University of Augsburg

Module Catalogue

Master's Programme Mathematics and Computer Science PO 2024

Faculty of Mathematics, Natural Sciences, and Materials Engineering

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Module MTH-1488: Algebraic geometry I

Algebraische Geometrie I

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Learning Outcomes / Competences:
Im Rahmen der Vorlesung haben die Studenten gelernt, ihr im Bachelorstudium im Bereich der Algebra erworbenes Wissen anhand konkreter Probleme aus der algebraischen Geometrie anzuwenden. Daneben ist neben einem mathematischen auch ein gutes intuitives Verständnis für geometrische Konstuktionen wie den projektiven Raum, Faserbündel, Produkte und Aufblasungen erreicht worden.

Remarks:
Wer MTH-1480 oder MTH-1481 oder MTH-1482 bereits bestanden hat, kann für dieses Modul nicht zugelassen werden: die Inhalte sind identisch.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
none

Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Algebraische Geometrie I
Mode of Instruction: lecture, exercise course
Language: German
Contact Hours: 6,00

Contents:
- Algebraische Varietäten
- Rationale Äquivalenz
- Divisoren
- Vektorbündel und Chernsche Klassen
- Kegel und Segresche Klassen
- Schnittprodukte
- Schnittmultiplizitäten
- Schnitte nicht-singulärer Varietäten
- Dynamisches Schnittverhalten
- Graßmannsche Varietäten
- Riemann-Rochscher Satz für nicht-singuläre Varietäten
- Bivariante Schnitttheorie
- Riemann-Rochscher Satz für singuläre Varietäten

Literature:

- W. Fulton: Intersection Theory. Springer-Verlag.
- I. Shafarevich: Basic Algebraic Geometry (I + II). Springer-Verlag.

Assigned Courses:

Algebraische Geometrie I (lecture)

*(in attendance) *

Examination

Algebraische Geometrie

portfolio exam, graded

Test Frequency:

each semester

Description:

Eine Prüfungsanmeldung und eine Prüfung zu diesem Modul kann in jedem Semester erfolgen. In den Semestern, in denen die zugehörige Veranstaltung nicht stattfindet, werden die Kompetenzen abweichend in einer mündlichen Prüfung geprüft.

Module MTH-1489: Algebraic geometry II

Algebraische Geometrie II

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Learning Outcomes / Competences:
Im Rahmen der Vorlesung haben die Studenten gelernt, ihr im Bachelorstudium im Bereich der Algebra erworbenes Wissen anhand konkreter Probleme aus der algebraischen Geometrie anzuwenden. Daneben ist neben einem mathematischen auch ein gutes intuitives Verständnis für geometrische Konstuktionen wie den projektiven Raum, Faserbündel, Produkte und Aufblasungen erreicht worden.

Remarks:
Wer MTH-1480 oder MTH-1481 oder MTH-1482 bestanden hat, kann für dieses Modul nicht zugelassen werden: die Inhalte sind identisch.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:		**Credit Requirements:**
none		Bestehen der Modulprüfung
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Algebraische Geometrie II
Mode of Instruction: lecture + exercise
Language: German
Frequency: every 4th semester
Contact Hours: 6,00

Contents:
- Algebraische Varietäten
- Rationale Äquivalenz
- Divisoren
- Vektorbündel und Chernsche Klassen
- Kegel und Segresche Klassen
- Schnittprodukte
- Schnittmultiplizitäten
- Schnitte nicht-singulärer Varietäten
- Dynamisches Schnittverhalten
- Graßmannsche Varietäten
- Riemann-Rochscher Satz für nicht-singuläre Varietäten
- Bivariante Schnitttheorie
- Riemann-Rochscher Satz für singuläre Varietäten

Literature:

- W. Fulton: Intersection Theory. Springer-Verlag.
- I. Shafarevich: Basic Algebraic Geometry (I + II). Springer-Verlag.

Examination

Algebraische Geometrie II

oral exam, graded

Test Frequency:

each semester

Description:

Die genauen Prüfungsmodalitäten werden am Anfang der Vorlesung bekannt gegeben.

Module MTH-1508: Scheme Theory I *Schematheorie I*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen	

Contents:

Das Modul besteht aus einer Einführung in die Sprache der modernen algebraischen Geometrie. Zentraler Begriff ist der des Schemas: Ein Schema ist ein geometrisches Objekt, welches lokal durch einen kommutativen Ring beschrieben wird. Die Anwendungsmöglichkeiten der Schematheorie sind vielfältig, da der Begriff eines kommutativen Ringes überall in der Mathematik auftaucht, etwa als Koordinatenring einer affinen Varietät oder als Ring ganzer Zahlen in einem Zahlkörper. Im Rahmen des Moduls werden grundlegende Eigenschaften von Schemata und Morphismen zwischen Schemata behandelt, etwa Glattheit, Normalität, Flachheit, Dimension, Irreduzibilität und Endlichkeit. Anschließend werden Kohomologietheorien für Schemata am Beispiel der Zariski- und der étalen Topologie besprochen.
Tensorprodukte, Flachheit und Vervollständigung von Ringen
Spektrum eines kommutativen Ringes
Geringte topologische Räume
Schemata
Reduzierte und ganze Schemata
Dimension
Basiswechsel
Algebraische Varietäten
Globale Eigenschaften von Morphismen
Normale Schemata
Reguläre Schemata
Flache und glatte Morphismen
Modulgarben
Grothendieck-Topologien und Siten
Zariski-Topologie
Étale Topologie
Studenten, die zudem Veranstaltungen in Differentialgeometrie besucht haben, werden ebenfalls auf differentialgeometrische Objekte eine neue Sichtweise kennenlernen.
Voraussetzungen: Kommutative Algebra/Computeralgebra (Algebra II)

Learning Outcomes / Competences:

Im Rahmen der Vorlesung lernen die Studenten ihr im Bachelorstudium im Bereich der Algebra erworbenes Wissen auf eine für die moderne Algebra und Zahlentheorie grundlegende Theorie anzuwenden. Aufgrund der Allgemeinheit der Schematheorie ist das abstrakte Denken der Studenten in großem Maße geschult. Geometrische Denkweisen werden erlernt und erfolgreich auf algebraische Fragestellungen angewandt. Zentral ist außerdem, daß sich die Studenten mit dem Begriff der Dimension auseinandergesetzt haben. Anschließend ist die Konstruktion und Anwendung von Kohomologietheorien am Beispiel der Schemata bekannt.

Remarks:

Wer MTH-1500 bzw. MTH-1502 bereits bestanden hat, kann für dieses Modul nicht zugelassen werden: die Inhalte sind identisch.

Workload:

Total: 240 h

Conditions:		**Credit Requirements:**
none		Bestehen der Modulprüfung
Frequency: each semester	**Recommended Semester:**	**Minimal Duration of the Module:** semester[s]

Contact Hours:	Repeat Exams Permitted:
6,00	any

Parts of the Module

Part of the Module: Schematheorie I
Language: German
Contact Hours: 6,00

Contents:

Das Modul besteht aus einer Einführung in die Sprache der modernen algebraischen Geometrie. Zentraler Begriff ist der des Schemas: Ein Schema ist ein geometrisches Objekt, welches lokal durch einen kommutativen Ring beschrieben wird. Die Anwendungsmöglichkeiten der Schematheorie sind vielfältig, da der Begriff eines kommutativen Ringes überall in der Mathematik auftaucht, etwa als Koordinatenring einer affinen Varietät oder als Ring ganzer Zahlen in einem Zahlkörper. Im Rahmen des Moduls werden grundlegende Eigenschaften von Schemata und Morphismen zwischen Schemata behandelt, etwa Glattheit, Normalität, Flachheit, Dimension, Irreduzibilität und Endlichkeit. Anschließend werden Kohomologietheorien für Schemata am Beispiel der Zariski- und der étalen Topologie besprochen.
Tensorprodukte, Flachheit und Vervollständigung von Ringen
Spektrum eines kommutativen Ringes
Geringte topologische Räume
Schemata
Reduzierte und ganze Schemata
Dimension
Basiswechsel
Algebraische Varietäten
Globale Eigenschaften von Morphismen
Normale Schemata
Reguläre Schemata
Flache und glatte Morphismen
Modulgarben
Grothendieck-Topologien und Siten
Zariski-Topologie
Étale Topologie
Studenten, die zudem Veranstaltungen in Differentialgeometrie besucht haben, werden ebenfalls auf differentialgeometrische Objekte eine neue Sichtweise kennenlernen.
Voraussetzungen: Kommutative Algebra/Computeralgebra (Algebra II)

Examination

MTH-1508 Schematheorie I
oral exam, graded
Test Frequency:
each semester

Module MTH-1509: Scheme Theory II *Schematheorie II*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen	

Contents:

Das Modul besteht aus einer Einführung in die Sprache der modernen algebraischen Geometrie. Zentraler Begriff ist der des Schemas: Ein Schema ist ein geometrisches Objekt, welches lokal durch einen kommutativen Ring beschrieben wird. Die Anwendungsmöglichkeiten der Schematheorie sind vielfältig, da der Begriff eines kommutativen Ringes überall in der Mathematik auftaucht, etwa als Koordinatenring einer affinen Varietät oder als Ring ganzer Zahlen in einem Zahlkörper. Im Rahmen des Moduls werden grundlegende Eigenschaften von Schemata und Morphismen zwischen Schemata behandelt, etwa Glattheit, Normalität, Flachheit, Dimension, Irreduzibilität und Endlichkeit. Anschließend werden Kohomologietheorien für Schemata am Beispiel der Zariski- und der étalen Topologie besprochen.
Tensorprodukte, Flachheit und Vervollständigung von Ringen
Spektrum eines kommutativen Ringes
Geringte topologische Räume
Schemata
Reduzierte und ganze Schemata
Dimension
Basiswechsel
Algebraische Varietäten
Globale Eigenschaften von Morphismen
Normale Schemata
Reguläre Schemata
Flache und glatte Morphismen
Modulgarben
Grothendieck-Topologien und Siten
Zariski-Topologie
Étale Topologie
Studenten, die zudem Veranstaltungen in Differentialgeometrie besucht haben, werden ebenfalls auf differentialgeometrische Objekte eine neue Sichtweise kennenlernen.
Voraussetzungen: Kommutative Algebra/Computeralgebra (Algebra II)

Learning Outcomes / Competences:

Im Rahmen der Vorlesung lernen die Studenten ihr im Bachelorstudium im Bereich der Algebra erworbenes Wissen auf eine für die moderne Algebra und Zahlentheorie grundlegende Theorie anzuwenden. Aufgrund der Allgemeinheit der Schematheorie ist das abstrakte Denken der Studenten in großem Maße geschult. Geometrische Denkweisen werden erlernt und erfolgreich auf algebraische Fragestellungen angewandt. Zentral ist außerdem, daß sich die Studenten mit dem Begriff der Dimension auseinandergesetzt haben. Anschließend ist die Konstruktion und Anwendung von Kohomologietheorien am Beispiel der Schemata bekannt.

Remarks:

Wer MTH-1501 bzw. MTH-1500 bereits bestanden hat, kann für dieses Modul nicht zugelassen werden: die Inhalte sind identisch.

Workload:

Total: 240 h

Conditions:		**Credit Requirements:**
none		Bestehen der Modulprüfung
Frequency: each semester	**Recommended Semester:**	**Minimal Duration of the Module:** semester[s]

Contact Hours:	Repeat Exams Permitted:
6,00	according to the examination regulations of the study program

Parts of the Module

Part of the Module: Schematheorie II

Language: German

Contact Hours: 6,00

Contents:

Das Modul besteht aus einer Einführung in die Sprache der modernen algebraischen Geometrie. Zentraler Begriff ist der des Schemas: Ein Schema ist ein geometrisches Objekt, welches lokal durch einen kommutativen Ring beschrieben wird. Die Anwendungsmöglichkeiten der Schematheorie sind vielfältig, da der Begriff eines kommutativen Ringes überall in der Mathematik auftaucht, etwa als Koordinatenring einer affinen Varietät oder als Ring ganzer Zahlen in einem Zahlkörper. Im Rahmen des Moduls werden grundlegende Eigenschaften von Schemata und Morphismen zwischen Schemata behandelt, etwa Glattheit, Normalität, Flachheit, Dimension, Irreduzibilität und Endlichkeit. Anschließend werden Kohomologietheorien für Schemata am Beispiel der Zariski- und der étalen Topologie besprochen.

Tensorprodukte, Flachheit und Vervollständigung von Ringen

Spektrum eines kommutativen Ringes

Geringte topologische Räume

Schemata

Reduzierte und ganze Schemata

Dimension

Basiswechsel

Algebraische Varietäten

Globale Eigenschaften von Morphismen

Normale Schemata

Reguläre Schemata

Flache und glatte Morphismen

Modulgarben

Grothendieck-Topologien und Siten

Zariski-Topologie

Étale Topologie

Studenten, die zudem Veranstaltungen in Differentialgeometrie besucht haben, werden ebenfalls auf differentialgeometrische Objekte eine neue Sichtweise kennenlernen.

Voraussetzungen: Kommutative Algebra/Computeralgebra (Algebra II)

Examination

MTH-1509 Schematheorie II

oral exam, graded

Test Frequency:

each semester

Module MTH-1518: Riemannian Geometry *Riemannsche Geometrie*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Bernhard Hanke		
Contents: What is the geometry of our space? Euclidean? But how are we to know whether two parallels behind the next bush still have the same distance? How are we to judge geometry on a large scale, even in outer space, when we can hardly move away from our patch of earth? Riemannian geometry introduces a concept flexible enough to describe a geometry that looks locally Euclidean, but about whose global structure we may have no knowledge. The distinguishing feature from Euclidean geometry is curvature, the most important concept in this theory. We will study this geometry in small and large scale. Naturally, we will also cover the basics of Einstein's General Relativity, in which the geometry of space and time is coupled with the mass distribution in the universe. Submanifolds of Euclidean space Covariant derivative (Levi-Civita derivative) Curvature General relativity Geodesics in the small and large Completeness Role of curvature for topology		
Learning Outcomes / Competences: Combining geometric thinking with analytical methods, understanding the interrelationships of local and global geometry.		
Workload: Total: 240 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: Introduction to Geometry		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Riemannsche Geometrie **Language:** English **Frequency:** every 4th semester **Workload:** 2 Std. Übung (Präsenzstudium) 4 Std. Vorlesung (Präsenzstudium) **Contact Hours:** 6,00
Contents:

Literature:

J.-H. Eschenburg, J. Jost: Differentialgeometrie und Minimalflächen. Springer, 2007.
W. Kühnel: Differentialgeometrie. Vieweg, 1999.
S.Gallot, D.Hulin, J.Lafontaine: Riemannian Geometry. Springer, 1990.
J. Jost: Riemannian Geometry and Geometric Analysis. Springer, 2008.
M. Do Carmo: Riemannian Geometry. Birkhäuser, 1992.
D.Gromoll, W.Klingenberg, W.Meyer: Riemannsche Geometrie im Großen. Springer LN 55, 1975.

Examination

Riemannian Geometry

oral exam / length of examination: 30 minutes, graded

Test Frequency:

this semester

Module MTH-1528: Differential Topology *Differentialtopologie*		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Bernhard Hanke		
Contents: This lecture is devoted to the theory of differentiable manifolds from the point of view of analysis and topology. The material covered is fundamental for a deeper understanding of differential geometry and global analysis. Differentiable manifolds Tangent space Flows Foliations Fiber bundles Transversality de Rham cohomology Chern-Weil theory exotic spheres H-Cobordism Theorem		
Learning Outcomes / Competences: Development and training of geometrical intuition while mastering modern mathematical language and reasoning. Understanding of the basic concepts of differential topology. Development of basic knowledge for special lectures in geometry and topology.		
Remarks: Cannot be combined together with MTH-1520.		
Workload: Total: 240 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: Knowledge to elementary geometry and topology		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Differential Topology **Language:** German / English **Frequency:** every 4th semester **Workload:** 4 Std. Vorlesung (Präsenzstudium) 2 Std. Übung (Präsenzstudium) **Contact Hours:** 6,00
Contents: -

Literature:

R. Bott, L. Tu: Differential Forms in Algebraic Topology. GTM Springer.
L. Conlon: Differentiable Manifolds - A First Course. Birkhäuser.
M. Hirsch: Differential Topology. GTM Springer.
J. Milnor: Topology from the Differentiable Viewpoint. Princeton University Press.
J. Milnor: Lectures on the H-Cobordism Thereom. Princeton University Press.

Assigned Courses:

Differential Topology (lecture + exercise)
*(in attendance) *

Examination

Differential Topology
portfolio exam / length of examination: 30 minutes, graded

Test Frequency:
this semester

Module MTH-1538: Algebraic Topology *Algebraische Topologie*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Bernhard Hanke		
Contents: This module provides an introduction to algebraic topoolgy, that is, the systematic use of algebraic tools in the study of topological problems. Mathematical content includes: Fundamental group, covering spaces, categories, cellular complexes, cellular and singular homology and cohomology, homotopy theory, fiber bundles.		
Learning Outcomes / Competences: Students will be able to use algebraic tools that allow them to translate geometric notion into exact arguments.		
Remarks: Dieses Modul kann nicht gleichzeitig mit MTH-1530 eingebracht werden		
Workload: Total: 240 h		
Conditions: Basic knowledge in algebra and geometry.		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Algebraische Topologie I
Language: English / German
Contact Hours: 6,00

Contents:

Dieses Modul bietet eine Einführung in die Algebraische Topoolgie, also die systematische Nutzung algebraischer Hilfsmittel beim Studium topologischer Fragestellungen.

Mathematische Inhalte sind unter anderem: Fundamentalgruppe, Überlagerungen, Kategorien, Zellkomplexe, zelluläre und singuläre Homologie und Kohomologie, Homotopietheorie, (Ko-)Faserungen

Lehr-/Lernmethoden:

Vorlesung und Übung

Literature:

Bredon, G.E.: Topology and Geometry, vol. 139, Graduate Texts in Mathematics. Springer-Verlag, 1993.

Dold, A.: Lectures on Algebraic Topology, vol. 200. Grundlehren der mathematischen Wissenschaften in Einzeldarstellungen, Springer-Verlag, 1972.

Spanier, E.: Algebraic Topology. McGraw-Hill, 1966.

May, J.P.: A Concise Course in Algebraic Topology, University of Chicago Press, 1999.

Assigned Courses:

Algebraische Topologie (lecture + exercise)
**(in attendance) **

Examination

Algebraische Topologie

portfolio exam, graded

Test Frequency:

this semester

Module MTH-1548: Calculus of Variations

Variationsrechnung

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Bernd Schmidt

Learning Outcomes / Competences:
Die Student(inn)en kennen klassische Herangehensweisen sowie moderne Zugänge zu Problemen der Variationsrechnung. Sie sind in der Lage, theoretische Modelle naturwissenschaftlicher Probleme in einfachen Fällen selbst zu formulieren, solche Modelle aber auch in komplexen Situationen zu verstehen und problemorientiert zu analysieren.

Remarks:
Kann nicht gemeinsam mit MTH-1540 eingebracht werden

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions: none		**Credit Requirements:** Solide Analysiskenntnisse, die die wesentlichen Inhalte der Vorlesungen Analysis 1, 2 und 3 sowie der Funktionalanalysis abdecken.
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Variationsrechnung
Language: English
Frequency: irregular
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
klassische Probleme der Variationsrechnung, Euler-Lagrange-Gleichungen, Funktionenraeume, (semi-)konvexe Analysis, direkte Methode der Variationsrechnung, Anwendungen
Voraussetzungen: Solide Kenntnisse der mehrdimensionalen Differential- und Integralrechnung sowie der Grundlagen der Funktionalanalysis.

Literature:
Dacorogna: Direct Methods in the Calculus of Variations. Springer.

Examination
Variationsrechnung
portfolio exam, graded
Test Frequency:
not this semester

Module MTH-1558: Nonlinear Partial Differential Equations *Nichtlineare partielle Differentialgleichungen*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Bernd Schmidt	
Learning Outcomes / Competences: Die Student(inn)en kennen moderne Zugänge zu ausgewählten Beispielklassen in der Theorie der partiellen Differentialgleichungen. Sie sind in der Lage, aufbauend auf den Inhalten der Vorlesung Forschungsliteratur in diesen Gebieten zu lesen und sich selbstständig in weiterführende Aspekte einzuarbeiten.	
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)	
Conditions: none	**Credit Requirements:** Solide Analysiskenntnisse, die die wesentlichen Inhalte der Vorlesungen Analysis 1, 2 und 3 sowie der Funktionalanalysis abdecken. Es wird dringend empfohlen, eine einführende Veranstaltung zu partiellen Differentialgleichungen gehört zu haben.

