.
- manage projects through planning, coordination, teamwork, control, and quality assurance.
- critically evaluate and apply relevant project management methods and techniques (e.g., effort estimation) through case studies.

Learning objectives: Personal competence

After successful completion of the submodule, students are able to,

- organize, structure, and communicate effectively in a team (2).

- formulate goals collaboratively and apply appropriate methods (3).
- delegate responsibilities within a team effectively (2).
- apply decision-making and problem-solving techniques (2).
- analyze differing stakeholder perspectives critically (3).
- engage constructively with diverse viewpoints and criticisms (3).
- accept and act upon feedback on their performance (3).
- provide constructive feedback to others in a team setting (2).
- plan and control their time and financial resources (2).
- manage and take responsibility for deliverables toward project stakeholders (2).
- motivate themselves and others effectively (3).
- recognize, de-escalate, and resolve conflicts early (3).

Teaching media

- Chalkboard, projector, and slides
- Case studies and group exercises

Literature

- Custom lecture script.
- Gessler, M. (Ed.): Competence-based Project Management (PM3), Nuremberg.
- Hindel, J., Hörmann, F., Müller, R., Schmied, J.: Basics of Project Management, dpunkt.
- Litke, H.-D.: Project Management, Hanser.
- Litke, H.-D., Kunow, I., Schulz-Wimmer, H.: Project Management – Best of, Haufe.
- Mellis, W., Werner, J.: Project Management in Software Development, Vieweg.
- Ottmann, R., Pfeiffer, A., Schelle, H.: Project Manager, Nuremberg.
- Wolf, H., Bleek, W.-G.: Agile Software Development: Values, Concepts, and Methods, dpunkt.
- PMI: A Guide to the Project Management Body of Knowledge (PMBOK® Guide).
- Kerzner, H.: Project Management: A Systems Approach to Planning, Scheduling, and Controlling.

More information about the course

The language of instruction and examination is English. Exceptions to this, i.e., German instead of English, are regulated by the study plan.

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Project	3

Person responsible for the module	Faculty
Prof. Dr. Jürgen Frikel	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1	1/2	mandatory	5

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Project	4 SWS	5

Notes on the assignment requirement or options
The language of instruction and examination is English. Exceptions to this, i.e., German instead of English, are regulated by the study plan.

Submodule	Submodule abbreviation
Project	

Responsible person	Faculty
Prof. Dr. Jürgen Frikel	Informatik und Mathematik
Lecturer	**Availablilty of module**
All IM Professors	
Teaching method	
Project	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
0 h	150 h

Method of assessment
Project report with presentation

Content
In this submodule, students will work on specific problems provided and supervised by faculty members, with a focus on independent, problem-oriented work. Projects may be completed individually or, preferably, in teams. Students are responsible for researching and developing appropriate methodologies to solve their assigned problems, drawing on academic publications, existing software, data sets, and other resources. The selected methodologies and results will be documented in a written report and presented through an oral presentation.
Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • analyze complex mathematical problems and identify appropriate methods for their solution (2) • independently research, select, and apply relevant mathematical theories, computational tools, and other recourses to address the specific challenges posed by their project (3) • apply mathematical concepts to real-world and/or theoretical problems, bridging the gap between abstract theory and practical applications (3) • present their ideas and results effectively through oral presentations, with a focus on clear, concise, and structured communication of complex concepts (2) These objectives align with the professional competencies needed in both academic and industry-focused mathematical careers.

Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • to work independently, managing time and resources efficiently to meet project deadlines and objectives (3), • collaborate effectively by distributing tasks, communicating clearly, and solve problems collectively (3), • articulate complex methodologies and present their work, both in writing and orally (2).
Literature
The literature is project-specific and will be independently researched by the students and/or provided by the topic supervisor.

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Intergral Transforms and Applications	5a

Person responsible for the module	Faculty
Prof. Dr. Jürgen Frikel	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2			5

Recommended previous knowledge
Linear Algebra 1 and 2, Analysis 1, 2 and 3

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Integral Transforms and Applications	4 SWS	5

Submodule	Submodule abbreviation
Integral Transforms and Applications	**ITA**

Responsible person	Faculty
Prof. Dr. Jürgen Frikel	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Jürgen Frikel	
Teaching method	
Seminar-based lecture	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Oral examination: 30 minutes

Content
This course provides a comprehensive study of fundamental integral transforms such asconvolution, Fourier transform, and Fourier series, focusing on their exact mathematicaltreatment and practical applications. The course revisits essential concepts from functionalanalysis and integration theory to build a robust foundation for understanding these transforms. Topics • Review of Functional Analysis and Integration Theory: Brief recap of core principles infunctional analysis and central theorems of integration theory. • Convolution on -Spaces: Definition and mathematical properties of convolutions on -spaces; Function approximation using convolutions, with a focus on Dirac sequences;Importance of convolution in practical applications such as signal and image processing,deconvolution, and convolutional neural networks. • Fourier Transform: Fourier transform on ; Extension of the Fourier transform to ;Applications in signal and image processing, including filtering and deconvolution;Application to partial differential equations, with a detailed discussion on the heat equation. • Fourier Series: Real and complex forms of Fourier series; pointwise and uniformconvergence of Fourier series; Fourier series in Hilbert spaces; Practical applications ofFourier series. • Discrete Fourier Transform: Fundamental concepts and applications. • Optional Topics: Time-frequency analysis, such as Short-Time Fourier Transform(windowed Fourier transforms) and/or wavelets, and their applications.

Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • explain the concept integral transforms, and provide concrete examples along with theirapplication areas (1) • provide precise mathematical definitions of the integral transforms covered (1) • explain the fundamental mathematical properties of the integral transforms covered (2) • understand the relationship between these transforms and the mathematical proofs of thecentral theorems (3) • apply integral transforms coverd to practical problems, such as solving partial differentialequations and in signal and image processing (3) • explore and understand advanced topics related to integral transforms independently (3)
Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • recognize the importance of mathematical analysis in problem-solving (1), • critically engage with mathematical concepts (2), develop solutions using thesetechniques (2), and apply them effectively in applications (3) • communicate mathematical ideas effectively in both written and oral forms (3)
Teaching media
Projector, blackboard, computer lab
Literature
Along with the provided lecture slides and the basic literature on integration theory andfunctional analysis, the following references are recommended for further reading: • Stein, Elias M. und Rami Shakarchi (2003). Fourier analysis. Bd. 1. Princeton Lectures inAnalysis. An introduction. Princeton University Press, Princeton, NJ. • Folland, Gerald B. (1992). Fourier analysis and its applications. The Wadsworth & Brooks/Cole Mathematics Series. Wadsworth & Brooks/Cole Advanced Books & Software, PacificGrove, CA, S. x+433. • Christensen, Ole und Khadija L. Christensen (2005). Approximation theory. Applied andNumerical Harmonic Analysis. From Taylor polynomials to wavelets, Corrected secondprinting of the 2004 original. Birkhäuser Boston. • Stephane Mallat (2008). A Wavelet Tour of Signal Processing, Third Edition: The SparseWay (3rd. ed.). Academic Press, Inc., USA.