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Nichtlineare Partielle Differentialgleichungen

Language: English
Frequency: irregular
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:

Ausgewählte Aspekte der Theorie der Nichtlinearen Partiellen Differentialgleichungen

Voraussetzungen: Solide Kenntnisse der mehrdimensionalen Differential- und Integralrechnung, Funktionalanalysis sowie der schwachen Lösungtheorie linearer elliptischer Gleichungen.

Literature:

* Gilbarg, D., Trudinger, N.S.: Elliptic Partial Differential Equations of Second Order (Springer, 1977)

* Giusti, E.: Direct Methods in the Calculus of Variations (World Scientific Publishing, 2003)

* Giaquinta, M., Martinazzi, L.: An Introduction to the Regularity Theory for Elliptic Systems, Harmonic Maps and Minimal Graphs (Edizioni della Normale, 2012,

* Evans, L.C.: Partial Differential Equations (AMS, 1998),

* Renardy, M., Rogers, R.C.: An Introduction to Partial Differential Equations (Springer, 1993),

* Schweizer, B.: Partielle Differentialgleichungen (Springer, 2013)

Assigned Courses:

Nichtlineare partielle Differentialgleichungen: Mathematische Methoden für die Navier-Stokes-Gleichungen (lecture)

**(in attendance) **

Examination

Nichtlineare Partielle Differentialgleichungen

oral exam / length of examination: 25 keine Einheit gewählt, graded

Test Frequency:

this semester

Module MTH-1568: Stochastic Differential Equations

Stochastische Differentialgleichungen

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Dirk Blömker

Contents:
This module introduces the theory of stochastic differential equations.
Ito formula, Ito isometry, Ito integral, martingales, Brownian motion, existence and uniqueness theorem, diffusion processes, partial differential equations, Black-Scholes formula, Option pricing

Learning Outcomes / Competences:
The students know the fundamental terms, concepts and phenomena of stochastic
of stochastic analysis, especially of stochastic differential equations.
Ability to independently compile further literature
for applications in the field of financial mathematics and stochastic dynamics,
Competences in the independent processing of problems,
Skills in the formulation and processing of theoretical questions using the
theoretical questions with the help of the methods learned
Integrated acquisition of key qualifications:
Independent work with (English-language) scientific literature,
Scientific thinking, in-depth competences in the independent processing of problems, skills in formulating and processing theoretical questions.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
A good basic knowledge of probability theory and analysis is required.
and calculus.
Helpful, but not absolutely necessary, is previous knowledge of
in ordinary differential equations
and stochastic processes.

Credit Requirements:
Oral exam

Frequency: every 4th semester	**Recommended Semester:** 1. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Stochastische Differentialgleichungen
Mode of Instruction: lecture
Lecturers: Prof. Dr. Dirk Blömker
Language: English
Frequency: every 4th semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:

This module introduces the theory of stochastic differential equations.
Ito formula, Ito isometry, Ito integral, martingales, Brownian motion, existence and uniqueness theorem, diffusion processes, partial differential equations, Black-Scholes formula, Option pricing

Literature:

Oksendal: Stochastic Differential Equations. Springer.
Karatzas Shreve: Brownian Motion and Stochastic Calculus. Springer.
Evans: An Introduction to Stochastic Differential Equations.
Steele: Stochastic Calculus and Financial Applications. Springer.

Examination

Stochastische Differentialgleichungen

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1578: Dynamical Systems *Dynamische Systeme*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Dirk Blömker	
Contents: among others: dynamical systems, attractors, invariant manifolds, semi-flows, Markov semigroups, invariant measures, iterated mappings, chaos	
Learning Outcomes / Competences: The students know the basic terms, concepts and phenomena in the field of in the field of dynamical systems. Ability to work independently on further literature, Competences in the independent processing of problems, Skills to formulate and work on theoretical questions using the questions with the aid of the methods learnt. Integrated acquisition of key qualifications: Independent work with (English-language) scientific literature, scientific thinking, in-depth competences in the independent processing of problems, Skills in formulating and working on theoretical questions.	
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)	
Conditions: Good knowledge of linear algebra and analysis. Basic knowledge of functional analysis and differential equations is helpful.	**Credit Requirements:** oral exam

Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Dynamische Systeme

Mode of Instruction: lecture
Language: English
Frequency: every 4th semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
among others: dynamical systems, attractors, invariant manifolds, semi-flows, Markov semigroups, invariant measures, iterated mappings, chaos

Assigned Courses:

Dynamische Systeme (lecture)
**(in attendance) **

Examination

Dynamische Systeme

oral exam / length of examination: 30 minutes, graded

Test Frequency:

this semester

Module MTH-1588: Control Theory *Kontrolltheorie*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Tatjana Stykel		
Learning Outcomes / Competences: Förderung von abstraktem Denken, Anwenden analytischer und geometrischer Methoden im Anwendungszusammenhang. Die Studenten sollen in einem mathematisch relativ einfachen, linearen Kontext die grundlegenden Fragestellungen der Kontrolltheorie und Konzepte zu deren Lösung lernen. Ferner sollen sie die Befähigung zum selbständigen Erarbeiten der aktuellen Forschungsliteratur erwerben.		
Workload: Total: 240 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: none		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Kontrolltheorie

Language: German
Frequency: irregular
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:

Dieses Modul führt in die mathematische Kontrolltheorie ein.

- Lineare Steuerungssysteme
- Steuerbarkeit und Beobachtbarkeit
- Rekonstruierbarkeit und Beobachtbarkeit
- Stabilität
- Stabilisierbarkeit und Entdeckbarkeit
- Polvorgabe
- Linear-quadratisches Optimierungsproblem

Voraussetzungen: Kenntnisse in Analysis auf endlich dimensionalen Räumen, gewöhnliche Differentialgleichungen, Numerik

Literature:

Knobloch, H.W., Kwakernaak, H. Lineare Kontrolltheorie. Springer, 1985

Sontag, E.: Mathematical Control Theory. Springer, 1998.

Hinrichsen, D., Pritchard, A.J.: Mathematical Systems Theory I. Springer, 2005.

Examination

Kontrolltheorie

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1598: Numerical analysis of partial differential equations *Numerik partieller Differentialgleichungen*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Daniel Peterseim	
Learning Outcomes / Competences: Understanding of finite differences as well as the ideas of the finite element method generally as well as construction of Lagrange elements with respect to simplicial triangulations and a posteriori error estimation for elliptic problems; convergence results, connections between methods as well as their advantages and disadvantages, with respect to application to concrete problems in particular; complex algorithms; integrated acquisition of key qualifications: In small groups, students learn to define problems precisely, to develop numerical solution strategies and to assess their suitability, while developing social skills for working together in a team.	
Remarks: Kann nicht mit MTH-1590 gemeinsam eingebracht werden	
Workload: Total: 240 h 2 h exercise course (attendance) 4 h lecture (attendance)	
Conditions: Recommended: analysis (particularly functional analysis), introduction to numerical analysis, numerical analysis of ordinary differential equations	

Frequency: each winter semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Numerik partieller Differentialgleichungen

Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Malte Peter
Language: English / alle Sprachen
Frequency: each winter semester
Workload:

4 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)

Contact Hours: 6,00

Contents:

Es werden die Grundlagen der Standardmethoden zur numerischen Lösung partieller Differentialgleichungen behandelt.

Finite-Differenzen-Methode auf rechteckigen und nicht rechteckigen Gebieten
Finite-Elemente-Methode inkl. Triangulierung
Lagrange-Elemente
Adaptivität für elliptische Probleme

Literature:

Grossmann, C., Ross, H.-G.: Numerische Behandlung partieller Differentialgleichungen. Teubner, 2005 .
Hackbusch: Theorie und Numerik elliptischer Differentialgleichungen. Springer. 2010

Assigned Courses:

Numerik partieller Differentialgleichungen (lecture + exercise)

*(in attendance) *

Examination

Numerik partieller Differentialgleichungen

oral exam / length of examination: 30 minutes, graded

Test Frequency:

only in the winter semester

Module MTH-1608: Multiscale Methods *Multiskalenmethoden*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Malte Peter		
Learning Outcomes / Competences: Deeper understanding of the finite element method in its most important versions; connections between methods as well as their advantages and disadvantages, with respect to application to concrete problems in particular; understanding of the problems arising from multiple scales as well as basic solution ideas; complex algorithms; integrated acquisition of key qualifications: In small groups, students learn to define problems precisely, to develop numerical solution strategies and to assess their suitability, while developing social skills for working together in a team.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		
Frequency: irregular	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Multiskalenmethoden
Mode of Instruction: lecture + exercise
Language: English / German
Frequency: irregular
Workload:
4 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Aufbauend auf grundlegende Inhalte der Module Numerik partieller Differentialgleichungen bzw. Methoden der finiten Elemente werden weiterführende Aspekte der Finite-Elemente-Methode behandelt, insbesondere im Hinblick auf Multiskalenprobleme.
Finite-Elemente-Methode und parabolische Gleichungen
Discontinuous Galerkin Method
Einführung in Multiskalenprobleme
Multiskalen-Finite-Elemente-Methode
Voraussetzungen: Es wird empfohlen, die mit dem erfolgreichen Absolvieren einer der Module "Numerik partieller Differentialgleichungen" oder "Finite Elemente Methoden" einhergehenden Kompetenzen erworben zu haben.

Literature:
C. Grossmann, H.-G. Roos: Numerische Behandlung partieller Differentialgleichungen. Teubner.
Y. Efendiev, T. Y. Hou: Multiscale Finite Element Methods. Springer.

Examination

Multiskalenmethoden

module exam, mündliche Prüfung / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1618: Mathematical modelling *Mathematische Modellierung*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Malte Peter		
Learning Outcomes / Competences: Understanding of describing real-world processes in terms of mathematical objects; integrated acquisition of key qualifications: In small groups, students learn to define problems precisely, to develop numerical solution strategies and to assess their suitability, while developing social skills for working together in a team.		
Remarks: Kann nicht gemeinsam mit MTH-1610 eingebracht werden		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Mathematische Modellierung **Mode of Instruction:** lecture + exercise **Language:** English / alle Sprachen **Frequency:** irregular **Contact Hours:** 6,00

Examination
Mathematische Modellierung portfolio exam, graded **Test Frequency:** this semester

Module MTH-1628: Combinatorial Optimization *Kombinatorische Optimierung (Optimierung III)*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Mirjam Dür		
Remarks: Dieses Modul kann nicht gemeinsam mit MTH-1620		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Module Introduction to Optimisation (MTH-1140) - recommended Module Introduction to Nonlinear and Combinatorial Optimisation (MTH-1200) - recommended		
Frequency: each summer semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Kombinatorische Optimierung (Optimierung III)
Mode of Instruction: lecture
Language: German
Frequency: each summer semester
Contact Hours: 6,00

Contents:

In dieser Vorlesung geht es um folgende Themen der diskreten Optimierung:

- Komplexität und Algorithmen
- Matchings
- Flüsse und Netzwerke
- Kostenminimale Flüsse
- Approximationsalgoritmen

Examination

Kombinatorische Optimierung (Optimierung III)

oral exam / length of examination: 30 minutes, graded

Test Frequency:

only in the summer semester

Module MTH-1658: Discrete Mathematics (Optimisation IV) *Diskrete Mathematik (Optimierung IV)*	8 ECTS/LP
Version 1.0.0 Person responsible for module: apl. Prof. Dr. Dirk Hachenberger	
Contents: Ergänzung zur Vorlesung Kombinatorische Optimierung aus dem Sommersemester, insbesondere sollen voraussichtlich folgende Themen behandelt werden: NP-Vollständigkeit, Matroide, Zirkulationen und Flüsse minimaler Kosten, Netzwerk-Simplex-Algorithmus	
Learning Outcomes / Competences: Die Studierenden sollen anhand fortgeschrittener Fragestellungen vertiefte Kenntnisse über diskrete Optimierungsprobleme erwerben. Insbesondere soll die Interaktion von allgemeinen theoretischen Ansätzen und konkreten Problemen auf einem höheren Abstraktionsniveau erfasst werden.	
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)	
Conditions: Module Introduction to Optimisation (MTH-1140) - recommended Module Introduction to Nonlinear and Combinatorial Optimisation (MTH-1200) - recommended Module Combinatorial Optimisation (Optimisation III) (MTH-1620) - recommended	

Frequency: as needed	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Diskrete Mathematik (Optimierung IV)

Mode of Instruction: lecture
Language: German
Frequency: as needed
Contact Hours: 6,00

Learning Outcome:

Die Studierenden sollen anhand fortgeschrittener Fragestellungen vertiefte Kenntnisse über diskrete Optimierungsprobleme erwerben. Insbesondere soll die Interaktion von allgemeinen theoretischen Ansätzen und konkreten Problemen auf einem höheren Abstraktionsniveau erfasst werden.

Contents:

Ergänzung zur Vorlesung Kombinatorische Optimierung aus dem Sommersemester, insbesondere sollen voraussichtlich folgende Themen behandelt werden: NP-Vollständigkeit, Matroide, Zirkulationen und Flüsse minimaler Kosten, Netzwerk-Simplex-Algorithmus

Literature:

Jungnickel, D.: Graphs, Networks and Algorithms, 4th edition (English), Springer, 2013.

Examination

Diskrete Mathematik (Optimierung IV)

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1668: Mathematical Statistics (Stochastics III)

Mathematische Statistik (Stochastik III)

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Sarah Friedrich

Contents:
Auswahl aus fortgeschrittenen Themen der Statistik, z.B.

nichtparametrische Methoden (z.B. Kerndichteschätzer), lineare Modelle, Markov-Ketten,
Bayessche Statistik
oder
Zeitreihenmodelle, ARMA-Prozesse, Parameter-Schätzung bei abhängigen Daten, Zustandsraum-Modelle

Learning Outcomes / Competences:
Verständnis der mathematischen Grundlagen bei den unter „Inhalte“ genannten fortgeschrittenen Themen der Statistik; Fähigkeit, Daten mit Hilfe von geeigneten Modellen zu analysieren und zu interpretieren; Kenntnisse von wichtigen statistischen Modellen und Schätzverfahren

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
Einführung in die Stochastik (Stochastik I) / Stochastik II

Lineare Algebra I und Analysis I und II

Frequency: each winter semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Statistische Modelle und Verfahren (Stochastik III)

Language: German
Frequency: each winter semester
Workload:
4 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)
Contact Hours: 6,00

Learning Outcome:
Verständnis der mathematischen Grundlagen bei den unter „Inhalte“ genannten fortgeschrittenen Themen der Statistik; Fähigkeit, Daten mit Hilfe von geeigneten Modellen zu analysieren und zu interpretieren; Kenntnisse von wichtigen statistischen Modellen und Schätzverfahren

Contents:
Auswahl aus fortgeschrittenen Themen der Statistik, z.B.

nichtparametrische Methoden (z.B. Kerndichteschätzer), lineare Modelle, Markov-Ketten,
Bayessche Statistik
oder
Zeitreihenmodelle, ARMA-Prozesse, Parameter-Schätzung bei abhängigen Daten, Zustandsraum-Modelle

Literature:

Themenabhängig - wird in der Vorlesung bekanntgegeben

Assigned Courses:

Mathematische Statistik (Stochastik III) (lecture)

*(in attendance) *

Mathematische Statistik (Stochastik III) (exercise course)

*(in attendance) *

Examination

Statistische Modelle und Verfahren (Stochastik III)

module exam, Klausur / length of examination: 90 minutes, graded

Test Frequency:

this semester

Module MTH-1678: Probability IV *Stochastische Prozesse (Stochastik IV)*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Stefan Großkinsky		
Learning Outcomes / Competences: Die Studierenden sollen die nötigen mathematischen Konzepte zur Beschreibung zufälliger, zeitabhängiger Prozesse verstehen und mit ihnen umgehen können. Darüber hinaus sollen sie wichtige Beweiskonzepte und Konstruktionen aus dem Bereich der stochastischen Prozesse beherrschen.		
Remarks: Kann nicht gemeinsam mit MTH-1670 eingebracht werden		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Lineare Algebra I Analysis I Analysis II Einführung in die Stochastik (Stochastik I) Einführung in die mathematische Statistik (Stochastik II)		
Frequency: each summer semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Stochastische Prozesse (Heydenreich)
Lecturers: Prof. Dr. Markus Heydenreich
Language: English / German
Frequency: every 4th semester
Contact Hours: 6,00

Contents:

Es werden folgende Kernthemen behandelt:

1. Strenge Einführung des Begriffs "Stochastischer Prozess" und "Stochastisches Feld" mit Beispielen.
2. Pfadeigenschaften der Stochastischen Prozesse.
3. Gaußsche Prozesse, Lévy-Prozesse.
4. Brownsche Bewegung und ihre Eigenschaften.
5. Poisson-Prozess.
6. Irrfahrten und Konvergenz gegen Brownsche Bewegung.

Literature:

Wird in der Vorlesung bekannt gegeben.

Part of the Module: Stochastische Prozesse (Großkinsky)
Lecturers: Prof. Dr. Stefan Großkinsky
Language: English / German
Frequency: every 4th semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
- Prozesse in diskreter Zeit: Markov Ketten, Gaußsche Prozesse, Martingale
- Konstruktion stochastischer Prozesse nach Kolmogorov und Pfadeigenschaften
- Erneuerungsprozesse, Poisson Prozess, Markov Ketten in stetiger Zeit
- Diffusionsprozesse, Brownsche Bewegung
- Sprungprozesse, Lévy Prozesse

Literature:
Wird in der Vorlesung bekannt gegeben.

Examination
Stochastische Prozesse (Stochastik IV)
oral exam / length of examination: 30 minutes, graded
Test Frequency:
only in the summer semester

Module MTH-1688: Optimisation IV (Global Optimisation)

Optimierung IV (Globale Optimierung)

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Mirjam Dür

Learning Outcomes / Competences:
Nach der Teilnahme an diesem Modul verfügen die Studierenden über detailliertes und aktuelles Wissen auf dem Gebiet der Globalen Optimierung. Sie können Problemstellungen und Ergebnisse des Gebiets präzise beschreiben und diskutieren. Darüber hinaus verstehen die Studierenden grundlegende Konzepte, Methoden, Verfahren und Techniken aus dem genannten Gebiet und können diese in Entwicklungsprojekten anwenden und dort aktiv mitarbeiten. Außerdem verfügen sie über die Team- und Kommunikationsfähigkeit, um Problemstellungen auf dem Gebiet zu erörtern, Fragen und Zwischenergebnisse zu diskutieren und zu präsentieren.

Workload:
Total: 240 h

Conditions:
- Modul Einführung in die Optimierung (Optimierung I) (MTH-1140) - empfohlen
- Modul Nichtlineare und kombinatorische Optimierung (Optimierung II) (MTH-1200) - empfohlen
- Modul Kombinatorische Optimierung (Optimierung III) (MTH-1620) - empfohlen

Credit Requirements:
Bestehen der Modulprüfung

Frequency: irregular (usu. winter semester)

Recommended Semester:
1. - 4.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
6,00

Repeat Exams Permitted:
according to the examination regulations of the study program

Parts of the Module

Part of the Module: Globale Optimierung (Optimierung IV)

Lecturers: Prof. Dr. Mirjam Dür
Language: German
Frequency: irregular (usu. winter semester)

Contents:
- Konvexe Relaxierungen und konvexe Hüllfunktionale
- D.C. Funktionen
- Quadratische Optimierungsprobleme
- Branch-and-Bound für boxrestringierte Probleme
- Branch-and-Bound für konvex restringierte Probleme
- Branch-and-Bound für nichtkonvexe Probleme
- Heuristiken

Literature:
- O.Stein: Grundzüge der Globalen Optimierung. Springer Verlag 2018
- M.Locatelli, F.Schoen: Global Optimization. SIAM 2013
- R.Horst, P.Pardalos, N.V.Thoai: Introduction to Global Optimization. Kluwer Academic Publishers 1995

Assigned Courses:

Globale Optimierung (Optimierung IV) (lecture + exercise)
**(in attendance) **

Examination

Globale Optimierung (Optimierung IV)

module exam, Der konkrete Typ der Modulprüfung (Klausur oder mündliche Prüfung oder Portfolio) wird jeweils spätestens eine Woche vor Beginn der Veranstaltung bekannt gegeben., graded

Test Frequency:

this semester

Module MTH-1698: Parabolic Partial Differential Equations *Parabolische partielle Differentialgleichungen*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Dirk Blömker	
Contents: selected topics in parabolic PDEs, existence and uniqueness of solutions, energy estimates, dynamics	
Learning Outcomes / Competences: The students know modern approaches to selected example classes in the theory of parabolic partial differential equations. They are able to read research literature in these areas based on the contents of the lecture and to work independently on further aspects.	
Workload: Total: 240 h	
Conditions: Prerequisites: Solid knowledge of multidimensional differential and integral calculus, functional analysis. Knowledge of ordinary differential equations or the weak solution theory of linear elliptic equations is helpful.	**Credit Requirements:** oral exam

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Parabolische partielle Differentialgleichungen

Language: English
Frequency: irregular
Contact Hours: 6,00

Contents:

Voraussetzungen: Solide Kenntnisse der mehrdimensionalen Differential- und Integralrechnung, Funktionalanalysis. Hilfreich sind Kenntnisse in gewöhnlichen Differentialgleichungen oder der schwachen Lösungtheorie linearer elliptischer Gleichungen.

Examination

Parabolische partielle Differentialgleichungen

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1788: Stochastic Modelling of Complex Systems

Stochastische Modellierung komplexer Systeme

8 ECTS/LP

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr. Stefan Großkinsky

Learning Outcomes / Competences:
Verständnis von mathematischen Konzepten in der stochastischen Modellierung, insbesondere für komplexe Systeme aus vielen wechselwirkenden Bestandteilen.

Studierende erlernen wie ein Anwendungsbeispiel mathematisch beschrieben werden kann, sowie wichtige Techniken für die deren theoretische und numerische Analyse.

Besonders wichtig ist das Verständnis von Skalenlimiten in großen Systemen, das asymptotische Verhalten und mögliche Phasenübergänge in komplexen Systemen.

Workload:
Total: 240 h

Conditions:		**Credit Requirements:**
Wahrscheinlichkeits- und Maßtheorie		Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Stochastische Modellierung komplexer Systeme

Language: English / German
Contact Hours: 6,00

Contents:

1. Kurze Wiederholung/Einführung von Markov Prozessen in stetiger Zeit als Zufallsvariablen auf dem Pfadraum.
2. Beschreibung von Feller Markov Prozessen durch Halbgruppen und Generatoren auf dem Raum der stetigen Testfunktionen. Beispiele: Markov-Ketten, Diffusionspozesse, Sprungprozesse, Lévy Prozesse.
3. Charakterisierung von Markov Prozessen durch Martingalprobleme, Formeln von Dynkin, Itô, Feynman-Kac und Girsanov.
4. Stochastische Interagierende Teilchensysteme (IPS) als Modelle komplexer Systeme und als Feller Prozesse: Spin-systeme, Votermodell, Kontaktprozess, Exklusions- und Inklusionspozess, Zero-range Prozess.
5. Charakterisierung von stationären Verteilungen, Reversibilität, Erhaltungssätze und Symmetrien. Theorie der Phasenübergänge. Als wichtige Tools führen wir Dualität und Kopplung ein.
6. Hydrodynamische Grenzwertsätze, die das Verhalten von IPS auf großen Skalen durch PDEs oder ODEs beschreiben im Sinne eines funktionalen GGZ.
7. Funktionaler ZGS zur Beschreibung der Fluktuationen, z.B. Donskers Invarianzprinzip für Brownsche Bewegung und Ornstein-Uhlenbeck Prozesse.
8. Große Abweichungen für Markov Prozesse.

Examination

Stochastische Modellierung komplexer Systeme
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-1809: Approaches Axiomatic Set Theory *Betrachtungen zur Axiomatische Mengenlehre*	8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Contents:

- Axiomatische Mengenlehre
- Logische Grundlagen
- ZFC-Axiome
- Ordinalzahlen
- Kardinalzahlen
- Große Kardinalzahlen
- Ausblick

Learning Outcomes / Competences:

1. **Grundlegende Vertrautheit mit den Axiomen**: Die Studierenden sollen ein Verständnis für die grundlegenden Axiome der Mengenlehre entwickeln, insbesondere das Zermelo-Fraenkel-Axiomensystem und das Auswahlaxiom.
2. **Fähigkeit zur Formulierung von mathematischen Aussagen**: Die Studierenden sollen in der Lage sein, mathematische Aussagen in der Sprache der Mengenlehre zu formulieren und dabei die vorgegebenen Axiome korrekt anzuwenden.
3. **Verständnis von Mengenoperationen**: Die Studierenden sollen die grundlegenden Mengenoperationen wie Vereinigung, Schnitt, Differenz und kartesisches Produkt verstehen und in konkreten Beispielen anwenden können.
4. **Einsicht in die Konstruktion von Zahlen**: Die Studierenden sollen verstehen, wie natürliche Zahlen, ganze Zahlen, rationale Zahlen und reelle Zahlen in der Mengenlehre konstruiert werden können.
5. **Beweistechniken in der Mengenlehre**: Die Studierenden sollen grundlegende Beweistechniken wie direkten Beweis, Beweis durch Kontraposition, Beweis durch Widerspruch und Mengeninklusion beherrschen und auf verschiedene mathematische Aussagen anwenden können.
6. **Verständnis von Abbildungen und Relationen**: Die Studierenden sollen das Konzept von Abbildungen zwischen Mengen sowie von Relationen verstehen und in der Lage sein, diese zu analysieren und zu beschreiben.
7. **Kardinalität und Ordnungen**: Die Studierenden sollen ein Verständnis für verschiedene Arten von Kardinalität (endlich, abzählbar unendlich, überabzählbar) und Ordnungsrelationen entwickeln.
8. **Anwendung der Mengenlehre in anderen mathematischen Bereichen**: Die Studierenden sollen in der Lage sein, die Konzepte und Techniken der axiomatischen Mengenlehre in anderen mathematischen Disziplinen wie Analysis, Topologie oder Algebra anzuwenden.
9. **Fähigkeit zur kritischen Reflexion**: Die Studierenden sollen in der Lage sein, die Annahmen und Axiome der Mengenlehre zu reflektieren und deren Auswirkungen auf die Mathematik zu verstehen.
10. **Selbstständiges Lernen und Forschen**: Die Studierenden sollen in der Lage sein, eigenständig weiterführende Literatur zu recherchieren und komplexe mathematische Konzepte im Kontext der axiomatischen Mengenlehre zu verstehen und zu analysieren

Workload:
Total: 240 h

Conditions:	**Credit Requirements:**
Keine besonderen Voraussetzungen nötig.	Bestehen der Modulprüfung

Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:**
	from 1.	semester[s]

Contact Hours:	Repeat Exams Permitted:
6,00	according to the examination regulations of the study program

Parts of the Module

Part of the Module: Betrachtungen zur Axiomatische Mengenlehre
Language: German / English
Frequency: irregular
Contact Hours: 6,00

Examination
MTH-1809 Betrachtungen zur Axiomatische Mengenlehre
oral exam / length of examination: 20 minutes
work period for assignment: 4 months, graded
Test Frequency:
each semester

Module MTH-1820: Entropy and Information *Entropie und Information*		6 ECTS/LP
Version 1.1.0 (since WS15/16 to SoSe25) Person responsible for module: Prof. Dr. Fritz Colonius		
Learning Outcomes / Competences: Förderung von abstraktem Denken, Anwenden analytischer Methoden in der Dynamik. Verständnis für die Querverbindungen mathematischer Einzelgebiete am Beispiel der Beziehungen zwischen Maßtheorie, Wahrscheinlichkeitstheorie und Dynamik.		
Workload: Total: 180 h 2 h exercise course (attendance) 2 h lecture (attendance)		
Conditions: none		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Entropie und Information

Language: German
Frequency: every 4th semester
Workload:
2 Std. Übung (Präsenzstudium)
2 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Contents:

Dieses Modul führt in die Aspekte der Theorie dynamischer Systeme ein.
Topologische und maßtheoretische Entropie
symbolische Dynamik
Voraussetzungen:

Literature:

Lind, D., Marcus, B.: An introduction to Symbolic Dynamics and Coding. Cambridge University Press, 2003.
Robinson: Dynamical Systems, Stability, Symbolic Dynamics and Chaos. CRC Press, 1998.

Examination

Entropie und Information

oral exam / length of examination: 30 minutes, graded

Module MTH-1860: Introduction to Projective Geometry *Einführung in die Projektive Geometrie*	6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: apl. Prof. Dr. Dirk Hachenberger	
Contents: Die Projektive Geometrie ist eines der klassischen Teilgebiete der Reinen Mathematik. Dieses Gebiet ist ursprünglich aus Fragen der Perspektive entstanden und kann heutzutage kurz als "Lineare Algebra vom geometrischen Standpunkt aus gesehen" bezeichnet werden. Alle notwendigen geometrischen Begriffe werden in der Vorlesung entwickelt werden. Neben den klassischen Fragestellungen (Einführung von Koordinaten, Kollineationen, Projektivitäten, Kegelschnitte und Quadriken...) sollen insbesondere die endlichen projektiven Räume behandelt werden. Diese Strukturen haben durch Bezüge zu Designs, Codes und Kryptosystemen neuerdings auch eine gewisse Bedeutung in den Anwendungen erlangt. Einige derartige Aspekte sollen ebenfalls angesprochen werden.	
Learning Outcomes / Competences: Erkenntnis der engen Verflechtung von Algebra und Geometrie; Mathematische Allgemeinbildung (Einblick in eines der klassischen Gebiete der Mathematik, das derzeit im Studium fast immer zu kurz kommt.	
Workload: Total: 180 h 4 h lecture (attendance)	
Conditions: Module Linear Algebra I (MTH-1000) - recommended Module Linear Algebra II (MTH-1010) - recommended	

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Einführung in die Projektive Geometrie

Mode of Instruction: lecture
Language: German
Frequency: irregular
Workload:
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Learning Outcome:
Erkenntnis der engen Verflechtung von Algebra und Geometrie; Mathematische Allgemeinbildung (Einblick in eines der klassischen Gebiete der Mathematik, das derzeit im Studium fast immer zu kurz kommt.

Contents:

Die Projektive Geometrie ist eines der klassischen Teilgebiete der Reinen Mathematik. Dieses Gebiet ist ursprünglich aus Fragen der Perspektive entstanden und kann heutzutage kurz als "Lineare Algebra vom geometrischen Standpunkt aus gesehen" bezeichnet werden. Alle notwendigen geometrischen Begriffe werden in der Vorlesung entwickelt werden. Neben den klassischen Fragestellungen (Einführung von Koordinaten, Kollineationen, Projektivitäten, Kegelschnitte und Quadriken...) sollen insbesondere die endlichen projektiven Räume behandelt werden. Diese Strukturen haben durch Bezüge zu Designs, Codes und Kryptosystemen neuerdings auch eine gewisse Bedeutung in den Anwendungen erlangt. Einige derartige Aspekte sollen ebenfalls angesprochen werden.

Voraussetzungen: Lineare Algebra I

Lineare Algebra II

Literature:

Beutelspacher, A., Rosenbaum, U.: Projektive Geometrie. Von den Grundlagen bis zu den Anwendungen. Wiesbaden, 1992.

Lenz, H.: Vorlesungen über die projektive Geometrie. Leipzig, 1965.

Examination

Einführung in die Projektive Geometrie

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1878: Mathematical Gauge Theory *Mathematische Eichtheorie*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Bernhard Hanke		
Learning Outcomes / Competences: Entwicklung und Schulung der geometrischen Anschauung bei gleichzeitiger Beherrschung der modernen mathematischen Sprache und Argumentationsweise. Verständnis der grundlegenden Konzepte der Mathematischen Eichtheorie und ihrer Verbindung zur Differentialgeometrie, Topologie und Analysis.		
Workload: Total: 240 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: none		
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Mathematische Eichtheorie

Language: German
Frequency: irregular
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:

Inhalt dieser Vorlesung ist die Differentialgeometrie auf Faserbündeln über glatten Mannigfaltigkeiten. Nach einer Einführung in die grundlegenden Begriffe aus der Lie-Theorie werden Hauptfaserbündel und Vektorbündel behandelt. Anschließend diskutieren wir Zusammenhänge, ihre Krümmung und Holonomie. Im letzten Teil der Vorlesung stellen wir de Rham-Kohomologie und die Chern-Weil-Theorie charakteristischer Klassen vor.
Voraussetzungen: Einführung in die Geometrie
Topologie

Literature:

Baum, Helga: Eichfeldtheorie. Springer.
Conlon, Lawrence: Differentiable Manifolds. Birkhäuser.

Examination

Mathematische Eichtheorie
module exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-1900: Introduction to Cryptography

Einführung in die Kryptographie

6 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: apl. Prof. Dr. Dirk Hachenberger

Contents:
Die Kryptographie ist dasjenige Teilgebiet der Mathematik, das sich mit der sicheren Übermittlung geheim zu haltender Nachrichten bzw. umgekehrt mit der Analyse verschlüsselter Texte beschäftigt. Derartige Themenbereiche sind von zunehmender wirtschaftlicher Bedeutung (Electronic Banking). Dabei ergeben sich viele interessante Fragestellungen wie z.B. die Möglichkeit von elektronischen Unterschriften und Zeitstempeln sowie Fragen der Authentifikation und Zugangskontrolle. In der Vorlesung soll eine Einführung in die wichtigsten Probleme und Methoden der Kryptographie gegeben werden. Nach einer kurzen historischen Einleitung werden auch einige praktisch verwendete Systeme (DES, AES, RSA-System) behandelt.

Learning Outcomes / Competences:
Algebra, Zahlentheorie und Kombinatorik sind klassische Kerngebiete der Reinen Mathematik. Die Studenten sollen an einem konkreten Beispiel erkennen, dass auch diese Teile der Mathematik praktisch relevante Anwendungen hat.

Workload:
Total: 180 h
4 h lecture (attendance)

Conditions:
Als Voraussetzungen werden lediglich die Grundvorlesungen in Linearer Algebra I und II sowie elementare Wahrscheinlichkeitstheorie benötigt.

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Einführung in die Kryptographie
Mode of Instruction: lecture
Language: German
Frequency: irregular
Workload:
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Contents:
Die Kryptographie ist dasjenige Teilgebiet der Mathematik, das sich mit der sicheren Übermittlung geheim zu haltender Nachrichten bzw. umgekehrt mit der Analyse verschlüsselter Texte beschäftigt. Derartige Themenbereiche sind von zunehmender wirtschaftlicher Bedeutung (Electronic Banking). Dabei ergeben sich viele interessante Fragestellungen wie z.B. die Möglichkeit von elektronischen Unterschriften und Zeitstempeln sowie Fragen der Authentifikation und Zugangskontrolle. In der Vorlesung soll eine Einführung in die wichtigsten Probleme und Methoden der Kryptographie gegeben werden. Nach einer kurzen historischen Einleitung werden auch einige praktisch verwendete Systeme (DES, AES, RSA-System) behandelt.
Voraussetzungen: Als Voraussetzungen werden lediglich die Grundvorlesungen in Linearer Algebra I und II sowie elementare Wahrscheinlichkeitstheorie benötigt. Auch wenn es sich um keine Pflichtvorlesung handelt, ist die Vorlesung insbesondere auch den Studenten der Wirtschaftsmathematik sehr zu empfehlen.

Literature:
Stinson, D.: Cryptography: Theory and Practice (Discrete Mathematics and its Applications).

Examination

Einführung in die Kryptographie

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1928: Nonlinear Control Theory *Nichtlineare Kontrolltheorie*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Fritz Colonius	
Learning Outcomes / Competences: Vertiefte Einsicht in die geometrische Interpretation von kontrolltheoretischen Objekten und Konzepten, die hier nichtlinearen Charakter haben und differentialgeometrische Methoden erfordern. Die Studenten sollen in die Lage versetzt werden, diese Strukturen im Anwendungszusammenhang (hier. in der Regelungstheorie) selbständig zu erkennen und die in der Veranstaltung behandelten Methoden einzusetzen. Darüber hinaus sollen sie in die Lage versetzt werden., aktuelle Forschungsliteratur selbständig zu erarbeiten.	
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)	
Conditions: none	

Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Nichtlineare Kontrolltheorie

Language: German
Frequency: each semester
Workload:
4 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Dieses Modul bietet eine Einführung in die Theorie Nichtlinearer Kontrollsysteme
Akzessibilität und Lie-algebraische Bedingungen
Kontrollmengen
Beziehungen zur Theorie dynamischer Systeme
Voraussetzungen:

Literature:
Sastry: Nonlinear Systems. Springer.
Jurdjevic: Geometric Control Theory. Cambridge.
Coron: Control and Nonlinearity. American Mathematical Society.

Examination

Nichtlineare Kontrolltheorie
oral exam / length of examination: 30 minutes, graded

Module MTH-1948: String Topology

String Topology

8 ECTS/LP

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr. Kai Cieliebak

Learning Outcomes / Competences:
Learning about methods for computing homology and homotopy groups, algebraic structures arising in the topology of loop spaces, and their applications in geometry.

Remarks:
Cannot be combined together with MTH-1940.

Workload:
Total: 240 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions: none		**Credit Requirements:** Passing the module exam.
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: String Topology

Language: English / German
Frequency: irregular
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
This course is an introduction to the algebraic topology of loop spaces, an area of growing importance in mathematics and physics. It covers the following topics: homology of based and free loop spaces, Pontrjagin product and Hopf algebras, Chas-Sullivan operations and Batalin-Vilkovisky algebras, Hochschild and cyclic homology of the de Rham complex, minimal models and applications to closed geodesics.
Voraussetzungen: Basic algebraic and and differential topology (singular homology, manifolds, differential forms)

Literature:
Cohen, R., Hess, K., Voronov, A.: String topology and cyclic homology. Birkhäuser.
Griffiths, P., Morgan, J.: Rational homotopy theory and differentiel forms. Birkhäuser.

Examination

String Topology
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-1950: Coding Theory

Codierungstheorie

6 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: apl. Prof. Dr. Dirk Hachenberger

Contents:
Die Codierungstheorie ist eine relativ junge mathematische Disziplin, die sich mit dem Entwurf von optimalen fehlererkennenden und fehlerkorrigierenden Codes beschäftigt.
Solche Codes werden überall dort verwendet, wo Informationen (bildlich gesprochen) über einen gestörten Nachrichtenkanal übertragen werden: Durch eine geeignete Codierung der Information vor der Sendung, ist es möglich auch bei Verfälschung die ursprüngliche Nachricht zu rekonstruieren.
Zu den wichtigsten Anwendungen gehören die Übertragung von Satellitenbildern sowie die Verbesserung der Qualität beim Abspielen von Compact Discs. Der mathematische Reiz der Codierungstheorie liegt im Zusammenspiel von Algebra, Kombinatorik und Zahlentheorie, zumal die sog. linearen Codes über endlichen Körpern sehr erfolgreich in der Praxis eingesetzt werden.

Nach einer Einführung und der Formulierung der Hauptproblemstellung verfolgen wir in dieser Vorlesung das Ziel, einige der wichtigsten Klassen von (optimalen) Codes zu beschreiben:

- Dazu zählen zunächst die *Hamming-Codes* und die *Reed-Solomon Codes*, die zur allgemeineren Familie der *zyklische Codes*, insbesondere den BCH-Codes gehören.
- Die *Reed-Muller-Codes* dienen als Ausgangspunkt für die Konstruktion der (optimalen) *Kerdock-* und *Preparata-Codes.*
- Die grundlegenden *Goppa-Codes* sind im Rahmen der *Funktionenkörper-Codes* mittlerweile vielfach verallgemeinert worden.

Learning Outcomes / Competences:
Algebra, Kombinatorik und Zahlentheorie sind klassische Kerngebiete der Mathematik. An dem konkreten Beispiel der Codierungstheorie sollen die Studierenden erkennen, dass durch das Zusammenspiel sehr interessante praktische Problemstellungen adäquat modelliert und gelöst werden können.