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Algebra	5a

Person responsible for the module	Faculty
Prof. Dr. Georg Illies Prof. Dr. Oliver Stein	Computer Science and Mathematics Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Linear Algebra 1 and 2, Analysis 1 and 2, Elementary Number Theory, Probability Theory and Statistics 1

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Algebra	4 SWS	5

Submodule	Submodule abbreviation
Algebra	**ALG**

Responsible person	Faculty
Prof. Dr. Georg Illies	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Georg Illies Prof. Dr. Oliver Stein	

Teaching method
Seminar-based lecture

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Written examination: 90 minutes

Content
Group Theory: • Definition and properties of groups and their homomorphisms. • Basic constructions of groups and examples. • Operations of groups on sets. • Applications of group theory to symmetry. Ring Theory: • Definition and properties of rings and their homomorphisms. • Integral domains and principal ideal domains. • Univariate and multivariate polynomial rings. • Applications of polynomial rings in coding theory. Field Theory: • Definition and properties of fields and field extensions. • Splitting fields. • Finite Fields. • Applications of Finite Fields in cryptography. • Outlook on Galois theory.

Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • understand the basic concepts of modern algebra. • be able to solve basic algebraic problems. • gain insight into some applications of algebraic concepts. • develop the ability to reduce concrete problems in application fields to algebraic structures and solution methods. • explore advanced topics like Galois theory, if covered.
Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • grasp and thoroughly understand mathematical abstractions, (1) • make such abstractions to analyze problems themselves (3) • and to communicate in such abstract terms (3).
Teaching media
Blackboard, Projector, Script, Exercises and Solutions
Literature
• Dummit, Foote, „Abstract Algebra“, Third Ed., Wiley, 2003 • Gallian, “Contemporary Abstract Algebra“, 10th Ed., CRC Press, 2020 • Karpfinger, Meyberg, “Algebra”, 5. Aufl., Springer, 2021 • Lang, „Algebra“, Rev. Third Ed., Springer, 2002 • Lee, „Abstract Algebra“, Springer, 2018

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Applied Algebraic Geometry	5a

Person responsible for the module	Faculty
Prof. Dr. Jonny Dambrowski	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
n/a

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Applied Algebraic Geometry	4 SWS	5

Submodule	Submodule abbreviation
Applied Algebraic Geometry	**AAG**

Responsible person	Faculty
Prof. Dr. Jonny Dambrowski	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Jonny Dambrowski	

Teaching method
Seminar-based lecture

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	german	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Written examination: 90 minutes

Content

Commutative algebra:
- Ring and Field theory, polynomials, power series, ideals,
- Gröbner bases, Buchberger algorithm, applications

Elimination theory, resultants
Affine spaces and varieties, properties,
- Coordinate ring, polynomial and rational maps,
- Dimension, applications (e.g. geometric proof automata,
- Construction of a general solution of 1st order ordinary differential equations, robotics)

Projective spaces and varieties, properties,

- Intersection theory of projective closure of affine varieties,
- Grassmannian, application (e.g. machine vision)

Learning objectives: Subject competence

After successful completion of the submodule, students are able to,
- deepen their knowledge of algebra, in particular commutative algebra (2),
- solve geometric problems using algebraic methods (2),
- analyze affine and projective varieties, especially in dimension 1 and analyze their properties (3) and also to visualize them (2),
- calculate in polynomial rings and ideals (2),
- calculate in homogeneous and Pluecker coordinates (2),

- understand algorithms for the determination of generating systems in ideals, intersection multiplicities of algebraic curves and their genus (3)

Learning objectives: Personal competence
After successful completion of the submodule, students are able to, Reference to preliminary remarks of this module handbook
Literature

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Coding Theory	5a

Person responsible for the module	Faculty
Prof. Dr. Georg Illies	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Linear Algebra 1 and 2, Analysis 1 and 2, Elementary Number Theory, Probability Theory and Statistics 1 and 2

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Coding Theory	4 SWS	5

Submodule	Submodule abbreviation
Coding Theory	**COD**

Responsible person	Faculty
Prof. Dr. Georg Illies	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Georg Illies	

Teaching method
Seminar-based lecture

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	german	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Written examination: 90 minutes

Content

- Information theory (Huffman coding, entropy, Shannon's theorem)
- Check digit schemes based on groups
- Hamming distance, error detection and correction
- Linear codes (e.g., Golay codes, Reed-Muller codes)
- Construction principles for codes (e.g., Plotkin construction)
- Bounds for codes (e.g., Hamming, singleton, Plotkin)
- Cyclic codes (e.g., BCH codes, Reed-Solomon codes)
- Outlook on geometric codes

Learning objectives: Subject competence

After successful completion of the submodule, students are able to,

- present the aims and principles of coding theory and its application (1),
- present common coding schemes and their properties (1),
- apply common coding schemes (2),
- implement coding schemes (2)

Learning objectives: Personal competence

After successful completion of the submodule, students are able to,

- communicate professionally (2),
- work on problems analytically and persistently (2).