Workload:
Total: 180 h
4 h lecture (attendance)

Conditions:
Lineare Algebra I und II, Grundlagen der Algebra, der Kombinatorik und der elementare Zahlentheorie.I

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Codierungstheorie
Mode of Instruction: lecture
Language: German
Frequency: irregular
Workload:
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Learning Outcome:

Algebra, Kombinatorik und Zahlentheorie sind klassische Kerngebiete der Mathematik. An dem konkreten Beispiel der Codierungstheorie sollen die Studierenden erkennen, dass durch das Zusammenspiel sehr interessante praktische Problemstellungen adäquat modelliert und gelöst werden können.

Contents:

Die Codierungstheorie ist eine relativ junge mathematische Disziplin, die sich mit dem Entwurf von optimalen fehlererkennenden und fehlerkorrigierenden Codes beschäftigt.
Solche Codes werden überall dort verwendet, wo Informationen (bildlich gesprochen) über einen gestörten Nachrichtenkanal übertragen werden: Durch eine geeignete Codierung der Information vor der Sendung, ist es möglich auch bei Verfälschung die ursprüngliche Nachricht zu rekonstruieren.
Zu den wichtigsten Anwendungen gehören die Übertragung von Satellitenbildern sowie die Verbesserung der Qualität beim Abspielen von Compact Discs. Der mathematische Reiz der Codierungstheorie liegt im Zusammenspiel von Algebra, Kombinatorik und Zahlentheorie, zumal die sog. linearen Codes über endlichen Körpern sehr erfolgreich in der Praxis eingesetzt werden.

Nach einer Einführung und der Formulierung der Hauptproblemstellung verfolgen wir in dieser Vorlesung das Ziel, einige der wichtigsten Klassen von (optimalen) Codes zu beschreiben:

- Dazu zählen zunächst die *Hamming-Codes* und die *Reed-Solomon Codes*, die zur allgemeineren Familie der *zyklische Codes*, insbesondere den BCH-Codes gehören.
- Die *Reed-Muller-Codes* dienen als Ausgangspunkt für die Konstruktion der (optimalen) *Kerdock*- und *Preparata-Codes.*
- Die grundlegenden *Goppa-Codes* sind im Rahmen der *Funktionenkörper-Codes* mittlerweile vielfach verallgemeinert worden.

Literature:

Folgende Liste ist lediglich eine kleine Auswahl. Wir werden zusammen mit dem Vorlesungsskript eine umfassendere Literaturliste ausgeben.

- *Lidl, R., Niederreiter, H.*: Introduction to Finite Fields and their Applications (revised edition). Cambridge University Press, 1994.
- *Pretzel, O.*: Error-Correcting Codes and Finite Fields. Clarendon Press, Oxford, 1992.

Examination

Codierungstheorie

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1968: Quantitative Risk Management *Quantitative Methoden des Risikomanagements*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Ralf Werner		
Learning Outcomes / Competences: Erarbeitung der mathematischen Grundlagen im Risikomanagement, Qualifizierung zur Anwendung in Banken, Versicherungen und Asset Management , Befähigung zum selbständigen Erarbeiten weiterführender Fachliteratur		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Für diese Veranstaltung werden Grundlagen der Stochastik und der Finanzmathematik sowie Grundwissen über Finanzprodukte vorausgesetzt.		
Frequency: irregular alle 2-4 Semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Quantitative Methoden des Risikomanagements

Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Ralf Werner
Language: German
Frequency: irregular alle 2-4 Semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Dieses Modul führt in die quantitativen Grundlagen und Methoden der Risikomodellierung ein.
Mathematische Modellierung von Risiken
Nutzentheorie
Risikomaße und -kennzahlen
Risikoentlastungsstrategien
Abhängigkeitsmodellierung
Marktrisikomodellierung
Kreditrisikomodellierung
Simulation und Validierung von Risikomodellen

Examination

Quantitative Methoden des Risikomanagements
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-1978: Lie Groups and Their Representations *Liegruppen und ihre Darstellungen*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Jost-Hinrich Eschenburg		
Learning Outcomes / Competences: Ziel der Vorlesung ist es, die Kompakten Liegruppen und ihre Darstellungen (Stichwort: Weylsche Charakterformel) zu verstehen.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Liegruppen und ihre Darstellungen

Language: German

Workload:

2 Std. Übung (Präsenzstudium)

4 Std. Vorlesung (Präsenzstudium)

Contact Hours: 6,00

Contents:

Symmetrien werden in der Mathematik durch Gruppen beschrieben. Für den Würfel zum Beispiel gibt es 24 nicht unterscheidbare (achsenparallele) Positionen, deren Übergänge durch eine Gruppe von 24 Drehungen beschrieben werden. Neben solchen diskreten Symmetrien gibt es auch kontinuierliche, wie zum Beispiel bei der Kugel: Sie lässt sich durch beliebige Drehungen um ihr Zentrum in eine andere, ununterscheidbare Lage bringen. Solche Symmetrien werden durch kontinuierliche Gruppen, sog. Lie-Gruppen beschrieben (nach dem norwegischen Mathematiker Sophus Lie benannt). Das einfachste nichttriviale Beispiel ist die Gruppe aller Drehungen um den Ursprung im euklidischen Raum, die Drehgruppe SO(3). Sie ist nicht nur eine Gruppe, sondern gleichzeitig eine differenzierbare Mannigfaltigkeit (eine Untermannigfaltigkeit im Vektorraum aller reellen 3x3-Matrizen), und die Gruppenoperationen sind differenzierbare Abbildungen. Die Drehgruppe wirkt durch Transformationen auf der Kugel und kennzeichnet damit die Symmetrien der Kugel. Mit jeder abstrakten Gruppe ist also auch ihre Wirkung durch Transformationen auf bestimmten Räumen (anderen Mannigfaltigkeiten) von Bedeutung. Die einfachsten Wirkungen sind die linearen: das sind differenzierbare Gruppenhomomorphismen von eine Gruppe G in eine Matrizengruppe, d.h. in die Gruppe der invertierbaren linearen Abbildungen auf einem Vektorraum. Die Gruppe SO(3) wirkt linear auf dem dreidimensionalen euklidischen Raum, aber sie kann auch noch auf andere Arten als Matrizengruppe dargestellt werden: Eine Drehmatrix A konjugiert eine symmetrische spurfreie 3x3-Matrix S zu einer anderen solchen Matrix S' = ASA* ; damit bewirkt A eine lineare Transformation S nach S' auf dem 5-dimensionalen Vektorraum der spurfreien symmetrischen reellen 3x3-Matrize n. Damit haben wir eine 5-dimensionale Darstellung der Gruppe SO(3). Ziel der Vorlesung ist es, die Kompakten Liegruppen und ihre Darstellungen (Stichwort: Weylsche Charakterformel) zu verstehen.

Voraussetzungen:

Literature:

Adams, F. A.: Lectures on Lie Groups. Benjamin, New York, 1969.
Hsiang, W.Y.: Lectures on Lie Groups. World Scientific, 2000.

Examination

Liegruppen und ihre Darstellungen

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1988: Numerical Methods for Model Reduction *Numerische Verfahren zur Modellreduktion*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Tatjana Stykel		
Contents: The fundamentals of control theory, various model reduction techniques for linear and nonlinear problems and their application to practical problems		
Learning Outcomes / Competences: Understanding of different model reduction methods, their advantages and disadvantages for different applications; integrated acquisition of key qualifications: the students learn in small groups to define problems precisely, to develop numerical methods and strategies and to assess their suitability; the social competence to work together in a team is also developed.		
Workload: Total: 240 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: Linear Algebra I, II; Calculus I, II; Numerics I, II		
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Modellreduktion
Language: English
Frequency: irregular
Contact Hours: 6,00

Learning Outcome:
Understanding of different model reduction methods, their advantages and disadvantages for different applications; integrated acquisition of key qualifications: the students learn in small groups to define problems precisely, to develop numerical methods and strategies and to assess their suitability; the social competence to work together in a team is also developed.

Contents:
The fundamentals of control theory, various model reduction techniques for linear and nonlinear problems and their application to practical problems

Literature:
Antoulas, A.C.: Approximation of Large-Scale Dynamical Systems. SIAM, Philadelphia, PA, 2005.
Zhou, K., Doyle, J.C., Glover, K.: Robust and Optimal Control. Prentice Hall, Upper Saddle River, NJ, 1996.

Examination
Modellreduktion
oral exam, Portfolio / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-1998: Graph Theory *Graphentheorie*	8 ECTS/LP
Version 1.0.0 Person responsible for module: apl. Prof. Dr. Dirk Hachenberger	
Learning Outcomes / Competences: Graphen dienen praktisch als Standardmodell für jede Art von Objekten, die mit einer binären Relation versehen sind. Anhand ausgewählter Themengebiete erwerben Studierende anhand des Studiums grundlegender Problemstellungen ein tieferes Verständnis für diskrete Strukturen. Dabei wird insbesondere die algebraische, kombinatorisch und zahlentheoretische Denkweise geschult.	
Remarks: Die Module MTH-1990 und MTH-1991 unterscheiden sich im Aufwand (SWS und LP), sind aber inhaltlich nahezu identisch. Daher dürfen Studierende nur eines dieser beiden Module einbringen.	
Workload: Total: 240 h	
Conditions: Lineare Algebra I und II, Grundlagen der Algebra, der Kombinatorik und der elementaren Zahlentheorie	**Credit Requirements:** Bestehen der Modulprüfung Ausschluss-Bedingung: Dieses Modul darf nicht eingebracht werden, wenn das Modul MTH-1990 bereits eingebracht wurde!

Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Graphentheorie
Mode of Instruction: lecture + exercise
Language: German
Frequency: irregular

Learning Outcome:
Die Studierenden werden anhand des Studiums einer diskreten algebraischen Struktur ein vertieftes Verständnis von algebraischer, kombinatorischer und zahlentheoretischer Denkweise erwerben.

Examination
Graphentheorie
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-2000: Financial Optimisation *Financial Optimization*		3 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Ralf Werner		
Learning Outcomes / Competences: Erarbeitung der mathematischen Grundlagen, Qualifizierung zur Anwendung in der industriellen Praxis, Befähigung zum selbständigen Erarbeiten weiterführender Fachliteratur		
Workload: Total: 90 h 2 h lecture (attendance)		
Conditions: Lineare und Nichtlineare Optimierung, Stochastik		
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Financial Optimization

Mode of Instruction: lecture
Lecturers: Prof. Dr. Ralf Werner
Language: German
Frequency: irregular
Workload:
2 Std. Vorlesung (Präsenzstudium)
Contact Hours: 2,00
ECTS Credits: 3.0

Contents:
Markowitz-Portfoliooptimierung, Indextracking & Portfolioreplikation, Cash-Flow-Matching & Portfolio Immunisierung, Szenariooptimierung & Stochastische Optimierung, Robuste Optimierung im Asset Management, Semi-infinite Optimierung für Bewertungsprobleme, Dynamische Optimierung für Stoppprobleme

Examination

Financial Optimization
module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 120 Minuten, graded
Test Frequency:
this semester
Description:
Mündliche Prüfung à 30 Minuten

Module MTH-2010: Numerics of Stochastic Differential Equations

Numerik Stochastischer Differentialgleichungen

6 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: Prof. Dr. Dirk Blömker

Contents:
numerical method for stochastic differential equations, Euler-Maruyama, weak and strong convergence, error estimates

Learning Outcomes / Competences:
The students know the basic terms, concepts and phenomena of the numerical treatment of stochastic differential equations.
of the numerical treatment of stochastic differential equations, can implement the corresponding algorithms and are familiar with the basics of stochastic analysis.
Ability to work independently on further literature.
Competences in the independent processing and implementation of numerical algorithms,
Skills in formulating and working on theoretical and applied problems using the
and applied questions with the help of the methods learnt.
Integrated acquisition of key qualifications:
Independent work with (English-language) scientific literature,
working with scientific computers,
in-depth competences in the independent processing of problems,
Skills in formulating and working on applied questions.

Workload:
Total: 180 h
2 h exercise course (attendance)
2 h lecture (attendance)

Conditions:
knowledge in stochastic differential equations and numerical methods for ordinary differential equations are helpful

Credit Requirements:
oral exam

Frequency: irregular

Recommended Semester:
1. - 4.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
4,00

Repeat Exams Permitted:
any

Parts of the Module

Part of the Module: Numerik Stochastischer Differentialgleichungen
Language: German / English
Frequency: irregular
Workload:
2 Std. Übung (Präsenzstudium)
2 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Contents:

Dieses Modul führt in die Theorie der numerischen Behandlung stochastischer Differentialgleichungen ein.
Stochastische Differentialgleichungen
Zeitdiskretisierung
Fehlerabschätzungen
Implementierung numerischer Verfahren
Spektrales Galerkinverfahren für stochastische partielle DGL
Voraussetzungen: Die Vorlesung verwendet die grundlegende Theorie stochastischer Differentialgleichungen.
Zwingend notwendig ist ein gutes Grundwissen in der Wahrscheinlichkeitstheorie,
stochastischen Prozessen und der Analysis.
Hilfreich, aber nicht zwingend notwendig, sind Vorkenntnisse
in gewöhnlichen Differentialgleichungen und Numerik gewöhnlicher Differentialgleichungen,
sowie Programmiererfahrung.

Examination

Numerik Stochastischer Differentialgleichungen

oral exam / length of examination: 30 minutes, graded

Module MTH-2030: Parametric Optimisation

Parametrische Optimierung

5 ECTS/LP

Version 1.0.0 (since SoSe17)
Person responsible for module: Prof. Dr. Ralf Werner

Contents:
- Parametrische lineare Optimierung
- Parametrische unrestringierte nicht-lineare Optimierung
- Parametrische restringierte nicht-lineare Optimierung
- Anwendungen

Learning Outcomes / Competences:
- Erarbeitung der mathematischen Grundlagen der parametrischen Optimierung
- Qualifizierung zur Anwendung in Theorie und Praxis
- Befähigung zum selbständigen Erarbeiten weiterführender Fachliteratur

Remarks:
Die Veranstaltung wird vorzugsweise als Blockveranstaltung angeboten.

Workload:
Total: 150 h
3 h lecture and exercise course (attendance)

Conditions:
- Kenntnisse in Optimierung (etwa im Umfang von Optimierung I und II)
- Kenntnisse in numerischen Optimierungsverfahren (etwa Numerische Verfahren der nicht-linearen Optimierung)
- Grundkenntnisse in Funktionalanalysis

Credit Requirements:
Bestehen der Modulprüfung

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 3,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Parametrische Optimierung
Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Ralf Werner
Language: German
Frequency: irregular
Contact Hours: 3,00
ECTS Credits: 5.0

Learning Outcome:
- Erarbeitung der mathematischen Grundlagen der parametrischen Optimierung
- Qualifizierung zur Anwendung in Theorie und Praxis
- Befähigung zum selbständigen Erarbeiten weiterführender Fachliteratur

Contents:
- Parametrische lineare Optimierung
- Parametrische unrestringierte nicht-lineare Optimierung
- Parametrische restringierte nicht-lineare Optimierung
- Anwendungen

Literature:

wird am Anfang der Vorlesung bekannt gegeben

Examination

Parametrische Optimierung

oral exam / length of examination: 15 minutes, graded

Test Frequency:

not this semester

Module MTH-2058: Numerical Optimisation Methods for Business Mathematics (Numerical Methods for Business Mathematics I) *Numerische Optimierungsverfahren der Wirtschaftsmathematik (Numerische Verfahren der Wirtschaftsmathematik I)*	8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Tatjana Stykel

Contents:
Numerische Optimierungsverfahren

Learning Outcomes / Competences:
Verständnis der grundlegenden Fragestellungen der linearen und quadratischen Programmierung sowie allgemeiner Minimierungsprobleme inkl. Algorithmik und Konvergenzanalyse; Kenntnisse der einfachsten Verfahren zur Lösung endlichdimensionaler Optimierungsprobleme, insbesondere mit Nebenbedingungen; integrierter Erwerb von Schlüsselqualifikationen: Die Studierenden lernen in Kleingruppen, Problemstellungen präzise zu definieren, numerische Lösungsstrategien zu entwickeln und deren Tauglichkeit abzuschätzen, dabei wird die soziale Kompetenz zur Zusammenarbeit im Team weiterentwickelt.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
Programmierkenntnisse, grundlegende Kenntnisse der Numerik

Frequency: jedes 3. Semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Numerische Optimierungsverfahren der Wirtschaftsmathematik (Numerische Verfahren der Wirtschaftsmathematik I)
Mode of Instruction: lecture + exercise
Language: German
Frequency: jedes 3. Semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Numerische Verfahren der linearen und nichtlinearen Optimierung, insbesondere Optimierung ohne und mit Nebenbedingungen, quadratische und sequentielle quadratische Optimierung

Assigned Courses:

Numerische Optimierungsverfahren der Wirtschaftsmathematik (lecture + exercise)
**(in attendance) **

Examination

Numerische Optimierungsverfahren der Wirtschaftsmathematik (Numerische Verfahren der Wirtschaftsmathematik I)

portfolio exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-2068: Numerical Methods of Financial Mathematics *Numerische Verfahren der Finanzmathematik (Numerische Verfahren der Wirtschaftsmathematik II)*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Malte Peter	
Contents: Finanzmathematik und zugehörige numerische Verfahren	
Learning Outcomes / Competences: Verständnis der grundlegenden Fragestellungen der Finanzmathematik und der einfachsten numerischen Verfahren zur Lösung der zugrundeliegenden Probleme inkl. Algorithmik und Konvergenzanalyse; Kenntnisse der Grundlagen der Optionspreisbewertung inkl. Black-Scholes-Modell, der Monte-Carlo-Methoden, der stochastischen Differentialgleichungen und deren numerischer Lösung sowie der Finite-Differenzen-Approximationen zur Lösung parabolischer Probleme; integrierter Erwerb von Schlüsselqualifikationen: Die Studierenden lernen in Kleingruppen, Problemstellungen präzise zu definieren, numerische Lösungsstrategien zu entwickeln und deren Tauglichkeit abzuschätzen, dabei wird die soziale Kompetenz zur Zusammenarbeit im Team weiterentwickelt.	
Workload: Total: 240 h 2 h exercise course (attendance) 4 h lecture (attendance)	
Conditions: Grundlegende Kenntnisse der Numerik und der Stochastik	

Frequency: each semester 24/25	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Numerische Verfahren der Finanzmathematik (Numerische Verfahren der Wirtschaftsmathematik II)

Mode of Instruction: lecture + exercise
Language: German
Frequency: every 4th semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Bewertung von Optionen, insbesondere Grundlagen der Optionsbewertung, Ito-Kalkül, Black-Scholes-Formel und Black-Scholes-Gleichungen, Monte-Carlo-Methoden und Finite-Differenzen-Verfahren

Examination

Numerische Verfahren der Finanzmathematik (Numerische Verfahren der Wirtschaftsmathematik II)
module exam, mündliche Einzelprüfung / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-2100: Design Theory *Design Theorie*		3 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: apl. Prof. Dr. Dirk Hachenberger		
Contents: Es handelt sich um eine Einführung in die Design Theorie (Blockpläne) unter Betonung der algebraischen Aspekte (Symmetriegruppen) oder Auflistung von Themen.		
Learning Outcomes / Competences: Anwendbarkeit algebraischer Denkweisen in einem kombinatorischen Zusammenhang.		
Workload: Total: 90 h 2 h lecture (attendance)		
Conditions: Gründliche Kenntnis der Linearen Algebra (insbesondere Eigenwerte, Determinanten und symmetrische Bilinearformen). Grundlagen aus der Algebra (Gruppen, Ringe, Körper).		
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Design Theorie

Mode of Instruction: lecture
Language: German
Frequency: irregular
Workload:
2 Std. Vorlesung (Präsenzstudium)
Contact Hours: 2,00
ECTS Credits: 3.0

Contents:
Es handelt sich um eine Einführung in die Design Theorie (Blockpläne) unter Betonung der algebraischen Aspekte (Symmetriegruppen) oder Auflistung von Themen
Voraussetzungen: Gründliche Kenntnis der Linearen Algebra (insbesondere Eigenwerte, Determinanten und symmetrische Bilinearformen). Grundlagen aus der Algebra (Gruppen, Ringe, Körper).