Teaching media
Blackboard, Projector, Script, Exercises and Solutions
Literature
• Berlekamp, “Algebraic Coding Theory”, Rev. Ed., World Scientific, 2015 • van Lint, “Introduction to Coding Theory”, 3rd Ed., Springer, 1999 • Ling, Xing, “Coding Theory: A first Course”, Cambridge, 2016 • Jones, Jones, “Information and Coding Theory”, Springer, 2008 • Roman, “Coding and Information Theory”, Springer, 1992 • Willems, “Codierungstheorie”, de Gruyter, 1999

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Functional Analysis	5a

Person responsible for the module	Faculty
Prof. Dr. Wolfgang Lauf Prof. Dr. Oliver Stein	Computer Science and Mathematics Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Linear Algebra 1 and 2, Analysis 1 and 2, Approximation theory

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Functional Analysis	4 SWS	5

Submodule	Submodule abbreviation
Functional Analysis	**FAN**

Responsible person	Faculty
Prof. Dr. Oliver Stein Prof. Dr. Wolfgang Lauf	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Wolfgang Lauf Prof. Dr. Oliver Stein	

Teaching method
Seminar-based lecture

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Written examination: 90 minutes

Content
Functional analysis unifies the theory of linear algebra and analysis and generalizes it to infinite dimensional vector spaces. Thereby, it provides the necessary theoretical framework to solve advanced problems, which occur in many fields of applied mathematics. The lecture covers the basic topics in functional analysis with a focus on applications. • Metric spaces: fundamental concepts and examples, complete spaces, Banach fixed-point theorem • Normed spaces: basic concepts and important examples (e.g. Lebesgue spaces), Banach spaces, equivalence of norms • Hilbert spaces: fundamental concepts and examples, best approximation, orthonormal bases and orthonormal expansions • Linear operators on normed spaces: bounded operators, important examples of bounded operators, inverse operators and the Neumann series, the Riesz representation theorem
Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • name and explain the most important Banach- and Hilbert spaces (1) • discuss the structure of metric spaces, normed spaces and inner product spaces and to describe the concepts behind Banach- and Hilbert spaces (1) • analyze linear operators on Banach- and Hilbert spaces (2) • transfer equations from analysis to operator equations and to apply methods of functional analysis to solve them (3)

Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • recognize the importance of mathematical analysis in problem-solving (1) • critically engage with mathematical concepts (2), develop solutions using these techniques (2) and apply them effectively in applications (3) • communicate mathematical ideas effectively in both written and oral forms (3)
Teaching media
Board, projector and computer algebra systems
Literature
• Alt, W.: Lineare Funktionalanalysis, Springer-Verlag, (2012) • Axler, S.: Measure, Integration & Real Analysis, Springer-Verlag, (2020) • Burg, K. et. al., Partielle Differentialgleichungen und funktionalanalytische Grundlagen, Springer-Verlag, (2010). • Muscat, J.: Functional Analysis, Springer-Verlag, (2014) • Kreyszig, E.: Introductory Functional Analysis with Applications, John Wiley, (1978) • Saxe, K.: Beginning Functional Analysis, Springer-Verlag, (2002) • Heuser, H.: Funktionalanalysis, Teubner Verlag, (1992). • Rynnne, B., Youngson, M.: Linear Functional Analysis, (2008)

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Generative Adversarial Networks	4a

Person responsible for the module	Faculty
Prof. Dr. Stefanie Vogl	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1-2	1		5

Recommended previous knowledge
Basic Knowledge in Python, Statistical Learning, Neural Networks

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Generative Adversarial Networks	4 SWS	5

Submodule	**Submodule abbreviation**
Generative Adversarial Networks	**GAN**

Responsible person	Faculty
Prof. Dr. Stefanie Vogl	Computer Science and Mathematics
Lecturer	Availablilty of module
Prof. Dr. Stefanie Vogl	
Teaching method	
Seminar-based lecture	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Project report with presentation

Content
This module introduces the theory and practice of generative networks. Students will explore various generative models, including Variational Autoencoders (VAEs) and Generative Adversarial Networks (GANs). The course emphasizes understanding the theoretical foundations, practical implementations, and real-world applications of generative networks in domains such as image synthesis, data augmentation, and creative AI. Learning Outcomes By the end of this course, students will be able to: 1)Explain the principles and mechanisms of key generative models. 2)Implement and train VAEs, GANs, and other generative networks using Python and TensorFlow/PyTorch. 3)Critically evaluate the performance and limitations of generative models. 4)Apply generative networks to solve real-world problems in data generation, augmentation, and creativity. Course Content 1) Introduction to Generative Models - Generative vs. discriminative approaches - Key applications of generative networks 2) Variational Autoencoders (VAEs) - Theory of latent variable models - KL-divergence and evidence lower bound (ELBO) - Implementation and examples 3) Generative Adversarial Networks (GANs) - Minimax optimization and adversarial loss - Common GAN architectures (DCGAN, StyleGAN, etc.) - Challenges (e.g., mode collapse, stability) and solutions 4) Other Generative Architectures
Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • understand the fundamental concepts and structures of generative networks (3). • know different types of generative networks and their areas of application (2). • implement generative networks using Python and popular libraries (e.g. Keras) (2). • evaluate and optimize the performance of generative networks (3). • contextualize current research questions and developments in the field (2)
Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • explain and to communicate the mathematical content in oral and in written form using appropriate technical terms (2) • work on and to solve mathematical problems in a self-reliant way as well as in work teams (3)

- discuss and to critically dispute their compiled solutions and check for plausibility (2)
- present their results with slides in an oral presentation (3)

Teaching media

- blackboard
- slides
- practical lectures with Jupyter Notebooks (Python)

Literature

- Géron, A. (2022).#Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow. " O'Reilly Media, Inc.".
- Goodfellow, I., Bengio, Y., & Courville, A. (2016).#Deep learning. MIT press.
- Foster, D. (2022).#Generative deep learning. " O'Reilly Media, Inc.".
- Valle, R. (2019).#Hands-On Generative Adversarial Networks with Keras: Your guide to implementing next-generation generative adversarial networks. Packt Publishing Ltd.
- Razavi-Far, R., Ruiz-Garcia, A., Palade, V., & Schmidhuber, J. (Eds.). (2022).#Generative adversarial learning: architectures and applications. Springer International Publishing.