Literature:
Jacobs K., Jungnickel D., Einführung in die Kombinatorik, 2004, 2. Auflage, Verlag: de Gruyter

Examination

Design Theorie
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-2111: Interest Rate and Credit Models *Zins- und Kreditmodelle*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Ralf Werner		
Learning Outcomes / Competences: Erarbeitung der mathematischen Grundlagen für die Bewertung und das Hedgen von Zins- und Kreditderivaten Qualifizierung zur Anwendung in Banken, Versicherungen und Asset Management Befähigung zum selbständigen Erarbeiten weiterführender Fachliteratur		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Für diese Veranstaltung werden Kenntnisse der zeitstetigen Finanzmathematik vorausgesetzt, wie sie z.B. im Modul "Numerische Verfahren der Finanzmathematik" vermittelt werden (Black-Scholes Modell, Ito-Integral und Ito-Formel, risikoneutrale Bewertung).		
Frequency: irregular alle 2-4 Semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Zins- und Kreditmodelle

Mode of Instruction: lecture + exercise

Lecturers: Prof. Dr. Ralf Werner

Language: German

Frequency: irregular alle 2-4 Semester

Workload:

4 Std. Vorlesung (Präsenzstudium)

2 Std. Übung (Präsenzstudium)

Contact Hours: 6,00

Contents:

Dieses Modul behandelt Modelle zur Bewertung von Zins- und Kreditderivaten.

Inhaltsübersicht als Auflistung:

Ho-Lee Binomialmodell in diskreter Zeit

Ein-Faktor-Short-Rate-Modelle

Affine Zinsmodelle

Heath-Jarrow-Morton Modell

Merton-Modell

Intensitäts- und Hazardrate-Modelle

Bewertung des Kontrahentenausfallrisiko

Literature:

Literatur wird in der Vorlesung bekannt gegeben.

Examination

Zins- und Kreditmodelle

module exam, Mündliche Prüfung à 30 Minuten oder Klausur á 120 Minuten, graded

Test Frequency:

not this semester

Description:

Die Prüfungsform wird rechtzeitig bekannt gegeben.

Module MTH-2118: Continuous Time Finance

Zeitstetige Finanzmathematik

8 ECTS/LP

Version 1.0.0

Person responsible for module: Prof. Dr. Ralf Werner

Contents:

Brownsche Bewegung und stochastische Integration (Ito Formel)
Finanzmarktmodelle in stetiger Zeit (Semimartingalmodelle)
Arbitrage
Vollständigkeit
Hauptsatz der Finanzmathematik
Black-Scholes Modell
Bewertung und Hedging in unvollständigen Märkten

Learning Outcomes / Competences:

Erarbeitung der mathematischen Grundlagen für die Bewertung und das Hedgen von Derivaten
Qualifizierung zur Anwendung in Banken, Versicherungen und Asset Management
Befähigung zum selbständigen Erarbeiten weiterführender Fachliteratur

Workload:

Total: 240 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions:		**Credit Requirements:**
Diskrete Finanzmathematik Stochastik IV		Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Zeitstetige Finanzmathematik

Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Ralf Werner
Language: German / English
Frequency: irregular
Contact Hours: 6,00

Contents:

Brownsche Bewegung und stochastische Integration (Ito Formel)
Finanzmarktmodelle in stetiger Zeit (Semimartingalmodelle)
Arbitrage
Vollständigkeit
Hauptsatz der Finanzmathematik
Black-Scholes Modell
Bewertung und Hedging in unvollständigen Märkten

Literature:

Literatur wird in der Vorlesung bekannt gegeben.

Examination

Zeitstetige Finanzmathematik

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-2140: Mathematics of General Theory of Relativity

Mathematik der Allgemeinen Relativitätstheorie

6 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Learning Outcomes / Competences:
Die Studenten lernen die Grundlagen der (pseudo-)riemannschen Geometrie und von Cartan-Geometrien kennen und finden in der Allgemeinen Relativitätstheorie eine Anwendung dieser Ideen auf eine grundlegende physikalische Theorie.
Die Studenten können geometrische Konzepte wie Krümmung und Torsion anschaulich verstehen.

Workload:
Total: 180 h
2 h lecture (attendance)
2 h exercise course (attendance)

Conditions:
none

Frequency:	Recommended Semester:	Minimal Duration of the Module:
	1. - 4.	1 semester[s]

Contact Hours:	Repeat Exams Permitted:
4,00	any

Parts of the Module

Part of the Module: Mathematik der Allgemeinen Relativitätstheorie

Mode of Instruction: lecture, exercise course
Language: German / English
Frequency: irregular
Workload:
2 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Contents:
Es werden die mathematischen Grundlagen der Differentialgeometrie entwickelt, so daß die Einsteinschen Feldgleichungen der Allgemeinen Relativitätstheorie motiviert, aufgestellt und interpretiert werden können und Beispiele gerechnet werden können.
Folgende Themen werden durch das Modul unter anderem abgedeckt:
Koordinatensysteme
Symmetrien und Kovarianz
Vektorfelder, Differentialformen und Tensoren
Parallelverschiebung
Krümmung und Torsion
Geodäten
Die Einsteinschen Feldgleichungen und der Energie-Impuls-Tensor
Einstein-Cartan-Geometrie
Schwarzschildlösung und weitere exakte Lösungen
Voraussetzungen: Die Studenten kennen sich in der mehrdimensionalen Analysis und der Linearen Algebra über den reellen und komplexen Zahlen aus. Die Studenten haben ein Grundverständnis von grundlegenden physikalischen Begriffen (Kraft, Beschleunigung, Raum und Zeit, etc.).

Literature:

R. W. Sharpe: Differential Geometry

R. P. Feynman: Feynman Lectures on Gravitation

Ch. Misner. K. Thorne, J. Wheeler: Gravitation

S. M. Carroll: Spacetime and Geometry

Examination

Mathematik der Allgemeinen Relativitätstheorie

oral exam / length of examination: 120 minutes, graded

Test Frequency:

each semester

Module MTH-2158: Algebraic Number Theory *Algebraische Zahlentheorie*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marco Hien		
Learning Outcomes / Competences: Die Teilnehmer lernen die fundamentalen Techniken und Ergebnisse aus der algebraischen Zahlentheorie kennen. Sie eignen sich wichtige Werkzeuge von allgemeinem Interesse, wie Gruppenkohomologie, an. Sie sehen, wie verschiedene Methoden - algebraische, komplex-analytische, nicht-archimedisch analytische, homologische - benutzt werden können und müssen, um ein möglichst weites Verständnis von den Zahlkörpern zu erhalten. Dadurch erlernen sie den Austausch von Ideen zwischen den mathematischen Teilgebieten.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		
Frequency: each semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Algebraische Zahlentheorie
Language: German
Frequency: irregular
Contact Hours: 6,00

Contents:

Die Vorlesung bespricht weitergehende Erkenntnisse aus der algebraischen Zahlentheorie.
Inhaltsübersicht als Auflistung:
Verzweigungstheorie
Bewertungen auf Zahlkörpern
Gruppenkohomologie
Lokale Klassenkörpertheorie
Globale Klassenkörpertheorie
Analytische Methoden - L-Reihen
Voraussetzungen: Algebra, Grundkenntnisse über die Ringe ganzer Zahlen in Zahlkörpern

Literature:

J. Neukirch: Algebraische Zahlentheorie, Springer-Verlag
J. Neukirch, A. Schmidt, K. Wingberg: Cohomology of number fields, Springer-Verlag
J. Neukirch (herausgegeben von A. Schmidt): Klassenkörpertheorie, Springer-Verlag

Examination

MTH-2158 Algebraische Zahlentheorie
oral exam / length of examination: 30 minutes, graded
Test Frequency:
each semester

Module MTH-2178: Time Series Analysis *Zeitreihenanalyse (Stochastik IV)*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Gernot Müller		
Learning Outcomes / Competences: Fähigkeit, mit Hilfe statistischer Methoden zeitliche Abhängigkeiten in Daten aufzudecken, zu beschreiben, und für die Zustandsschätzung und Vorhersage zu nutzen.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Stochastik I, Stochastik II		
Frequency: jedes 3. Semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Zeitreihenanalyse

Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Gernot Müller
Language: German
Frequency: jedes 3. Semester
Contact Hours: 6,00

Contents:

stationäre stochastische Prozesse, Autokovarianzfunktion, WN- und ARMA-Prozesse, Analyse im Zeitbereich, Analyse im Frequenzbereich, Periodogramm, Schätzen von Modellparametern, Vorhersage, rekursive Algorithmen, Zustandsraum-Modelle

Literature:

Brockwell, P.J., Davis, R.A. (1991 / 2009). Time Series - Theory and Methods. Springer

Examination

Zeitreihenanalyse

module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 90 Minuten, graded

Test Frequency:

not this semester

Description:

Die Prüfungsform wird rechtzeitig bekannt gegeben.

Module MTH-2180: Generalised Linear Models *Generalisierte Lineare Modelle*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Gernot Müller		
Learning Outcomes / Competences: Verständnis der stochastischen und statistischen Konzepte von verallgemeinerten Regressionsmodellen; Fähigkeit, für vorliegende Daten geeignete Regressionsmodelle auszuwählen und mit Hilfe von statistischen Methoden an Daten anzupassen.		
Workload: Total: 180 h 2 h exercise course (attendance) 2 h lecture (attendance)		
Conditions: Stochastik I, Stochastik II		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Generalisierte Lineare Modelle

Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Gernot Müller
Language: German
Frequency: every 4th semester
Workload:
2 Std. Übung (Präsenzstudium)
2 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Contents:

binäre Regressionsmodelle, Binomial-Regression,
logistische Regression, Parameterschätzung,
Überdispersion, Poisson- und Gamma-Regression,
loglineare Modelle, lineare Modelle mit zufälligen Effekten

Literature:

McCullagh, P., Nelder, J.A. (1989). Generalized Linear Models, 2nd ed. Chapman & Hall / CRC.
Fahrmeir, L., Kneib. T, Lang, S. (2007). Regression: Modelle, Methoden und Anwendungen. Springer.

Examination

Generalisierte Lineare Modelle

module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 90 Minuten, graded

Test Frequency:

not this semester

Description:

Die Prüfungsform wird rechtzeitig bekannt gegeben.

Module MTH-2218: Stochastic Evolution Equations

Stochastische Evolutionsgleichungen

8 ECTS/LP

Version 1.0.0

Person responsible for module: Prof. Dr. Dirk Blömker

Contents:

Infinite dimensional spaces
Fourier series and transforms
cylindrical Wiener processes
analytic semigroups
stochastic evolution equations
stochastic dynamical systems

Learning Outcomes / Competences:

The students know the basic terms, concepts and phenomena in the field of stochastic evolution equations and stochastic dynamic systems.
Ability to work independently on further research literature, competences in the independent processing of problems, skills in the formulation and processing of theoretical questions with the help of the methods learned.
Integrated acquisition of key qualifications:
Independent work with (English-language) scientific literature, scientific thinking,
deepened competences in the independent processing of problems.

Workload:

Total: 240 h

Conditions:

Knowledge of calculus on infinite dimensional spaces and basic knowledge of stochastics.

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Stochastic Evolution Equations

Language: German
Frequency: irregular
Contact Hours: 6,00

Contents:

-

Examination

Stochastic Evolution Equations

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-2228: Adaptive Finite Element Methods

Adaptive Finite Elemente-Verfahren

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Daniel Peterseim

Contents:
Diese Vorlesung betrachtet fortgeschrittene Finite-Elemente-Verfahren mit folgenden Inhalten:

In dieser Vorlesung werden Theorie und Implementierung fortgeschrittener Finite-Elemente-Verfahren betrachtet. Dies beinhaltet die folgenden Themengebiete:
1. Residuenbasierte und hierarchische Fehlerschätzer
2. Effizienz und Zuverlässigkeit von Fehlerschätzern
3. Implementierung adaptiver finiter Elemente mit hängenden Knoten
4. Dual gewichtete Residuen
5. Unstetige Galerkin-Verfahren (discontinuous Galerkin, DG) für Transportprobleme
6. DG-Verfahren für Erhaltungsgleichungen

Learning Outcomes / Competences:
In dieser Vorlesung werden Theorie, Anwendung und Implementierung fortgeschrittener Finite-Elemente-Verfahren erlernt, mit einem Schwerpunkt auf A-Posteriori-Fehlerschätzer für Finite Elemente-Approximationen partieller Differentialgleichungen sowie nicht-konforme Finite-Elemente-Verfahren.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
Numerik partieller Differentialgleichungen

Frequency: irregular	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Adaptive Finite Elemente-Verfahren
Language: German
Frequency: irregular
Contact Hours: 6,00

Learning Outcome:
In dieser Vorlesung werden Theorie, Anwendung und Implementierung fortgeschrittener Finite-Elemente-Verfahren erlernt, mit einem Schwerpunkt auf A-Posteriori-Fehlerschätzer für Finite Elemente-Approximationen partieller Differentialgleichungen sowie nicht-konforme Finite-Elemente-Verfahren.

Contents:
In dieser Vorlesung werden Theorie und Implementierung fortgeschrittener Finite-Elemente-Verfahren betrachtet. Dies beinhaltet die folgenden Themengebiete:
1. Residuenbasierte und hierarchische Fehlerschätzer
2. Effizienz und Zuverlässigkeit von Fehlerschätzern
3. Implementierung adaptiver finiter Elemente mit hängenden Knoten
4. Dual gewichtete Residuen
5. Unstetige Galerkin-Verfahren (discontinuous Galerkin, DG) für Transportprobleme
6. DG-Verfahren für Erhaltungsgleichungen

Literature:

R. Verfuerth; A Posteriori Error Estimation Techniques for Finite Element Methods. Oxford University Press, Oxford, 2013

J. Hesthaven, T. Warburton; Nodal Discontinuous Galerkin Methods: Algorithms, Analysis, and Applications. Springer, New York, 2008

Examination

Adaptive Finite Elemente-Verfahren

module exam, Der konkrete Typ der Modulprüfung (Klausur oder mündliche Prüfung oder Portfolio) wird jeweils spätestens eine Woche vor Beginn der Veranstaltung bekannt gegeben., graded

Test Frequency:

not this semester

Module MTH-2257: Symplectic Geometry *Symplectic Geometry*		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Kai Cieliebak		
Learning Outcomes / Competences: Learning about techniques of symplectic geometry and their applications in the theory of classical mechanical systems.		
Remarks: Cannot be combined together with MTH-2250.		
Workload: Total: 240 h		
Conditions: none		**Credit Requirements:** Passing the module exam.
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Symplectic Geometry and Hamiltonian Dynamics
Language: English / German
Frequency: every 4th semester
Contact Hours: 6,00

Contents:

This course is an introduction to symplectic techniques in the theory of Hamiltonian systems. It covers the following topics: Hamilton's equations, symplectic manifolds, symmetries and Noether's theorem, symplectic reduction, rigid bodies, integrable systems, stability and the KAM theorem, chaos, applications to celestial mechanics, fluid dynamics, and quantum mechanics.
Voraussetzungen: Basic differential geometry (manifolds, differential forms)

Literature:

V.I.Arnold, Mathematical Methods of Classical Mechanics (Springer)
H.Hofer and E.Zehnder, Symplectic Invariants and Hamiltonian Dynamics (Birkhaeuser)

Assigned Courses:

Symplectic Geometry (lecture + exercise)
**(in attendance) **

Examination

Symplectic Geometry and Hamiltonian Dynamics
oral exam / length of examination: 30 minutes, graded
Test Frequency:
this semester

Module MTH-2258: Contact Topology *Contact Topology*		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Kai Cieliebak		
Learning Outcomes / Competences: Learning about the theory of contact structures and their interactions with other fields.		
Remarks: Cannot be combined together with MTH-2251.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Basic differential geometry (manifolds, differential forms)		**Credit Requirements:** Passing the module exam.
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Contact Topology
Language: English / German
Frequency: irregular
Contact Hours: 6,00

Contents:

This course is an introduction to contact structures and their interactions with other fields. It covers the following topics, with an emphasis on dimension three: foliations and contact structures, Legendrian and transverse knots, Bennequin's inequality, the tight versus overtwisted dichotomoy, symplectic fillings, convex surface theory.

Literature:

H.Geiges, An Introduction to Contact Topology (Cambridge Univ. Press)

Examination

Contact Topology

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-2278: Advanced Topics in Algebraic Topology *Algebraische Topologie (Vertiefung)*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Bernhard Hanke		
Learning Outcomes / Competences: This course covers advanced topics in algebraic topology. The students develop skills for working with original literature in the field of algebraic topology. The module also prepares for further seminars and theses in this field.		
Workload: Total: 240 h		
Conditions: none		
Frequency: irregular	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Algebraische Topologie (Vertiefung)
Language: German / English
Frequency: irregular
Contact Hours: 6,00

Contents:

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Literature:

Bredon, G.E.: Topology and Geometry, vol. 139, Graduate Texts in Mathematics. Springer-Verlag, 1993.

Dold, A.: Lectures on Algebraic Topology, vol. 200. Grundlehren der mathematischen Wissenschaften in Einzeldarstellungen, Springer-Verlag, 1972.

May, J. P.: A Concise Course in Algebraic Topology, University of Chicago Press.

Spanier, E.: Algebraic Topology. McGraw-Hill, 1966.

Examination
Algebraische Topologie (Vertiefung)
portfolio exam / length of examination: 120 minutes, graded
Test Frequency:
not this semester

Module MTH-2280: Stochastic Models for Financial and Energy Markets *Stochastische Modelle für Finanz- und Energiemärkte*	3 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Gernot Müller	
Learning Outcomes / Competences: Kenntnisse über die Funktionsweise und die theoretischen Eigenschaften von Modellen, die zur Beschreibung von Preisen an Finanz- und Energiemärkten geeignet sind; Fähigkeit, die Modelle auf Daten anzuwenden.	
Workload: Total: 90 h 2 h lecture (attendance)	
Conditions: Stochastik I / II, empfohlen: Zeitreihenanalyse	

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Stochastische Modelle für Finanz- und Energiemärkte

Mode of Instruction: lecture
Lecturers: Prof. Dr. Gernot Müller
Language: German
Frequency: irregular
Contact Hours: 2,00
ECTS Credits: 3.0

Contents:

Levy-Prozesse, alpha-stabile Zufallsvariablen, alpha-stabile Prozesse, ARMA-Modelle, SV-Modelle, CARMA-Modelle, zeitstetige SV-Modelle, COGARCH-Modelle, Schätzverfahren; Anwendungen auf Finanz- und Energiemarkt-Daten.

Literature:

neuere wissenschaftliche Veröffentlichungen

Examination

Stochastische Modelle für Finanz- und Energiemärkte

module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 90 Minuten, graded

Test Frequency:

not this semester

Description:

Die Prüfungsform wird rechtzeitig bekannt gegeben.

Module MTH-2300: Selected Topics in Nonlinear Functional Analysis

Ausgewählte Kapitel der Nichtlinearen Funktionalanalysis

6 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: Prof. Dr. Bernd Schmidt

Learning Outcomes / Competences:
Die Student(inn)en kennen moderne Zugänge zu ausgewählten Problemen in der Theorie der nichtlinearen Funktionalanalysis. Sie sind in der Lage, aufbauend auf den Inhalten der Vorlesung Forschungliteratur in diesen Gebieten zu lesen und sich selbstständig in weiterführende Aspekte einzuarbeiten.

Workload:
Total: 180 h

Conditions:
Solide Analysiskenntnisse, die die wesentlichen Inhalte der Vorlesungen Analysis 1, 2 und 3 sowie der Funktionalanalysis abdecken.

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Ausgewählte Kapitel der Nichtlinearen Funktionalanalysis
Mode of Instruction:
Language: German
Frequency: irregular
Contact Hours: 4,00
ECTS Credits: 6.0

Contents:
Inhaltsübersicht als Auflistung:
- Abbildungsgrad
- Verzweigungstheorie
- Anwendungen

Voraussetzungen: Solide Kenntnisse der mehrdimensionalen Differential- und Integralrechnung, Funktionalanalysis.

Literature:
Ambrosetti, A., Arcoya D.:
An Introduction to Nonlinear Functional Analysis and Elliptic Problems
(Birkhäuser 2011),
Antman, S.:
Nonlinear Problems of Elasticity
(Springer 2005),
Deimling, K.:
Nichtlineare Gleichungen und Abbildungen
(Springer 1974)
Kielhöfer, H.: Bifurcation Theory
(Springer 2004)
Nirenberg, L.:
Topics in Nonlinear Functional Analysis
(AMS 2001)

Examination

Ausgewählte Kapitel der Nichtlinearen Funktionalanalysis

portfolio exam, graded

Test Frequency:

not this semester

Module MTH-2328: Markov Chains and Monte-Carlo-Simulation *Markov-Ketten und Monte-Carlo-Simulation*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Gernot Müller		
Learning Outcomes / Competences: Verständnis der mathematischen Konzepte für Markov-Ketten, Verständnis der Funktionsweise von Markov-Chain-Monte-Carlo-Algorithmen, Fähigkeit, solche Algorithmen selbstständig an Modelle zu adaptieren.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Stochastik I / Stochastik II		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Markov-Ketten und Monte-Carlo-Simulation

Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Gernot Müller
Language: German
Frequency: every 4th semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Markov-Ketten in diskreter / stetiger Zeit und mit diskretem / stetigem Zustandsraum, Stationarität, Ergodizität, Reversibilität, Markov-Chain-Monte-Carlo-Algorithmen

Literature:
Bremaud, P. (2008). Markov Chains, Gibbs Fields, Monte Carlo Simulation, and Queues. Springer.
Meyn, S.P., Tweedie, R.L. (1993). Markov Chains and Stochastic Stability. Springer.
Robert, C.P., Casella, G. (2004). Monte Carlo Statistical Methods. Springer

Examination

Markov-Ketten und Monte-Carlo-Simulation
module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 90 Minuten, graded
Test Frequency:
not this semester
Description:
Die Prüfungsform wird rechtzeitig bekannt gegeben.

Module MTH-2330: Ergodic Theory and Random Dynamical Systems *Ergodentheorie und zufällige Dynamische Systeme*		6 ECTS/LP
Version 1.0.0 (since WS15/16 to SoSe25) Person responsible for module: Prof. Dr. Fritz Colonius		
Learning Outcomes / Competences: Verständnis der Konzepte zur maßtheoretischen Analyse von dynamischen Systemen bis hin zum Multiplikativen Ergodentheorem und seinem Beweis.		
Workload: Total: 180 h		
Conditions: none		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Ergodentheorie und zufällige Dynamische Systeme

Language: German
Frequency: irregular
Contact Hours: 4,00
ECTS Credits: 6.0

Contents:

Das Ziel ist der Beweis des Multiplikativen Ergoden-theorems (MET) für zufällige dynamische Systeme in diskreter Zeit. Es beschreibt das Stabilitätsverhalten linearer Systeme. Dafür werden Grundlagen aus der Ergodentheorie wie der Birkhoffsche Ergodensatz und der subadditive Ergodensatz sowie einige Hilfsmittel aus der Multilinearen Algebra benötigt. Diese Hilfsmittel werden in der Vorlesung entwickelt und dann zum Beweis des MET verwendet. Voraussetzungen: gute Kenntnis des Lebesgue-Integrals

Literature:

wird in der Vorlesung bekanntgegeben

Examination

Ergodentheorie und zufällige Dynamische Systeme

oral exam / length of examination: 20 minutes, graded

Module MTH-2348: Holomorphic Curves - An Introduction to Modern Methods of Symplectic Geometry *Holomorphic curves - an introduction to the modern methods of symplectic geometry*		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Urs Frauenfelder		
Learning Outcomes / Competences: Restricted three body problem Global surface of section Contact topology Holomorphic curves Symplectic field theory		
Remarks: Cannot be combined together with MTH-2340.		
Workload: Total: 240 h		
Conditions: Knowledge of differential geometry and functional analysis.		**Credit Requirements:** Passing the module exam.
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Holomorphic curves
Language: English / German
Frequency: irregular
Contact Hours: 6,00

Contents:

The goal of this lecture is to make students familiar with global methods in Hamiltonian mechanics. The Hamiltonian system which plays a major role in this lecture is the restricted three body problem. In this problem one studies the dynamics of a massless body (the satellite) which is attracted by two massive bodies (the earth and the moon) according to Newton's law of gravitation. The dynamics of the satellite is prescribed by the flow of a vector field on a three dimensional energy hypersurface. One of the major questions in this lecture is if this flow admits a global surface of section. Such a global surface of section is a gadget which allows one to store the information carried by the flow on the three dimensional energy hypersurface in an area preserving map from the two dimensional disk to itself, i.e., such a gadget reduces the complexity of the problem by one dimension. Global surfaces of section can be constructed with the help of holomorphic curves. In this lecture we will study the rich interplay between holomorphic curves, contact topology and dynamics which brings students to the forefront of modern research.

Literature:

McDuff, Salamon
J-holomorphic Curves and Symplectic Topology
AMS

Examination

Holomorphic curves - an introduction to the modern methods of symplectic geometry (8LP)

oral exam / length of examination: 30 minutes, graded

Test Frequency:

this semester

Module MTH-2358: Model Categories *Modellkategorien*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Learning Outcomes / Competences: Die Studenten haben eine algebraische Theorie von Kategorien kennengelernt. Sie können übliche Konstruktionen in der homologischen Algebra und in der algebrasichen Topologie axiomatisch verstehen und Parallelen ziehen. Sie sind in der Lage, wissenschaftlich auf dem Gebiet der homotopischen Algebra und der Homotopietheorie zu arbeiten.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		
Frequency: each semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Modellkategorien **Mode of Instruction:** lecture, exercise course **Language:** German **Frequency:** irregular **Contact Hours:** 6,00

Contents:

Modellkategorien axiomatisieren und verdeutlichen sowohl die wesentlichen Konstruktionen in der Homotopietheorie topologischer Räume als auch der homologischen Algebra der Kettenkomplexe. Sie wurden zu diesem Zwecke 1967 von Daniel Quillen eingeführt. Ein grundlegendes Wissen über Modellkategorien ist daher unumgänglich, wenn man in der algebraischen Topologie oder der homologischen Algebra arbeiten möchte. Mit Hilfe von Modellkategorien sind in letzter Zeit Theorien von Unendlich-Kategorien oder auch Algebra über dem Sphärenspektrum anstelle den ganzen Zahlen entwickelt worden.

Ausgangspunkt der Theorie der Modellkategorien ist eine Kategorie M zusammen mit einer Klasse W von Morphismen, nach denen die Kategorie lokalisiert werden soll, d.h. die formal als invertierbar angesehen werden sollen. Eine Modellstruktur auf M ist dann eine Wahl von zwei weiteren Klassen auf M, den sogenannten Faserungen und Kofaserungn, um effektiv Aussagen über die Lokalisierung machen zu können. Diese Wahl ist vergleichbar mit der einer Basis eines Vektorraumes in der Linearen Algebra.

Unter anderem werden folgende Themen angesprochen:

Modellkategorien

Homotopiekategorie

Quillen-Äquivalenzen

Kettenkomplexe

Kompakt erzeugte Räume

Simpliziale Mengen

Monoidale Modellkategorien

Triangulierte Kategorien

Spektra

Voraussetzungen: Grundlegende Kenntnisse in Topologie und Kategorientheorie

Weitergehende Kenntnisse in algebraischer Topologie oder homologischer Algebra sind hilfreich aber nicht nötig

Literature:

W. G. Dwyer et al.: Homotopy Limit Functors on Model Categories and Homotopical Categories

P. Gabriel, M. Zisman: Calculus of Fractions and Homotopy Theory

S. I. Gelfand, Yu. I. Manin: Methods of Homological Algebra

P. G. Goerss, J. F. Jardine: Simplicial Homotopy Theory

Ph. S. Hirschhorn: Model Categories and Their Localizations

M. Hovey: Model Categories

J. Lurie: Higher Topos Theory

J. P. May, K. Ponto: More Concise Algebraic Topology: Localization, Completion, and Model Categories

D. G. Quillen: Homotopical algebra

Examination

MTH-2358 Modellkategorien

oral exam / length of examination: 30 minutes, graded

Test Frequency:

each semester

Module MTH-2380: Bayesian Statistics and Econometrics

Bayessche Statistik und Ökonometrie

6 ECTS/LP

Version 2.0.0 (since SoSe17)
Person responsible for module: Prof. Dr. Gernot Müller

Learning Outcomes / Competences:
Verständnis der mathematischen Konzepte in der Bayesschen Statistik, Kenntnisse über Vor- und Nachteile der Bayesschen Statistik gegenüber der frequentistischen Statistik, Kenntnisse über Einsatzmöglichkeiten der Bayesschen Statistik in der Ökonometrie,
Fähigkeit, Bayessche Verfahren bei praktischen Problemen selbstständig einzusetzen.

Workload:
Total: 180 h
3 h lecture (attendance)
1 h exercise course (attendance)

Conditions:
Stochastik I, Stochastik II

Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Bayessche Statistik und Ökonometrie
Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Gernot Müller
Language: German
Frequency: every 4th semester
Contact Hours: 4,00
ECTS Credits: 6.0

Contents:
Grundlagen der Bayesschen Statistik, Prior-Verteilungen (konjugierte, nichtinformative), Posterior-Verteilungen, Optimalität von Bayesschätzern, Bayes-Tests, Schätzungen der Posterior-Verteilung über MCMC Methoden, Bayessche Netzwerke, Anwendungen der Bayesschen Statistik in der Ökonometrie.
Voraussetzungen: Stochastik 1 und 2

Literature:
Blake, A., and Mumtaz, H. (2012). Applied Bayesian Econometrics for Central Bankers. Bank of England / CCBS Technical Handbook No. 4.
Carlin, B.P., and Louis, Th.A. (2009). Bayesian Methods for Data Analysis. Chapman and Hall.
Efron, B. (1986). Why Isn't Everyone a Bayesian? The American Statistician 40 (1) 1-5
Gelman, A., Carlin, J.B., Stern, H.S., and Rubin, D.R. (1995). Bayesian Data Analysis. Chapman and Hall.
Geweke, J. (2005). Contemporary Bayesian Econometrics and Statistics., Wiley.
Geweke, J., Koop, G., and van Dijk, H. (Eds.) (2011). The Oxford Handbook of Bayesian Econometrics. Oxford.
Koop, G. (2003). Bayesian Econometrics. Wiley.
Robert, Ch. (2007). The Bayesian Choice. Springer.

Examination

Bayessche Statistik und Ökonometrie

module exam, Mündliche Prüfung / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-2450: Seminar in Combinatorics *Seminar zur Kombinatorik*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: apl. Prof. Dr. Dirk Hachenberger		
Learning Outcomes / Competences: Die selbständige Erarbeitung mathematischer Inhalte und eine wissenschaftliche Präsentation in Wort und Schrift.		
Workload: Total: 180 h 2 h seminar (attendance)		
Conditions: none		
Frequency: irregular	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Seminar zur Kombinatorik
Language: German
Frequency: irregular

Learning Outcome:
Die selbständige Erarbeitung mathematischer Inhalte und eine wissenschaftliche Präsentation in Wort und Schrift.

Literature:
Die konkrete Themenauswahl und dazu gehörende Literatur wird in der Vorbesprechung zum Seminar bekanntgegeben.

Examination
Seminar zur Kombinatorik
seminar / length of examination: 90 minutes, graded
Test Frequency:
not this semester

Module MTH-2498: Finite Fields

Endliche Körper

8 ECTS/LP

Version 1.0.0
Person responsible for module: apl. Prof. Dr. Dirk Hachenberger

Learning Outcomes / Competences:
Die Studierenden werden anhand des Studiums einer diskreten algebraischen Struktur ein vertieftes Verständnis von algebraischer, kombinatorischer und zahlentheoretischer Denkweise erwerben.

Remarks:
Die Module MTH-2240 und MTH-2490 unterscheiden sich im Aufwand (SWS und LP), sind aber inhaltlich nahezu identisch. Daher dürfen Studierende nur eines dieser beiden Module einbringen.

Workload:
Total: 240 h
6 h lecture and exercise course (attendance)

Conditions:	**Credit Requirements:**
Lineare Algebra I und II, Grundlagen der Algebra, der Kombinatorik und der elementaren Zahlentheorie.	Ausschluss-Bedingung: Dieses Modul darf nicht eingebracht werden, wenn das Modul MTH-2240 oder MTH-2590 bereits eingebracht wurde!

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Endliche Körper
Mode of Instruction: lecture, lecture + exercise
Lecturers: apl. Prof. Dr. Dirk Hachenberger
Language: German
Frequency: irregular

Learning Outcome:
Die Studierenden werden anhand des Studiums einer diskreten algebraischen Struktur ein vertieftes Verständnis von algebraischer, kombinatorischer und zahlentheoretischer Denkweise erwerben.

Examination
Endliche Körper
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-2510: Advanced Methods in Machine Learning *Advanced Methods in Machine Learning*		3 ECTS/LP
Version 1.0.0 (since WS20/21) Person responsible for module: Prof. Dr. Gernot Müller		
Contents: basics of machine learning, learnability, bias-complexity tradeoff, VC-dimension, deep feedforward networks, several case studies		
Learning Outcomes / Competences: Understanding of advanced concepts of machine learning; ability to apply these concepts to data and to interpret the results		
Workload: Total: 90 h 1 h exercise course (attendance) 1 h lecture (attendance)		
Conditions: Stochastik I, Stochastik II		**Credit Requirements:** Passing the module exam
Frequency: irregular / 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Methods in Machine Learning

Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Gernot Müller
Language: German / English
Frequency: irregular every 4th semester
Contact Hours: 2,00
ECTS Credits: 3.0

Contents:

-

Literature:

recent publications about machine learning (depending on the current semester)

Examination

Advanced Methods in Machine Learning

module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 60 Minuten / length of examination: 60 minutes, graded

Test Frequency:

not this semester

Module MTH-2511: Advanced Methods in Machine Learning II *Advanced Methods in Machine Learning II*		3 ECTS/LP
Version 1.0.0 (since WS21/22) Person responsible for module: Prof. Dr. Gernot Müller		
Contents: linear predictors, half-spaces, Perceptron algorithm, boosting, AdaBoost, support vector machines		
Learning Outcomes / Competences: Understanding of advanced concepts of machine learning; ability to apply these concepts to data and to interpret the results		
Workload: Total: 90 h 1 h exercise course (attendance) 1 h lecture (attendance)		
Conditions: Stochastik I, Stochastik II, AMML (MTH-2510)		**Credit Requirements:** Passing the module exam
Frequency: irregular / 4h semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Methods in Machine Learning II
Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Gernot Müller
Language: German / English
Frequency: irregular / 4h semester
Contact Hours: 2,00
ECTS Credits: 3.0

Contents:
-

Literature:
recent publications about machine learning (depending on the semester)

Examination
Advanced Methods in Machine Learning II
module exam, - / length of examination: 60 minutes, graded
Test Frequency:
not this semester

Module MTH-2528: Algebraic Groups and Homogeneous Spaces *Algebraic groups and homogeneous spaces*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Remarks: momentan nicht angeboten!		
Workload: Total: 240 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Algebraic groups and homogeneous spaces
Language: English
Frequency: irregular
Contact Hours: 6,00

Examination
MTH-2528 Algebraic groups and homogeneous spaces
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-2538: Perverse Sheaves

Perverse Garben

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Marco Hien

Contents:

- Einführung in die Theorie der derivierten Kategorien und speziell die derivierte Kategorie der Garben auf einem topologischen Raum.
- Verdier-Dualität
- triangulierte Kategorien und t-Strukturen
- Definition und Anwendungen des Begriffs "Perverse Garben"

Learning Outcomes / Competences:

Die Vorlesung führt in die modernen Techniken der Theorie der Garben auf Mannigfaltigkeiten (insbesondere der derivierten Kategorie von Garben) ein. Die enstprechenden Konstruktionen, derivierte Kategorien, triangulierte Kategorien, t-Strukturen werden abstrakt besprochen und im Hinblick auf Garben studiert.

Der Begriff "Perverse Garben" wird entwickelt und die Anwendungen (im Sinn der Riemann.Hilbert-Korrespondenz) werden besprochen.

Die Teilnehmer erlernen fundamentale Kenntnisse und Techniken, die in vielen Bereichen der Algebraischen Geometrie, Komplexen Geomtrie, Symplektischen Geometrie oder Algebraischen Topologie Anwendung finden.

Workload:
Total: 240 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions:		**Credit Requirements:**
none		Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Perverse Garben
Mode of Instruction: lecture + exercise
Language: German / English
Frequency: irregular
Contact Hours: 6,00

Examination
MTH-2538 Perverse Garben
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-2548: Floer Homology *Floer Homologie*		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Urs Frauenfelder		
Contents: Arnold conjecture, Analysis of pseudoholomorphic curves, Rabinowitz action functional		
Remarks: Cannot be combined together with MTH-2540.		
Workload: Total: 240 h		
Conditions: none		**Credit Requirements:** Passing the module exam.
Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Floer Homologie

Language: German / English
Frequency: irregular
Contact Hours: 6,00

Contents:

Arnold conjecture, Analysis of pseudoholomorphic curves, Rabinowitz action functional

Assigned Courses:

Floer Homology (lecture + exercise)

**(in attendance) **

Examination

Floer Homologie

oral exam / length of examination: 30 minutes, graded

Test Frequency:

this semester

Module MTH-2581: Advanced Survival Analysis

Advanced Survival Analysis

8 ECTS/LP

Version 1.2.0 (since WS22/23)
Person responsible for module: Prof. Dr. Sarah Friedrich

Contents:

- Besonderheiten von Überlebenszeitdaten: Zensierung/Trunkierung
- Martingale, Zählprozesse, stochastische Integrale
- Nelson-Aalen, Kaplan-Meier und Aalen-Johansen Schätzer
- Konkurrierende Risiken und Mehrstadienmodelle
- Cox Regression
- Asymptotik (schwache Konvergenz, gleichmäßige Konsistenz), Martingaltheorie

Learning Outcomes / Competences:
Nach der Teilnahme an diesem Modul verfügen die Studierenden über detailliertes und aktuelles Wissen auf dem Gebiet der Überlebenszeitanalyse (Survival Analysis). Sie können Problemstellungen und Ergebnisse des Gebiets präzise beschreiben und diskutieren. Darüber hinaus verstehen die Studierenden mathematische Konzepte, Methoden, Verfahren und Techniken, um Ereigniszeitdaten zu analysieren.

Workload:
Total: 240 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions: Stochastik I + II		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Survival Analysis

Mode of Instruction: lecture + exercise
Language: German / English
Frequency: irregular
Contact Hours: 6,00
ECTS Credits: 8.0

Literature:

- Andersen, Borgan, Gill, Keiding: Statistical Models Based on Counting Processes, Springer 1993
- Aalen, Borgan, Gjessing: Survival and Event History Analysis, Springer 2008
- Beyersmann, Allignol, Schumacher: Competing Risks and Multistate Models with R, Springer 2012

Examination

Advanced Survival Analysis
module exam, Die genauer Prüfungsform wird in der jeweiligen Veranstaltung bekannt gegeben., graded
Test Frequency:
not this semester

Module MTH-2598: Topics in Galois Fields

Topics in Galois Fields

8 ECTS/LP

Version 1.0.0
Person responsible for module: apl. Prof. Dr. Dirk Hachenberger

Contents:

1. Algebraic and number theoretical foundation
2. Multiplicative group, existence and uniqueness
3. Mappings for extensions of finite fields and normal bases
4. The algebraic closure of a finite field
5. Irreducible polynomials over finite fields
6. Factorization of univariate polynomials over finite fields
7. Nomal bases and cyclotomic modules
8. Characters, Gauss sums and the DFT
9. Primitive normal bases
10. Basis representation and arithmetics
11. Primitive elements in affine hyperplanes

Learning Outcomes / Competences:
"Finite fields" (resp. "Galois fields") belong to the fundamental structures which play an important role in modern applications, such as Coding Theory, Cryptography or Signal processing. After establishing the classical results on finite fields, our focus will be on developments from the last 25 years.

Remarks:
Concerning the contents, the previous modules MTH-2240 and MTH-2490 are nearly identical to MTH-2590. It is therefore possible to earn credit points only for one of these modules.

Workload:
Total: 240 h

Conditions:	**Credit Requirements:**
Linear Algebra; foundations of Algebra, Combinatorics and elementary Number Theory.	This module can only be credited, when module MTH-2240 or module MTH-2490 have not already been credited.

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Topics in Galois Fields: Lectures and Exercises
Mode of Instruction: lecture + exercise
Lecturers: apl. Prof. Dr. Dirk Hachenberger
Language: English
Frequency: irregular
Contact Hours: 6,00

Learning Outcome:
"Finite fields" (resp. "Galois fields") belong to the fundamental structures which play an important role in modern applications, such as Coding Theory, Cryptography or Signal processing. After establishing the classical results on finite fields, our focus will be on developments from the last 25 years.