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Inverse Problems and Imaging	4a

Person responsible for the module	Faculty
Prof. Dr. Jürgen Frikel	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Linear Algebra 1 and 2, Analysis 1, 2 and 3

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Compulsory elective module - Inverse Problems and Imaging	4 SWS	5

Submodule	**Submodule abbreviation**
Compulsory elective module – Inverse Problems and Imaging	**IPB**

Responsible person	Faculty
Prof. Dr. Jürgen Frikel	Computer Science and Mathematics
Lecturer	Availablilty of module
Prof. Dr. Jürgen Frikel	
Teaching method	
Seminar-based and project-based lecture	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 3	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Portfolio examination

Content
This course provides a comprehensive introduction to the analysis of linear inverse problems and regularization theory, emphasizing on precise mathematical formulations and imaging applications. The course revisits essential concepts from functional analysis and integration theory to provide a robust foundation for these topics. Topics: Review of basic concepts from functional analysis and integration theory: A brief recap of fundamental principles, including Hilbert spaces, compact operators, and the main results from integration theory. Fundamentals of Inverse Problems: • Well- and ill-posedness of inverse problems and their implications • Generalized solution concepts: least squares and generalized inverses • Analysis of operator behavior through singular value decomposition (SVD) • Understanding and quantifying degree of Ill-posedness using SVD Regularization theory and regularization methods: • Types of regularization and parameter choice rules (e.g. Morozov discrepancy principle) • Spectral (filter based) regularization using SVD • Tikhonov regularization and more general variational regularization • Landweber regularization and other iterative regularization methods Individual projects on imaging techniques: Students will engage in individually supervised projects focusing on specific imaging applications. These projects will involve independent exploration of topics, including mathematical modeling, theoretical analysis, and numerical implementation
Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • Explain what an inverse problem is, provide examples, and name application areas (1) • Understand the significance of inverse problems in real-world contexts and their inherent challenges (2) • Describe the concept of ill-posedness, analyze its implications, and propose suitable generalized solution strategies (2) • Understand the theoretical foundations of regularization methods and their practical implementation to address instability in inverse problems (3) • Identify and implement common regularization techniques and parameter selection methods to stabilize solutions (3) • Independently explore mathematical models and/or implement numerical solutions for imaging applications (3)
Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • recognize the importance of mathematical analysis in problem-solving (1), • critically engage with mathematical concepts (2), • develop solutions using these techniques (2),

- and apply them effectively in applications (3) ,
- communicate mathematical ideas effectively in both written and oral forms (3)

Teaching media
Projector, blackboard, computer lab

Literature

- Lecture slides and specific references for individual projects will be provided during the course: In addition to that, following references are recommended for further reading:
- H.W. Engl, M. Hanke & A. Neubauer (1996), Regularization of Inverse Problems, vol. 375, Mathematics and its Applications, Kluwer Academic Publishers Group, Dordrecht
- A. Kirsch (2011), An Introduction to the Mathematical Theory of Inverse Problems, 2nd ed., Springer, New York
- O. Scherzer, M. Grasmair, H. Grossauer, M. Haltmeier & F. Lenzen (2009), Variational Methods in Imaging, vol. 167, Applied Mathematical Sciences, Springer, New York
- C. Clason (2020), Introduction to Functional Analysis, Compact Textbooks in Mathematics, Birkhäuser, Basel
- F. Natterer (1986), Mathematics of Computerized Tomography, Teubner
- S. Siltanen, J. Müller (2012), Linear and nonlinear inverse problems with practical applications, SIAM

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Neural Networks: Theory and Applications	4a

Person responsible for the module	Faculty
Prof. Dr. Stefanie Vogl	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Basic Knowledge in Python, Statistical Learning, Neural Networks

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Compulsory elective module - Neural Networks: Theory and Applications	4 SWS	5

Submodule	**Submodule abbreviation**
Compulsory elective module – Neural Networks: Theory and Applications	**NNE**

Responsible person	Faculty
Prof. Dr. Stefanie Vogl	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Stefanie Vogl	
Teaching method	
Seminar-based lecture with exercises	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Project report with presentation

Content
1) Introduction to Neural Networks • Historical overview • Biological inspiration • Basic terms and concepts 2) Neural Network Architecture • Neuron model • Layer architectures (simple perceptron, multilayer perceptrons) • Activation functions 3) Training Neural Networks • Forward and backward propagation • Loss functions • Optimization algorithms (gradient descent, stochastic gradient descent, Adam) 4) Regularization and Optimization • Overfitting and underfitting • Regularization techniques (L1, L2, dropout) Hyperparameter tuning 5) Special Network Architectures • Convolutional Neural Networks (CNNs) • Recurrent Neural Networks (RNNs) • Long Short-Term Memory Networks (LSTMs) • Auto-Encoders 6) Applications of Neural Networks • Image recognition • Time series analysis 7) Practical Implementation • Introduction to Keras (sequential models and functional API) • Implementing and training a simple neural network • Case studies and projects
Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • understand the fundamental concepts and structures of neural networks (3). • know different types of neural networks and their areas of application (2). • implement neural networks using Python and popular libraries (e.g. Keras) (2). • evaluate and optimize the performance of neural networks (3). • contextualize current research questions and developments in the field of neural networks (2)

Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • explain and to communicate the mathematical content in oral and in written form using appropriate technical terms (2) • work on and to solve mathematical problems in a self-reliant way as well as in work teams (3) • discuss and to critically dispute their compiled solutions and check for plausibility (2) • present their results with slides in an oral presentation (3)
Teaching media
Blackboard, slides, practical lectures with Jupyter Notebooks (Python)
Literature
• Géron, A. (2022). Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow. " O'Reilly Media, Inc.". • Vasilev, I., Slater, D., Spacagna, G., Roelants, P., & Zocca, V. (2019). Python Deep Learning: Exploring deep learning techniques and neural network architectures with Pytorch, Keras, and TensorFlow. Packt Publishing Ltd. • Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep learning. MIT press. • Gurney, K. (2018). An introduction to neural networks. CRC press

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Nonlinear Optimization	5a

Person responsible for the module	Faculty
Prof. Dr. Stefan Körkel	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Linear Algebra 1 and 2, Analysis 1 and 2, Programming Knowledge

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Nonlinear Optimization	4 SWS	5

Submodule	Submodule abbreviation
Nonlinear Optimization	**NOP**

Responsible person	Faculty
Prof. Dr. Stefan Körkel	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Stefan Körkel	

Teaching method
Seminar-based lecture

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60h	90h

Method of assessment
Written examination: 90-120 minutes or oral examination: 15-45 minutes

Content

- Optimality conditions for unconstrained and constrained problems
- Descent methods, gradient method, convergence analysis
- Conjugate gradient methods, linear and nonlinear
- Global convergence, linesearch, trust-region methods
- Newton-type methods, sequential quadratic programming, update formulas, convergence analysis
- Inequality constrained problems, active-set methods, interior-point-methods
- Nonlinear least-squares problems, Gauß-Newton method, regularization
- Derivative evaluation, automatic differentiation
- Practical implementation of the methods
- Software for nonlinear optimization

Learning objectives: Subject competence

After successful completion of the submodule, students are able to,

- formulate and prove optimality conditions for nonlinear optimization problems (3)
- understand, analyze, implement, use and compare several methods and algorithms (3)
- analyze local and global convergence behavior (3)
- apply the methods to problems from practice (3)