Contents:

1. Algebraic and number theoretical foundation
2. Multiplicative group, existence and uniqueness
3. Mappings for extensions of finite fields and normal bases
4. The algebraic closure of a finite field
5. Irreducible polynomials over finite fields
6. Factorization of univariate polynomials over finite fields
7. Nomal bases and cyclotomic modules
8. Characters, Gauss sums and the DFT
9. Primitive normal bases
10. Basis representation and arithmetics
11. Primitive elements in affine hyperplanes

Literature:

Dirk Hachenberger and Dieter Jungnickel, Topics in Galois Fields, Springer Nature Switzerland, Cham, 2020.

Examination

Topics in Galois Fields

term paper, graded

Test Frequency:

not this semester

Module MTH-2600: Nonparametric Statistics

Nichtparametrische Statistik

6 ECTS/LP

Version 1.0.0 (since WS22/23)
Person responsible for module: Prof. Dr. Sarah Friedrich

Contents:

- Besonderheiten der nichtparametrischen Statistik: Nichtparametrische Effekte und Hypothesen im Vergleich zur parametrischen und semi-parametrischen Statistik
- Empirische Verteilungen und Ränge
- Relative Effekte und deren Schätzer
- Einfaktorielle Versuchspläne: Wilcoxon-Mann-Whitney-Test, das nichtparametrische Behrens-Fischer-Problem, Kruskal-Wallis-Test
- Mehrfaktorielle Versuchspläne

Learning Outcomes / Competences:

Nach der Teilnahme an diesem Modul kennen die Studierenden den Unterschied zwischen der nichtparametrischen und der parametrischen Datenanalyse. Sie erkennen, wann eine nichtparametrische Datenanalyse notwendig ist, sind mit den Grundbegriffen der Rangstatistiken vertraut, können Rangverfahren für ausgewählte faktorielle Versuchspläne durchführen und kennen deren theoretische, mathematische Grundlagen.

Workload:

Total: 180 h
2 h exercise course (attendance)
2 h lecture (attendance)

Conditions: Stochastik I und II		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular (usu. winter semester)	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Übung Nichtparametrische Statistik

Mode of Instruction: lecture + exercise
Language: German / English

Literature:

Brunner, Konietschke, Bathke: *Rank and Pseudo-Rank Procedures for Independent Observations in Factorial Designs,* Springer 2018
Brunner, Munzel: *Nichtparametrische Datenanalyse,* Springer 2013

Examination

Nichtparametrische Statistik

module exam, Die genauer Prüfungsform wird in der jeweiligen Veranstaltung bekannt gegeben., graded

Test Frequency:

not this semester

Module MTH-2648: Category Theory

Kategorientheorie

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Contents:

- Set-theoretical basics
- Categories, functors, natural transformations
- Examples
- Limits and colimits
- Adjoint functors
- Kan-extensions
- Ends and coends
- Monoidal categories
- Localisation of categories
- Applications

Learning Outcomes / Competences:
The students have gained an overview of the essential concepts of category theory. They recognise universal constructions in other subfields of mathematics and can profitably apply category theory in other disciplines. They further perceive categories as algebraic objects that can be invariants of other structures. Finally, the students understand the basic theoretical problems that arise from a too naive notion of a set and have seen applications outside mathematics, e.g. in theoretical computer science.

Workload:
Total: 240 h

Conditions:

- To successfully complete the module, participants only need a certain mathematical maturity and an interest in dealing with abstract structures.

Credit Requirements:
Passing the module exam

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Kategorientheorie
Mode of Instruction: lecture
Language: German / English

Part of the Module: Übungen zur Kategorientheorie
Mode of Instruction: exercise course
Language: German / English

Examination

MTH-2648 Kategorientheorie

oral exam, graded

Test Frequency:

each semester

Description:

Es sind schriftliche Übungsaufgaben zu bearbeiten, mündlich an der Tafel vorzurechnen und am Ende eine kurze mündliche Prüfung zu bestehen.

Module MTH-2653: Reflections on Mathematical Logic *Betrachtungen zur Mathematischen Logik*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Contents: - Prädikatenlogik - Sequenzenkalkül - Gödelscher Vollständigkeitssatz - Kompaktheitssatz und Satz von Löwenheim-Skolem - ZFC - Modalitäten - Unentscheidbarkeit und Halteproblem - Gödelsche Unvollständigkeitssätze - Gentzens Konsistenzbeweis der Arthmetik - Konstruktive Logik - Modelltheorie - Nicht-Standard-Modelle - Logik 2. Stufe		
Workload: Total: 240 h		
Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: as needed	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Mathematische Logik **Language:** German
Examination **Mathematische Logik** portfolio exam, graded **Test Frequency:** each semester

Module MTH-2658: Homotopy Type Theory

Homotopietypentheorie

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Contents:
Initially, mathematical work within an intuitionistic type theory is taught. A special focus is placed on the concept of equality. Equality in elementary types is characterised. Homotopy theory concepts, the axiom of univalence and examples of higher inductive types are introduced. Higher inductive types are introduced. This homotopy-theoretic extension of the type theory is used to calculate selected homotopy groups and to develop abstract variants of classical results of algebraic topology.

Learning Outcomes / Competences:

- Mathematical reasoning and proving in a dependent type theory. This knowledge is a basis for the use of most computer-assisted proof systems.
- Fundamental understanding of issues and techniques in abstract homotopy theory. The ideas gained are transferable to other approaches such as higher category theory.
- Application of univalence and higher inductive types to homotopy theory problems. A study of advanced topics homotopy type theory becomes possible.

Workload:
Total: 240 h

Conditions:	**Credit Requirements:**
Experience with abstract mathematics, such as that gained in the context of introductory modules in the fields of topology and algebra. Elementary knowledge of these areas is helpful, but not required.	Pass the module exam

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Homotopietypetheorie

Mode of Instruction: lecture
Language: German / English
Frequency: each winter semester
Contact Hours: 4,00

Assigned Courses:

Homotopientypentheorie (lecture)
**(in attendance) **

Part of the Module: Übungen zur Homotopietypentheorie

Mode of Instruction: exercise course
Language: German / English
Frequency: each winter semester
Contact Hours: 2,00

Assigned Courses:

Homotopientypentheorie (lecture)
**(in attendance) **

Examination

Modulprüfung

portfolio exam, graded

Test Frequency:

this semester

Module MTH-2670: Computational Algebraic Geometry

Computational Algebraic Geometry

6 ECTS/LP

Version 1.0.0 (since SoSe24)
Person responsible for module: Prof. Dr. André Uschmajew

Contents:
1. Polynomial Rings
2. Gröbner Bases
3. Elimination Theory
4. Computer Algebra Systems
5. Applications

Learning Outcomes / Competences:
In this lecture we will learn about the algebra and the geometry of nonlinear polynomial equations. We will develop the theory of polynomial algebra and we will discuss how to solve these systems algorithmically using computer algebra. Depending on time and interest of the participants, we will see selected applications in statistics and data science.

Workload:
Total: 180 h

Conditions:		**Credit Requirements:**
Linear Algebra. A course in abstract algebra is useful but not necessary.		Bestehen der Modulprüfung
Frequency:	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Computational Algebraic Geometry
Language: English / German
Frequency: einmalig SoSe
Contact Hours: 4,00
ECTS Credits: 6.0

Literature:
David A. Cox, John Little, and Donal O'Shea. Ideals, Varieties, and Algorithms: An Introduction to Computational Algebraic Geometry and Commutative Algebra. Springer, 2007.
Viviana Ene and Jurgen Herzog. Gröbner Bases in Commutative Algebra. American Mathematical Society, 2012.

Examination
Computational Algebraic Geometry
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-2698: Inverse Problems

Inverse Probleme

8 ECTS/LP

Version 1.0.0

Person responsible for module: Prof. Dr. Jan-Frederik Pietschmann

Contents:

* Charakterisierung inverser Aufgaben anhand von angewandten Beispielen aus der Mathematik, den Naturwissenschaften und dem Ingenieurwesen
* die Hadamard'sche Korrektheitsdefinition und das Phänomen der Inkorrektheit
* Inverse Probleme als lineare und nichtlineare Operatorgleichungen in Banach- und Hilberträumen mit Schwerpunkt auf linearen Problemen
* Singulärwertzerlegung kompakter Operatoren und Grad der Inkorrektheit
* Theorie und Praxis der Regularisierung inkorrekter Aufgaben mit Mitteln der Analysis, Numerik, Optimierung und Stochastik
* Konvergenzraten und Quelldarstellungen
* Statistische Inverse Probleme

Learning Outcomes / Competences:

Ziel dieses Moduls ist die Einführung in die Mathematik inverser Probleme, wobei sowohl die angewandte Komponente (naturwissenschaftlich-technische und ökonomische Probleme inverser Natur) als auch die theoretische Komponente (funktionalanalytische Behandlung, Nutzung von Techniken der Analysis, Numerik, Optimierung und Stochastik) eine unverzichtbare Rolle spielen. Die Studenten erwerben die Kompetenz zum Erkennen inverser Problemstellungen und ihrer Instabilität und zum Überwinden der spezifischen Probleme durch angepasste Techniken der Regularisierung mittels objektiver und subjektiver Apriori-Informationen im Rahmen mathematischer Handwerkszeuge.

Remarks:

Kann nicht gemeinsam mit MTH-2690 eingebracht werden

Workload:

Total: 240 h

Conditions:		**Credit Requirements:**
Funktionalanalysis		Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Inverse Probleme

Language: German

Examination

Inverse Probleme

portfolio exam, graded

Test Frequency:

not this semester

Module MTH-2708: Advanced Discrete Probability

Fortgeschrittene Themen der diskreten Wahrscheinlichkeitstheorie

8 ECTS/LP

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr. Markus Heydenreich

Learning Outcomes / Competences:
Studierende lernen in diesem Kurs aktive Forschungsgebiete der diskreten Wahrscheinlichkeitstheorie kennen. Sie kennen wesentliche Theorielinien und können den Beweis zentraler Resultate skizzieren. Sie sind in der Lage mit den erlernten Techniken eigene Beweise zu erarbeiten.
Integrierter Erwerb von Schlüsselqualifikationen: Eigenständiges Arbeiten mit (englischsprachiger) wissenschaftlicher Literatur, wissenschaftliches Denken, vertiefte Kompetenzen in der selbständigen Bearbeitung von Problemstellungen

Workload:
Total: 240 h

Conditions:	**Credit Requirements:**
Lineare Algebra I Analysis I Analysis II Stochastik I Stochastik II (kann parallel gehört werden)	Bestehen der Modulprüfung

Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:**
	1. - 4.	1 semester[s]

Contact Hours:	**Repeat Exams Permitted:**
6,00	according to the examination regulations of the study program

Parts of the Module

Part of the Module: Fortgeschrittene Themen der diskreten Wahrscheinlichkeitstheorie
Language: English / German
Contact Hours: 6,00

Contents:
Im Kurs werden Studierende anhand ausgewählter Themen in aktuelle Forschungsthemen aus der diskreten Wahrscheinlichkeitstheorie eingeführt. Dabei werden sowohl grundlegende Beweistechniken erarbeitet also auch einige der neuesten Resultate präsentiert.
Themen und Format variieren, im Sommersemester 2025 findet ein Lesekurs zur Mathematischen Statistischen Physik statt.

Assigned Courses:

Advanced Discrete Probability (Fortgeschrittene Themen der diskreten Wahrscheinlichkeitstheorie) (lecture + exercise)
**(in attendance) **

Examination
Fortgeschrittene Themen der diskreten Wahrscheinlichkeitstheorie
portfolio exam, Die genaue Prüfungsform wird in der jeweiligen Veranstaltung bekannt gegeben., graded
Test Frequency:
this semester

Module MTH-2718: Homotopical Algebra *Homotopische Algebra*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Workload: Total: 270 h		
Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** semester[s]
	Repeat Exams Permitted: according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Homotopische Algebra I
Language: German / English

Examination
MTH-2718 Homotopische Algebra
oral exam, graded
Test Frequency:
each semester

Module MTH-2728: Non-Commutative Ring and Module Theory

Nicht-kommutative Ring- und Modultheorie

8 ECTS/LP

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr. Wolfgang Schneider

Contents:
Die Vorlesung behandelt klassische und neuere Elemente der nichtkommutativen Ring- und Modultheorie:

- Grundlagen (Untermoduln, Faktormoduln, Homomorphismen von Moduln und Ringen);
- Direkte Produkte, direkte Summen, freie Moduln;
- Injektive und projektive Moduln;
- Lokale Ringe und Endomorphismenringe;
- Halbeinfache Moduln und Ringe;
- Radikal und Sockel;
- Tensorprodukt;
- Total;
- Lokale Projektivität. lokale Injektivität.

Learning Outcomes / Competences:
Die Teilnehmer*innen lernen wichtige Inhalte der nichtkommutativen Ring- und Modultheorie kennen. Diese Inhalte machen deutlich, dass der Begriff des Vektorraums über einem Körper durch Ersetzung des Körpers durch einen Ring mit Einselement zum Begriff des Moduls verallgemeinert werden kann. Dabei wird beim Ring nicht die Kommutativität vorausgesetzt, was eine Unterscheidung von Links- und Rechtsmoduln notwendig macht. Durch Forderung diverser Eigenschaften gewinnt man unterschiedliche Klassen von Moduln wie die der freien, projektiven, injektiven, halbeinfachen und flachen Moduln. Die Teilnehmer*innen sollen für diese einzelnen Klassen ein tieferes Verständnis entwickeln. Insbesondere interessieren die Unterstrukturen und Endomorphismenringe von Moduln aus diesen Klassen. Dabei fließen auch Forschungsergebnisse aus der jüngeren Vergangenheit ein, die vor allem die Begriffe "Total, lokale Projektivität, lokale Injektivität" betreffen.

Remarks:
Kentnisse aus der Vorlesung "Einführung in die Algebra" sind hilfreich.

Workload:
Total: 240 h

Conditions:	**Credit Requirements:**
Kenntnisse aus der Vorlesung "Einführung in die Algebra" sind hilfreich.	Bestehen der Modulprüfung

Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Nicht-kommutative Ring- und Modultheorie
Language: German
Frequency: irregular
Contact Hours: 6,00

Contents:

Die Vorlesung behandelt klassische und neuere Elemente der nichtkommutativen Ring- und Modultheorie:

- Grundlagen (Untermoduln, Faktormoduln, Homomorphismen von Moduln und Ringen);
- Direkte Produkte, direkte Summen, freie Moduln;
- Injektive und projektive Moduln;
- Lokale Ringe und Endomorphismenringe;
- Halbeinfache Moduln und Ringe;
- Radikal und Sockel;
- Tensorprodukt;
- Total;
- Lokale Projektivität, lokale Injektivität

Literature:

F.Kasch: Moduln und Ringe, Springer;

R.Wisbauer: Grundlagen der Modul- und Ringtheorie, Verlag R.Fischer

Examination

Nicht-kommutative Ring- und Modultheorie

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-2738: Homotopy Theory *Homotopietheorie*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Wolfgang Steimle		
Learning Outcomes / Competences: Die Studierenden lernen grundlegende Konzepte, Techniken und Resultate der modernen Homotopietheorie und wissen, wie man sie in verschiedenen Bereichen der Geometrie und Algebra anwenden kann.		
Workload: Total: 240 h		
Conditions: keine		
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:**	

Parts of the Module

Part of the Module: Modulteil: Homotopietheorie
Language: German / English
Contact Hours: 6,00

Contents:

Die moderne Homotopietheorie ist eine axiomatische Theorie, die auf so unterschiedliche Bereichen der Mathematik wie Topologie, algebraischer Geometrie, Operatortheorie und Darstellungstheorie gleichermaßen anwendbar ist, und in deren Zentrum der Begriff von unendlich-Kategorien steht. Die Vorlesung bietet einen Einstieg in die moderne Homotopietheorie aus praxisorientierter Sicht, d. h. im Vordergrund steht nicht der systematische Aufbau der Theorie, sondern ein möglichst schneller Weg zu den zentralen Konzepten. Im Vordergrund steht dabei das Erlernen der kategoriellen Sprache und Techniken und der Überblick über verschiedene Anwendungen in unterschiedlichen Bereichen der Mathematik.

Examination

Prüfung

oral exam / length of examination: 45 minutes, graded

Test Frequency:

not this semester

Module MTH-2758: High-Dimensional Probability with Applications to Data Science

Hochdimensionale Wahrscheinlichkeitstheorie mit Anwendungen in Data Science

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Stefan Großkinsky
Koutsimpela, Angelina, Dr.

Contents:
1. Preliminaries on random variables
2. Concentration of sums of independent random variables
3. Random vectors in high dimensions
4. Random matrices
5. Concentration without independence
6. Quadratic forms, symmetrization and contraction
7. Random processes

Learning Outcomes / Competences:
Erlernen der wahrscheinlichkeitstheorietischen Grundlagen des Data Science. Studierende können Fragestellungen in Data Science mathematisch-präzise formulieren und rigorose Lösungen erarbeiten.

Workload:
Total: 240 h

Conditions:		**Credit Requirements:**
Probability Theory (e.g. Stochastik I), Analysis I+II. Linear Algebra I+II		Bestehen der Modulprüfung
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Hochdimensionale Wahrscheinlichkeitstheorie mit Anwendungen in Data Science
Language: English
Frequency: every 4th semester
Contact Hours: 6,00

Examination
Hochdimensionale Wahrscheinlichkeitstheorie mit Anwendungen in Data Science
portfolio exam, Die genaue Prüfungsform wird in der jeweiligen Veranstaltung bekannt gegeben., graded
Test Frequency:
only in the summer semester

Module MTH-3000: Selected Topics in Geometry *Spezielle Kapitel der Geometrie*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Kai Cieliebak		
Contents: Advanced topics such as fibre bundles, gauge theory, or characteristic classes.		
Learning Outcomes / Competences: Independent work with scientific literature, scientific reasoning, problem solving, presentation of results.		
Remarks: The modules MTH-3000 and MTH-3001 are mutually exclusive.		
Workload: 2 h lecture (attendance)		
Conditions: An advanced lecture on geometry or algebra such as Einführung in die Geometrie, Differentialtopologie, Differentialgeometrie, Kommutative Algebra		**Credit Requirements:** Passing the module exam. Exclusion condition: This module may not be brought in, if the module MTH-3001 has already been taken!
Frequency: irregular	**Recommended Semester:** 1. - 3.	**Minimal Duration of the Module:** semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Spezielle Kapitel der Geometrie
Language: German / English
Frequency: irregular
Contact Hours: 2,00
ECTS Credits: 6.0

Examination
Spezielle Kapitel der Geometrie
oral exam / length of examination: 20 minutes, graded
Test Frequency:
not this semester

Module MTH-3008: Selected Topics in Geometry *Spezielle Kapitel der Geometrie*	8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Kai Cieliebak	
Contents: Advanced topics such as fibre bundles, gauge theory, or characteristic classes.	
Learning Outcomes / Competences: Independent work with scientific literature, scientific reasoning, problem solving, presentation of results.	
Remarks: The modules MTH-3000 and MTH-3001 are mutually exclusive. Cannot be combined together with Modul MTH-3001.	
Workload: Total: 240 h 6 h lecture and exercise course (attendance)	
Conditions: An advanced lecture on geometry or algebra such as Einführung in die Geometrie, Differentialtopologie, Differentialgeometrie, Kommutative Algebra.	**Credit Requirements:** Passing the module exam. Exclusion condition: This module may not be brought in, if the module MTH-3000 has already been taken!

Frequency: irregular	**Recommended Semester:** 1. - 3.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Spezielle Kapitel der Geometrie
Language: German / English
Frequency: irregular
Contact Hours: 6,00

Learning Outcome:
Independent work with (English-language) scientific literature, scientific thinking, in-depth skills in the independent processing of problems, presentation of results.

Contents:
Advanced topics such as fibre bundles, gauge theory, or characteristic classes.