Learning objectives: Personal competence

After successful completion of the submodule, students are able to,

- model and analyze nonlinear optimization problems (3)

- use and implement methods for the solution (3)
- understand and apply proof techniques from this field (2)

Teaching media
Blackboard, projector, mathematical software

Literature

- Körkel, S. Nonlinear Optimization. Lecture notes, OTH Regensbörg
- Nocedal, J., Wright, S. Numerical Optimization
- Luenberger, D. G., Ye, Y.: Linear and Nonlinear Programming

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Numerical Methods in Financial Mathematics	4a

Person responsible for the module	Faculty
Prof. Dr. Wolfgang Lauf	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Linear Algebra 1 and 2, Analysis 1 and 2, Probability Theory and Statistics 1, Numerical Mathematics 1, Mathematical Software (e.g. Matlab)

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Compulsory elective module - Numerical Methods in Financial Mathematics	4 SWS	5

Submodule	Submodule abbreviation
Compulsory elective module – Numerical Methods in Financial Mathematics	**NFI**

Responsible person	Faculty
Prof. Dr. Wolfgang Lauf	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Wolfgang Lauf	

Teaching method
Seminar teaching with exercises

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1., 2., 3.	4 SWS	german/english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60h	90h

Method of assessment
written or oral examination

Content

- mathematical models for financial markets
- stochastic differential equations
- random numbers, Monte Carlo simulation
- finite-difference methods, finite-element methods
- European, American, exotic (stock) options

Learning objectives: Subject competence

After successful completion of the submodule, students are able to,

- understand mathematical models for financial markets (assumptions, validity, information value) (3),
- explain important numerical methods for pricing financial products (2),
- evaluate selected financial derivatives numerically (3).

Learning objectives: Personal competence

After successful completion of the submodule, students are able to,

- analyze their own learning progress and learning needs (3) and, if necessary, derive courses of action from this (3),
- work together with others in a goal-oriented manner (2),
- understand their interests and social situation (2),
- deal with them rationally and responsibly and communicate with them (2) and help shape their working and living environment (3),
- work scientifically in accordance with the "guidelines of good scientific practice" (2),

- present subject-specific content (2) and explain it to an audience in correct technical language (2).

Teaching media
blackboard, projector, notebook, mathematical software

Literature

- Albrecht, P., Maurer, R.: Investment- und Risikomanagement
- Günther, M., Jüngel, A.: Finanzderivate mit MATLAB
- Higham, D. J.: Financial Option Valuation
- Hull, J.C.: Options, Futures and Other Derivates
- Kuo, H.: Introduction to Stochastic Integration
- Seydel, R.: Tools for Computational Finance

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Numerical Optimization	5a

Person responsible for the module	Faculty
Prof. Dr. Martin Weiß	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Linear Algebra 1 and 2, Analysis 1 and 2, Programming in Matlab or Python, Numerical Mathematics

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Numerical Optimization	4 SWS	5

Submodule	Submodule abbreviation
Numerical Optimization	**NUO**

Responsible person	Faculty
Prof. Dr. Martin Weiß	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Martin Weiß	

Teaching method
Seminar-base lecture

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Project report with presentation

Content

Theory and practical implementation of numerical methods for:

- Computation of derivatives.
- Systems of nonlinear equation
- Nonlinear least squares problems without constraints.
- Quadratic problems with and without constraints.
- General nonlinear optimization with constraints
- Algorithms for nonlinear optimization, particularly SQP and interior point methods.
- Boundary value problems and optimal control for systems of ordinary differential equations, especially time-optimal control.
- Specialized methods: Convex optimization, stochastic methods, derivative-free methods.

Learning objectives: Subject competence

After successful completion of the submodule, students are able to,

- identify typical numerical methods for the numerical computation of derivatives and nonlinear optimization problems, and determine their orders of convergence. (1), (2)
- name typical numerical methods for nonlinear equation systems, nonlinear least squares problems, quadratic problems with and without constraints, general nonlinear optimization with constraints and explain their mathematical properties, including typical numerical effects. (1)
- analyze the behavior of these methods analytically using low-dimensional examples. (2)
- implement and apply numerical methods for nonlinear optimization in MATLAB, python or other programming languages, and diagnose their behavior. (3)

- use libraries for numerical optimization like the MATLAB Optimization Toolbox, numpy, scipy (3).
- create mathematical models for application problems for nonlinear optimization, implement solutions, and interpret the results. (3)

Teaching media
Projector, blackboard, computer lab, script, exercises

Literature

- Dennis Jr, J.E., Schnabel, R.B.I: Numerical Methods for Unconstrained Optimization and Nonlinear Equations
- Nocedal, J., Wright, S.J.: Numerical Optimization
- Reinhardt, R., Hoffmann, A., Gerlach, T.: Nichtlineare Optimierung. Theorie, Numerik, Experimente

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Public Key Cryptography	5a

Person responsible for the module	Faculty
Prof. Dr. Georg Illies Prof. Dr. Oliver Stein	Computer Science and Mathematics Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Linear Algebra 1 and 2, Analysis 1 and 2, Elementary Number Theory, Probability Theory and Statistics 1 and 2

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Public Key Cryptography	4 SWS	5

Submodule	Submodule abbreviation
Public Key Cryptography	**PKC**

Responsible person	Faculty
Prof. Dr. Georg Illies Prof. Dr. Oliver Stein	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Georg Illies Prof. Dr. Oliver Stein	

Teaching method
Seminar-based lecture

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Written examination: 90 minutes

Content

- Algebraic and number theoretic fundamentals
- Public-key cryptosystems (RSA, Diffie-Hellman, El-Gamal, knapsack, quadratic residues)
- Cryptanalysis of PK schemes: Factorization (Pollard p-1, sieve methods), DLog (baby-step-giant-step, Pollard-rho, index calculus), continued fractions, LLL lattice reduction
- Prime number generation
- Integrity, authentication, digital signatures (hash functions and hash trees, zero-knowlegde, RSA, DSA)
- Secret sharing, oblivious transfer, pairing based cryptography
- Elliptic curves and EC cryptography

Learning objectives: Subject competence

After successful completion of the submodule, students are able to,

- present the principles of modern cryptography and their application (1),
- present common public key algorithms and hybrid cryptosystems (1),
- evaluate their security based on knowledge of algorithmic number theory and cryptanalytical methods (3),
- implement and apply cryptographic protocols (2),
- implement and apply cryptanalytical procedures (2).

Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • communicate professionally (2), • work on problems analytically and persistently (2).
Teaching media
Blackboard, Projector, Script, Exercises and Solutions
Literature
• Buchmann, “Introduction to Cryptography”, 2nd Ed., Springer, 2004 • Delfs, Knebl, “Introduction to Cryptography: Principles an Applications”, 3rd Ed., Springer, 2015 • Hoffstein, Pipher, Silverman, “An Introduction to Mathematical Cryptography”, 2nd Ed., Springer, 2014 • Koblitz, “A Course in Number Theory and Cryptography”, 2nd Ed., Springer, 1994

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Reinsurance Pricing	4a

Person responsible for the module	Faculty
Prof. Dr. Michael Fröhlich	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Linear Algebra 1 and 2, Analysis 1 and 2, Elementary Number Theory, Probability Theory and Statistics 1 and 2

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Compulsory elective module - Reinsurance Pricing	4 SWS	5

Submodule	Submodule abbreviation
Compulsory elective module – Reinsurance Pricing	**RIP**

Responsible person	Faculty
Prof. Dr. Michael Fröhlich	Computer Science and Mathematics
Lecturer	Availablilty of module
Prof. Dr. Michael Fröhlich	

Teaching method
Seminar-based lecture

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	german	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Oral exam: 30 minutes / Admission requirement: successful completion of the assignments

Content
The submodule covers essential content from the field of pricing of reinsurance contracts. The pricing methods are illustrated and discussed using actuarial case studies. Additionally, the mathematical foundations of selected methods are explored in greater depth. Furthermore, special emphasis is placed on discussions and techniques related to explainability. Topics: • Definiiton of reinsurance. How does reinsurance work? • How a proportional reinsurance contract works • How a non-proportional reinsurance contract works • Pricing method Burning Cost for property and casualty business • Pricing method Exposure for property and casualty business • Stop Loss Pricing and aggregate XLs • Frequency-Severity analysis • Market curves • Development of pricing models
Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • Explain both proportional and non-proportional reinsurance contracts (1) • explain the principles of the pricing methods Burning-Cost and Exposure and selected learning techniques, as well as the importance of explainability in actuarial applications (1)

- reproduce mathematical and algorithmic foundations of selected pricing methods to strengthen theoretical understanding (2),
- apply selected mathematical methods to address specific actuarial pricing questions (3), interpret and analyze results from software outputs in the context of actuarial applications, and critically evaluate model finetuning with actuarial diligence (3).

Learning objectives: Personal competence

After successful completion of the submodule, students are able to,

- Explain the approaches applied to price Stop Loss contracts (1)
- discuss with lecturers and other students in a mathematically sophisticated manner and appropriate to actuarial applications of the pricing approaches (3),
- work and argue for the pricing results in accordance with good scientific practice and actuarial diligence (2),
- responsibly contribute to the actuarial professional environment in the application of mathematical methods (3).

Teaching media

Projector, blackboard, virtual via Zoom

Literature

- Pfeiffer, Chr.: Einführung in die Rückversicherung, Gabler Wiesbaden
- Liebwein,P.: Klassische und moderne Formen der Rückversicherung, Karlsruhe VVW
- Thomas Mack. Schadenversicherungsmathematik, volume 28. Verlag Versicherungswirtsch.,2002
- Andreas Schwepcke. Rückversicherung. VVWGmbH, 2004.
- Stefan Lippe, Herbert Sedlmair, and Thomas Witting. Praxisrelevante Aspekte
- der Burning-Cost-Kalkulation. Blätter der DGVFM, 20(2):97–121, 1991.

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Risk Theory	4a

Person responsible for the module	Faculty
Prof. Dr. Michael Fröhlich Prof. Dr. Anja Bettina Schmiedt	Computer Science and Mathematics Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Linear Algebra 1 and 2, Analysis 1 and 2, Probability Theory and Statistics 1 and 2

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Compulsory elective module - Risk Theory	4 SWS	5

Submodule	Submodule abbreviation
Compulsory elective module – Risk Theory	**RTH**

Responsible person	Faculty
Prof. Dr. Anja Bettina Schmiedt Prof. Dr. Michael Fröhlich	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Michael Fröhlich Prof. Dr. Anja Bettina Schmiedt	
Teaching method	
Seminar-based lecture	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Oral examination: 30 minutes

Content

The submodule covers essential content from the field of risk theory in actual science. Topics include:

- Descriptive and inductive data analysis
- Survival models and mortality tables
- Extended distribution models
- Risk measures
- Copulas and dependence
- Markov models
- Monte Carlo methods
- Maximum likelihood estimators and hypothesis tests
- Exponential families
- Linear and generalized linear models
- Credibility theory

Learning objectives: Subject competence

After successful completion of the submodule, students are able to,

- understand and apply modeling techniques such as QQ-plots (3),
- understand biometric principles and create mortality tables (3),
- understand and comprehend actuarial risk measures (2),
- understand and comprehend modeling with copulas and Markov models (2),
- understand and apply Monte Carlo methods (3),

- demonstrate experience with point estimators and hypothesis tests (2),
- understand and comprehend exponential families and generalized linear models (2),
- understand and comprehend credibility theory (2).

Learning objectives: Personal competence

After successful completion of the submodule, students are able to,

- discuss with lecturers and other students in a mathematically sophisticated manner (2),
- work and argue in accordance with good scientific practice and mathematical accuracy (3),
- discuss with lectures and other students appropriate to actuarial applications (2),
- responsibly contribute to the actuarial professional environment in the application of risk theory (3).

Teaching media

Projector, blackboard, computer lab

Literature

In addition to the notes and materials from the lectures and the references provided there, the following literature is recommended for supplementary and further reading:

- Asmussen, S., & Steffensen, M. (2020). Risk and Insurance. Springer.
- Bühlmann, H., & Gisler, A. (2005). A Course in Credibility Theory and its Applications. Springer.
- Charpentier, A. (Ed.). (2014). Computational Actuarial Science with R. CRC Press.
- Denuit, A., Hainaut, D., & Trufin, J. (2019). Effective Statistical Learning Methods for Actuaries I: GLMs and Extensions. Springer.
- Hastie, T., Tibshirani, R., & Friedman, J. H. (2009). The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Secon Edition, Springer.
- Klüppelberg, C., Straub, D., & Welpe, I. M. (Eds.). (2014). Risk - A Multidisciplinary Introduction. Springer.
- Korn, R., Korn, E., & Kroisandt, G. (2010). Monte Carlo Methods and Models in Finance and Insurance. CRC press.
- McNeil, A. J., Frey, R., & Embrechts, P. (2015). Quantitative Risk Management: Concepts, Techniques and Tools. Revised Edition, Princeton University Press.
- Nelsen, R. B. (2006). An Introduction to Copulas. Springer.
- Schmidli, H. (2017). Risk Theory. Springer.
- Reiss, R. D., & Thomas, M. (2007). Statistical Analysis of Extreme Values: With Applications to Insurance, Finance, Hydrology and Other Fields. Third Edition, Birkhäuser.
- Robert, C. P., & Casella, G. (2010). Introducing Monte Carlo Methods with R. Springer.
- Wüthrich, M. V., & Merz, M. (2023). Statistical Foundations of Actuarial Learning and its Applications. Springer.

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Compulsory elective module – Statistical Learning in Actuarial Science	4a

Person responsible for the module	Faculty
Prof. Dr. Anja Bettina Schmiedt	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Recommended previous knowledge
Analysis 1, Linear Algebra 1 and 2, Probability Theory and Statistics 1

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Compulsory elective module - Statistical Learning in Actuarial Science	4 SWS	5

Submodule	Submodule abbreviation
Compulsory elective module – Statistical Learning in Actuarial Science	**SLA**

Responsible person	Faculty
Prof. Dr. Anja Bettina Schmiedt	Computer Science and Mathematics
Lecturer	**Availablilty of module**
Prof. Dr. Anja Bettina Schmiedt	
Teaching method	
Seminar-based lecture	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	4 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
60 h	90 h

Method of assessment
Oral examination: 20 minutes Admission requirement: successful completion of the assignments

Content
The submodule covers essential content from the field of Actuarial Data Science, as also taught in the Actuarial Data Science Basic module of the German Actuarial Association. The methods are illustrated and discussed using actuarial case studies with notebooks. Additionally, the mathematical foundations of selected methods are explored in greater depth. Furthermore, special emphasis is placed on discussions and techniques related to explainability. Topics: • Actuarial Data Science Basics: introduction to basic topics, including digitalization, social environment and ethics, data protection, and data processing • Insurance Analytics: introduction to fundamental concepts, principles, and methods of data mining and modelling • Unsupervised Learning: cluster analysis and principal component analysis, including mathematical and algorithmic foundations, as well as applications • Supervised Learning: decision trees for classification and regression and tree-based ensemble methods, including mathematical resp. methodological and algorithmic foundations, as well as applications • Explainable AI: introduction to concepts, techniques, and case studies, with deep dives into selected post-hoc methods • Deep Learning: feedforward neural networks, including basic functionality and application to classification and regression problems • Actuarial applications using R software (partially Python)

Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • explain the principles of actuarial data science and selected learning techniques, as well as the importance of explainability in actuarial applications (1) • reproduce mathematical, methodological and algorithmic foundations of selected statistical methods to strengthen theoretical understanding (2), • apply selected statistical methods to address specific actuarial question (3), interpret and analyze results from software outputs in the context of actuarial applications, and critically evaluate model formation with actuarial diligence (3).
Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • discuss with lecturers and other students in a mathematically sophisticated manner and appropriate to actuarial applications (3), • work and argue in accordance with good scientific practice and actuarial diligence (2), • responsibly contribute to the actuarial professional environment in the application of statistical methods (3).
Teaching media
Projector, blackboard, computer lab
Literature
In addition to the notes and materials from the lectures and the references provided there, the following literature is recommended for supplementary and further reading: • Charpentier, A. (Ed.). (2014). Computational Actuarial Science with R. CRC Press. • Denuit, A., Hainaut, D., & Trufin, J. (2020). Effective Statistical Learning Methods for Actuaries II: Tree-Based Methods and Extensions. Springer. • Denuit, A., Hainaut, D., & Trufin, J. (2019). Effective Statistical Learning Methods for Actuaries III: Neural Networks and Extensions. Springer. • Hastie, T., Tibshirani, R., & Friedman, J. H. (2009). The Elements of Statistical Learning: Data Mining, Inference, and Prediction (2nd ed.). Springer. • Härdle, W.K., & Hlávka, Z. (2015). Multivariate Statistics (2nd ed.). Springer. • James, G., Witten, D., Hastie, T., & Tibshirani, R. (2021). An Introduction to Statistical Learning with Applications in R (2nd ed.). Springer. • Seehafer, M., Nörtemann, S., Offtermatt, J., Transchel, F., Kiermaier, A., Külheim, R., & Weidner, W. (2021). Actuarial Data Science: Machine Learning in Insurance. De Gruyter. • Wüthrich, M. V., & Merz, M. (2023). Statistical Foundations of Actuarial Learning and its Applications. Springer.

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Research Project 1	4b

Person responsible for the module	Faculty
Prof. Dr. Jürgen Frikel	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1.		5

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Research Project 1	2 SWS	5

Notes on the assignment requirement or options
If module 4b/c is chosen, the corresponding module 5b/c must be selected at the same time. The language of instruction and examination is English. Exceptions to this, i.e., German instead of English, are regulated by the study plan.

Submodule	Submodule abbreviation
Research Project 1	

Responsible person	Faculty
Prof. Dr. Jürgen Frikel	Informatik und Mathematik
Lecturer	**Availablilty of module**
All IM Professors	
Teaching method	
Project	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	2 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
0 h	150 h

Method of assessment
Project report with presentation

Content
In this submodule, students work on a current scientific research question in the field of mathematics or one of its applications. The project topic is supervised by a faculty member. The project assignment can be provided internally by professors of the mathematics department or externally in collaboration with a company. Students work independently on the project topic and are responsible for conducting their own research on relevant methods and techniques, as well as applying them to address the research question. The results are documented in a written scientific report and presented in an oral presentation.
Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • analyze, and systematically address a research question within a research project (3), • independently research, critically evaluate, and apply relevant methods and tools to solve the research question (3), • interpret experimental or theoretical results and place them in a scientific context (2), • develop mathematical/computational models and assess their applicability to specific problems (3), • document and present scientific results clearly, precisely, and in a structured manner, both in written and oral form (2). These objectives align with the professional competencies needed in both academic and industry-focused mathematical careers.

Teaching materials offered
• independently organize a complex research project, efficiently manage time and resources, and meet set goals on schedule (3), • present scientific content in a clear and structured manner in presentations (2), • work and communicate effectively, engaging in scientific discussions, and collaboratively developing solutions (3).
Literature
The literature is project-specific and will be independently researched by the students and/or provided by the topic supervisor.

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Research Project 1	5b

Person responsible for the module	Faculty
Prof. Dr. Jürgen Frikel	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Research Project 1	2 SWS	5

Notes on the assignment requirement or options
If module 5b/c is chosen, the corresponding module 4b/c must be selected at the same time. The language of instruction and examination is English. Exceptions to this, i.e., German instead of English, are regulated by the study plan.

Submodule	Submodule abbreviation
Research Project 1	

Responsible person	Faculty
Prof. Dr. Jürgen Frikel	Informatik und Mathematik
Lecturer	**Availablilty of module**
All IM Professors	
Teaching method	
Project	

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1,2	2 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study

Method of assessment
Project report with presentation

Content
In this submodule, students work on a current scientific research question in the field of mathematics or one of its applications. The project topic is supervised by a faculty member. The project assignment can be provided internally by professors of the mathematics department or externally in collaboration with a company. Students work independently on the project topic and are responsible for conducting their own research on relevant methods and techniques, as well as applying them to address the research question. The results are documented in a written scientific report and presented in an oral presentation.
Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • analyze, and systematically address a research question within a research project (3), • independently research, critically evaluate, and apply relevant methods and tools to solve the research question (3), • interpret experimental or theoretical results and place them in a scientific context (2), • develop mathematical/computational models and assess their applicability to specific problems (3), • document and present scientific results clearly, precisely, and in a structured manner, both in written and oral form (2). These objectives align with the professional competencies needed in both academic and industry-focused mathematical careers.

Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • independently organize a complex research project, efficiently manage time and resources, and meet set goals on schedule (3), • present scientific content in a clear and structured manner in presentations (2), • work and communicate effectively, engaging in scientific discussions, and collaboratively developing solutions (3)
Literature
More information about the course
The literature is project-specific and will be independently researched by the students and/or provided by the topic supervisor.

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Research Project 2	4c

Person responsible for the module	Faculty
Prof. Dr. Jürgen Frikel	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1.		5

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Research Project 2	2 SWS	5

Notes on the assignment requirement or options
If module 4b/c is chosen, the corresponding module 5b/c must be selected at the same time. The language of instruction and examination is English. Exceptions to this, i.e., German instead of English, are regulated by the study plan.

Submodule	Submodule abbreviation
Research Project 2	

Responsible person	Faculty
Prof. Dr. Jürgen Frikel	Informatik und Mathematik
Lecturer	**Availablilty of module**
All IM Professors	

Teaching method
Project

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	2 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
0 h	150 h

Method of assessment
Project report with presentation

Content
In this submodule, students work on a current scientific research question in the field of mathematics or one of its applications. The project topic is supervised by a faculty member. The project assignment can be provided internally by professors of the mathematics department or externally in collaboration with a company. Students work independently on the project topic and are responsible for conducting their own research on relevant methods and techniques, as well as applying them to address the research question. The results are documented in a written scientific report and presented in an oral presentation.
Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • analyze, and systematically address a research question within a research project (3), • independently research, critically evaluate, and apply relevant methods and tools to solve the research question (3), • interpret experimental or theoretical results and place them in a scientific context (2), • develop mathematical/computational models and assess their applicability to specific problems (3), • document and present scientific results clearly, precisely, and in a structured manner, both in written and oral form (2). These objectives align with the professional competencies needed in both academic and industry-focused mathematical careers.

Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • independently organize a complex research project, efficiently manage time and resources, and meet set goals on schedule (3), • present scientific content in a clear and structured manner in presentations (2), • work and communicate effectively, engaging in scientific discussions, and collaboratively developing solutions (3).
Literature
More information about the course
The literature is project-specific and will be independently researched by the students and/or provided by the topic supervisor.

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application

Module title	Module code
Research Project 2	5c

Person responsible for the module	Faculty
Prof. Dr. Jürgen Frikel	Computer Science and Mathematics

Semester taught according to the curriculum	Level of study	Module type	Credit value
1, 2	1		5

Assigned submodules

Nr.	Submodule title	Teaching hours	Credit value
1.	Research Project 2	2 SWS	5

Notes on the assignment requirement or options
If module 5b/c is chosen, the corresponding module 4b/c must be selected at the same time. The language of instruction and examination is English. Exceptions to this, i.e., German instead of English, are regulated by the study plan.

Submodule	Submodule abbreviation
Research Project 2	

Responsible person	Faculty
Prof. Dr. Jürgen Frikel	Informatik und Mathematik
Lecturer	**Availablilty of module**
Faculty IM Dean	

Teaching method
Project

Semester taught according to the curriculum	Teaching hours	Teaching language	Credit value
1, 2	2 SWS	english	5

Study hours required

Hours in attendance/lectures	Hours for self-study
0 h	150 h

Method of assessment
Project report with presentation

Content
In this submodule, students work on a current scientific research question in the field of mathematics or one of its applications. The project topic is supervised by a faculty member. The project assignment can be provided internally by professors of the mathematics department or externally in collaboration with a company. Students work independently on the project topic and are responsible for conducting their own research on relevant methods and techniques, as well as applying them to address the research question. The results are documented in a written scientific report and presented in an oral presentation.
Learning objectives: Subject competence
After successful completion of the submodule, students are able to, • analyze, and systematically address a research question within a research project (3), • independently research, critically evaluate, and apply relevant methods and tools to solve the research question (3), • interpret experimental or theoretical results and place them in a scientific context (2), • develop mathematical/computational models and assess their applicability to specific problems (3), • document and present scientific results clearly, precisely, and in a structured manner, both in written and oral form (2). These objectives align with the professional competencies needed in both academic and industry-focused mathematical careers.

Learning objectives: Personal competence
After successful completion of the submodule, students are able to, • independently organize a complex research project, efficiently manage time and resources, and meet set goals on schedule (3), • present scientific content in a clear and structured manner in presentations (2), • work and communicate effectively, engaging in scientific discussions, and collaboratively developing solutions (3)
Literature
The literature is project-specific and will be independently researched by the students and/or provided by the topic supervisor.

The numbers in brackets indicate the levels to be reached: 1 - understanding 2 - ability 3 - understand and application