Assigned Courses:

Globale Analysis (lecture + exercise)
**(in attendance) **

Examination
Spezielle Kapitel der Geometrie
oral exam / length of examination: 20 minutes, graded
Test Frequency:
this semester

Module MTH-3218: Spin Geometry *Spin-Geometrie*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Bernhard Hanke		
Learning Outcomes / Competences: Das Hauptergebnis dieser Vorlesung wird der Indexsatz von Atiyah und Singer sein, der als eines der wichtigstens Ergebnisse der Mathematik des 20. Jahrhunderts gilt. Dazu untersuchen wir Clifford-Algebren, Spin-Gruppen und ihre Darstellungen. Wir führen Dirac- und Laplace-Typ-Operatoren ein und untersuchen sie analytisch. Nach dem Beweis des Indexsatzes behandeln wir geometrische Anwendungen. Wir besprechen auch verwandte Themen, wie Hodge-Theorie.		
Workload: Total: 240 h		
Conditions: Elementare differentialgeometrische Begriffe wie Mannigfalten und Vektorbündel werden vorausgesetzt. Fortgeschrittenere Konzepte wie charakteristische Klassen werden je nach Vorkenntnissen der Hörer erklärt.		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Spin-Geometrie
Language: German
Frequency: irregular
Contact Hours: 6,00

Examination
Spin-Geometrie
module exam, graded
Test Frequency:
not this semester

Module MTH-3228: Selected Topics in Geometric Topology *Ausgewählte Themen der geometrischen Topologie*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Bernhard Hanke Steimle, Wolfgang, Prof. Dr.		
Contents: Students learn important methods and results from selected areas of geometry and topology and acquire the competence to apply the learned methods independently. The exact choice of topics is left to the lecturer and results from the lecture announcement.		
Workload: Total: 240 h		
Conditions: Good basic knowledge in the scope of one lecture course in topology or geometry.		
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Klassifikation von Mannigfaltigkeiten
Language: German

Examination

Ausgewählte Themen der geometrischen Topologie

module exam, Die Prüfungsform wird in der jeweiligen Veranstaltung bekannt gegeben., graded

Test Frequency:

not this semester

Module MTH-3258: Complex Geometry I *Complex Geometry I*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Workload: Total: 240 h		
Conditions: • Grundvorlesungen in linearer Algebra • Grundvorlesungen in Analysis • Funktionentheorie		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Complex Geometry I
Language: German

Examination
MTH-3258 Complex Geometry I
oral exam, graded
Test Frequency:
each semester

Module MTH-3269: Lie Groups and Homogeneous Spaces *Lie-Gruppen und homogene Räume*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Dr. Peter Quast		
Workload: Total: 240 h		
Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency:	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Lie-Gruppen und homogene Räume
Language: German
Contact Hours: 6,00

Examination
Lie-Gruppen und homogene Räume
module exam, schriftliche Prüfung oder mündliche Prüfung oder Portfolioprüfung, graded
Test Frequency:
not this semester

Module MTH-3308: Mathematical Physics *Mathematische Physik*	8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Urs Frauenfelder	
Contents: In this course several topics of mathematical physics are discussed like the question about the quantization of a classical mechanical system and the connection between its geometry and dynamics.	
Remarks: Cannot be combined together with MTH-3300.	
Workload: Total: 240 h	

Conditions: none		**Credit Requirements:** Passing the module exam.
Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Mathematische Physik
Language: German / English
Frequency: irregular
Contact Hours: 6,00

Examination
Mathematische Physik
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-3585: Selected Topics in Stochastic Analysis

Ausgewählte Kapitel der Stochastischen Analysis

6 ECTS/LP

Version 1.0.0 (since SoSe24)
Person responsible for module: Prof. Dr. Dirk Blömker

Contents:
numerical method for stochastic differential equations, Euler-Maruyama, weak and strong convergence, error estimates

Learning Outcomes / Competences:
The students know the basic terms, concepts and phenomena of the numerical treatment of stochastic differential equations.
of the numerical treatment of stochastic differential equations, can implement the corresponding algorithms and are familiar with the basics of stochastic analysis.
Ability to work independently on further literature.
Competences in the independent processing and implementation of numerical algorithms,
Skills in formulating and working on theoretical and applied problems using the
and applied questions with the help of the methods learnt.
Integrated acquisition of key qualifications:
Independent work with (English-language) scientific literature,
working with scientific computers,
in-depth competences in the independent processing of problems,
Skills in formulating and working on applied questions.

Workload:
Total: 180 h
2 h exercise course (attendance)
2 h lecture (attendance)

Conditions:
knowledge in stochastic differential equations and numerical methods for ordinary differential equations are helpful

Credit Requirements:
oral exam

Frequency: irregular

Recommended Semester:
1. - 4.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
4,00

Repeat Exams Permitted:
any

Parts of the Module

Part of the Module: Ausgewählte Kapitel der Stochastischen Analysis
Language: German / English
Frequency: irregular
Workload:
2 Std. Übung (Präsenzstudium)
2 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Learning Outcome:
Die Student(inn)en kennen moderne Zugänge zu ausgewählten Problemen in der Theorie der stochastischen Analysis. Sie sind in der Lage, aufbauend auf den Inhalten der Vorlesung Forschungliteratur in diesen Gebieten zu lesen und sich selbstständig in weiterführende Aspekte einzuarbeiten.

Examination

Ausgewählte Kapitel der Stochastischen Analysis

oral exam / length of examination: 30 minutes, graded

Module MTH-4290: Selected Topics in Mathematical Data Science *Spezielle Kapitel der Mathematical Data Science*	3 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. André Uschmajew	
Learning Outcomes / Competences: Die Studierenden vertiefen ihre Kenntnisse in speziell ausgewählten Kapiteln der Mathematical Data Science.	
Conditions: none	**Credit Requirements:** Bestehen der Modulprüfung

Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Spezielle Kapitel der Mathematical Data Science
Language: German / English

Assigned Courses:

Spezielle Kapitel der Mathematical Data Science (lecture)
**(in attendance) **

Examination
MTH-4290 Spezielle Kapitel der Mathematical Data Science
oral exam / length of examination: 30 minutes, graded
Test Frequency:
only in the winter semester

Module INF-0217: Practical Module Autonomous Driving *Praktikum Autonomes Fahren*	10 ECTS/LP

Version 2.0.0 (since WS21/22)
Person responsible for module: Prof. Dr. Bernhard Bauer
Prof. Dr. Lars Mikelsons

Learning Outcomes / Competences:
After participating in the practical course on autonomous driving, students will be able to solve practical problems of high complexity in conceptual design, development, and safeguarding of highly automated/autonomous vehicles using current methods and tools of model-based development. The students acquire in-depth subject-specific and interdisciplinary knowledge and skills, for example, from hardware-related computer science, software engineering, and the underlying driving physics and mathematics. They are able to develop concepts, methods, procedures, techniques, and technologies of the mentioned field in research projects and are able to apply innovative approaches in solving problems. This enables them to link up with international research and make their scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the area, define intermediate goals, and critically evaluate, classify, combine, present and document intermediate results and innovative ideas understandably.

Key qualification: Ability to think logically, analytically, and conceptually; Independent work with English-language specialist literature; Understandable, confident, and convincing presentation of ideas, concepts, and results; Quality awareness; Communication skills; Ability to work in teams and understand team processes; Project management skills.

Remarks:
The practical course is offered alternately by the two chairs mentioned above.

Workload:
Total: 300 h
150 h internship / practical course (attendance)
150 h studying of course content through exercises / case studies (self-study)

Conditions:		**Credit Requirements:**
Participation in one of the two seminars is recommended.		Passing the module exam
Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 10,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Praktikum Autonomes Fahren
Mode of Instruction: internship
Language: German / English
Frequency: irregular
Contact Hours: 10,00

Contents:

In this practical course, the participants learn how various selected partial aspects of autonomous driving can be implemented, simulated, and analyzed.

In addition, the participants will get to know, among other things, development tools frequently used in the automotive environment.

After an introductory course, the participants will implement autonomous driving functions in small groups with the help of the tools mentioned.

The developed results are finally demonstrated and evaluated.

Assigned Courses:

Praktikum Autonomes Fahren (internship)

**(in attendance) **

Examination

Practical Module Autonomous Driving

portfolio exam, graded

Test Frequency:

when a course is offered

Module INF-0243: Process Mining *Process Mining*	6 ECTS/LP

Version 1.2.0 (since SoSe17)
Person responsible for module: Prof. Dr. Robert Lorenz

Learning Outcomes / Competences:
Participants understand the following essential concepts of computer science at an advanced scientific level, including their mathematical and formal foundations: event log, partial order, Petri net, concurrency, sequential and causal semantics of a concurrent system, synthesis of a concurrent system, business process, process mining, process discovery, conformance checking. They can model concurrent systems of medium complexity in a suitable modeling language, as well as generate, evaluate, and convert different models for analysis and simulation for a given concurrent system. They are familiar with the various process mining use cases with appropriate solution techniques and quality criteria for their evaluation. Participants will have advanced mathematical formal methodology for the analysis and formalization of complex process discovery problems. They will be able to confidently select suitable algorithms for their solution with regard to qualitative and quantitative criteria, apply them, and interpret and evaluate the results.
Key qualifications: Ability to think logically, analytically, conceptually, and algorithmically; Independent work with textbooks and English-language specialist literature; Clear presentation of results; Quality awareness; Meticulousness; Principles of good scientific practice; Scientific methodology;

Workload:
Total: 180 h
45 h lecture (attendance)
15 h exercise course (attendance)
23 h studying of course content using literarture (self-study)
75 h studying of course content through exercises / case studies (self-study)
22 h studying of course content using provided materials (self-study)

Conditions: none		**Credit Requirements:** Passing the module examination
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Process Mining (Vorlesung)
Mode of Instruction: lecture
Language: German / English
Frequency: each summer semester
Contact Hours: 3,00

Contents:
The lecture provides a comprehensive overview of the field of process mining research:
- Modeling techniques: Petri nets, workflow nets, process trees, direct follows graphs
- Discovering algorithms: Alpha-Algorithm, Inductive Miner, Direct Follows Miner, Synthesis based discovery techniques
- Conformance checking: fitness, precision, generalization, simplicity
- Tools: PROM, Celonis

Literature:

English-language lecture notes

Wil M. P. van der Aalst:
Process Mining - Data Science in Action, Second Edition. Springer 2016, ISBN 978-3-662-49850-7

Wil M. P. van der Aalst, Boudewijn F. van Dongen: Discovering Petri Nets from Event Logs. Trans. Petri Nets and Other Models of Concurrency 7: 372-422 (2013)

Robin Bergenthum, Jörg Desel, Robert Lorenz, Sebastian Mauser: Process Mining Based on Regions of Languages. BPM 2007: 375-383

Wil M. P. van der Aalst, Josep Carmona:
The Process Mining Handbook. Springer 2022, ISBN 978-3-031-08848-3

Part of the Module: Process Mining (Übung)

Mode of Instruction: exercise course
Language: German / English
Frequency: each summer semester
Contact Hours: 1,00

Examination

Process Mining (Klausur)

written exam / length of examination: 90 minutes, graded

Test Frequency:

when a course is offered

Module INF-0277: Analysing Massive Data Sets

Analyzing Massive Data Sets

8 ECTS/LP

Version 1.2.0 (since SoSe18)
Person responsible for module: Prof. Dr. Peter Michael Fischer

Learning Outcomes / Competences:
After attending the course, students will be able to understand and evaluate the concepts and methods, procedures, techniques, and technologies for analyzing massively large data sets. Possible content includes:

- Fundamentals of information retrieval
- Similarity search and clustering
- Analysis of data streams and temporal data
- Web graphs: Link analysis and social networks
- Dynamic networks and information diffusion
- Recommender systems and online advertising
- Computational methods for massive data sets

Students will also be able to implement technical solution concepts for analyzing large data sets in programs.
Key Skills: Ability to think logically, analytically and conceptually, weigh up approaches to solutions, acquire abstraction skills; subject-specific in-depth knowledge; implement subject-specific solution concepts in programs and models; knowledge of the advantages/disadvantages of design alternatives and evaluation in the respective application context; selection and confident application of suitable methods; ability to make scientifically meaningful evaluations using suitable methods; ability to solve problems under practical boundary conditions; competence in recognizing significant technical developments;

Workload:
Total: 240 h
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using provided materials (self-study)
60 h lecture (attendance)
30 h exercise course (attendance)

Conditions:
Module Database Systems (INF-0073) - recommended
Module Discrete structures for computer science (INF-0109) - recommended
Module Computer Science 3 (INF-0111) - recommended

Frequency: Sommersemester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Analyzing Massive Data Sets (Vorlesung)
Mode of Instruction: lecture
Language: English
Frequency: irregular (usu. summer semester)
Contact Hours: 4,00

Contents:
The lecture covers basic concepts for the analysis of massively large data sets such as information extraction, similarity search, clustering, link and network analysis as well as their implementation.

Literature:

- Mining of Massive Datasets. J. Leskovec, A. Rajaraman, J.D. Ullman. Cambridge UniversityPress, 2014
- D. Easley, J. Kleinberg.Networks, Crowds, and Markets: Reasoning About a Highly Connected World.Cambridge University Press, 2010.
- R. Baeza-Yates, B. Ribeiro-Neto: Modern Information Retrieval

Weitere Literatur wird in der Vorlesung bekannt gegeben

Part of the Module: Analyzing Massive Data Sets (Übung)

Mode of Instruction: exercise course
Language: English / German
Frequency: irregular (usu. summer semester)
Contact Hours: 2,00

Examination

Analyzing Massive Data Sets

portfolio exam, graded

Test Frequency:

when a course is offered

Module INF-0293: Advanced Deep Learning *Advanced Deep Learning*	8 ECTS/LP
Version 1.0.0 (since WS18/19) Person responsible for module: Prof. Dr. Rainer Lienhart	

Learning Outcomes / Competences:
After participating in the practical module, students have detailed and up-to-date knowledge in the field of machine learning, can identify significant technical developments and can implement a complete pipeline for multimodal data processing with deep neural networks. They can precisely describe and discuss problems and results in the field and apply learned concepts and methods to similar problems in machine learning. In addition, the students analyse advanced concepts, methods, procedures, techniques and technologies from the field of machine learning to apply them in research projects, transfer them to current industry-related tasks and actively participate in them. The students learn to transfer scientifically challenging topics in the field of machine learning to other research questions and, building on this, to work out a complex project in group work. They also have the teamwork and communication skills to discuss problems in the field, to discuss, describe and present questions and interim results. In addition, students can conduct detailed experiments and assess, compare and check results for plausibility.
Key qualifications:

Advanced mathematical-formal methodology; Translating subject-specific solution concepts into programs and models; Methods for developing larger software systems, construction of abstractions and architectures; Interdisciplinary knowledge; Systematic further development of design methods; Skill of confident and convincing presentation of ideas and concepts; Understanding of team processes; Skill of working in teams; Ability to lead teams; Familiarity with procedures and processes in the application environment of computer science; Skill of solving problems under practical boundary conditions; Self-reflection; Responsible action against the background of inadequacy and conflicting interests; Ability to expand existing knowledge independently; Quality awareness, meticulousness

Workload:
Total: 240 h
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
120 h studying of course content through exercises / case studies (self-study)
20 h lecture (attendance)
40 h exercise course (attendance)

Conditions:	**Credit Requirements:**
Fundamental knowledge in computer vision (basic studies lectures "Multimedia Grundlagen 1", "Grundlagen der Signalverarbeitung und des Maschinellen Lernens", "Multimedia Grundlagen 2" as well as master's lectures "Multimedia 2" and "Machine Learning and Computer Vision")	Passing the portfolio examination

Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Deep Learning (Lecture)
Mode of Instruction: lecture
Language: English / German
Frequency: each winter semester
Contact Hours: 2,00

Contents:

- Deep Learning in general
- Deep Convolutional Neural Networks
- Transfer Learning
- Recurrent Neural Networks / LSTM Networks
- Natural Language Processing
- Multimodal Fusion (Vision+Language)
- Application: Image Captioning

Assigned Courses:

Advanced Deep Learning (lecture)
*(in attendance) **

Part of the Module: Advanced Deep Learning (Tutorial)

Mode of Instruction: exercise course
Language: English / German
Frequency: each winter semester
Contact Hours: 4,00

Assigned Courses:

Übung zu Advanced Deep Learning (exercise course)
*(in attendance) **

Examination

Advanced Deep Learning

portfolio exam, The final grade is made up of assessed exercise sheets and an assessed team project., graded

Test Frequency:

when a course is offered

Module INF-0308: Software-Intensive Systems

Software-intensive Systeme

6 ECTS/LP

Version 1.2.0 (since SoSe19)
Person responsible for module: Prof. Dr. Bernhard Bauer

Learning Outcomes / Competences:
Students can create (K3), evaluate (K6), and document software architectures. For this purpose, they can transfer technical solution concepts into models and know methods for developing such abstractions and architectures. They can describe the advantages and disadvantages of design alternatives (K4) and evaluate them in the respective application context (K6). Problems can be identified independently (K4), and solutions can be designed systematically (K5) and realized (K3). Furthermore, they have developed skills for the analysis and structuring of problems in enterprise architectures and know the concepts and procedures for creating such architectures. The students can name practice-relevant issues in enterprise architectures (K1). They can select and confidently apply suitable methods for architecture creation and evaluation. The students know modeling languages and patterns to create software and enterprise architectures. They have the competence to recognize significant technical developments.

Key qualification: Competence to network different subject areas; ability to work in a team and communicate; ability to expand existing knowledge independently; quality awareness; skill to present and document results in an understandable way; practical experience and professional qualification.

Workload:
Total: 180 h
22 h studying of course content using provided materials (self-study)
23 h studying of course content using literarture (self-study)
45 h lecture (attendance)
60 h studying of course content through exercises / case studies (self-study)
30 h exercise course (attendance)

Conditions:
The previous course "Software Architectures and Enterprise Architecture Management" and the course "Software-intensive Systems and Medical Devices" must not have been taken due to overlaps.

Frequency: irregular (usu. summer semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 5,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Software-intensive Systeme (Vorlesung)
Mode of Instruction: lecture
Language: German
Frequency: Sommersemester
Contact Hours: 3,00

Contents:
The lecture content includes patterns, modelling techniques and the evaluation of software architectures. Furthermore, the area of enterprise architecture management is addressed.

Literature:
- Bass et al: Software Architecture in Practice
- Clements et al: Documenting Software Architectures
- Clements et al: Evaluation of Software Architectures
- Kopetz: Real-Time Systems

Part of the Module: Software-intensive Systeme (Übung)
Mode of Instruction: exercise course
Language: German
Frequency: Sommersemester
Contact Hours: 2,00

Examination
Software-intensive Systeme
oral exam / length of examination: 30 minutes, graded
Test Frequency:
when a course is offered

Module INF-0309: Real-Time Systems *Echtzeitsysteme*	8 ECTS/LP

Version 1.11.0 (since WS19/20)
Person responsible for module:
Prof. Dr. Sebastian Altmeyer

Learning Outcomes / Competences:
The lecture imparts basic and advanced knowledge of real-time systems as they occur in almost all embedded systems, but especially in the areas of automotive, aerospace and robotics. The theoretical foundations will be based on the current state of research and will enable students to further engage with the topic of embedded real-time systems at a scientific level.

The lecture will provide students with the ability to distinguish and classify different embedded systems based on their real-time requirements. Students will learn to apply, compare, and critically analyze current methods for validation of timing behavior with respect to possible certification of timing behavior. This includes the optimization and selection of real-time schedules and their verification. The lecture will also cover different processor types, and will go into more detail about the specifics of single-core and multi-core processors in the real-time domain. Students will be able to classify processors based on their suitability for real-time systems and to investigate the impact of design decisions on real-time behavior and real-time behavior analysis.

The course material will be exemplified by case studies from the automotive and aerospace fields and applied by the students using a simple real-time system.

Key qualifications: Analytical-methodical competence, consideration of approaches to solutions, presentation of solutions to exercise problems; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; quality awareness, meticulousness; self-reflection; responsible action against a background of inadequacy and conflicting interests.

Workload:
Total: 240 h
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using provided materials (self-study)
60 h lecture (attendance)
30 h exercise course (attendance)

Conditions: none		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Echtzeitsysteme (Vorlesung)
Mode of Instruction: lecture
Language: German / English
Frequency: irregular (usu. winter semester)
Contact Hours: 4,00

Contents:

- WCET Analysis
- Scheduling Analysis
- Programming of real-time systems
- Processors for real-time systems
- Real-time operating systems
- Certification of real-time systems

Literature:

- Sanjoy Baruah, Marko Bertogna, Giorgio Buttazzo, Multiprocessor Scheduling for Real-Time Systems, Springer, 2015.
- Giorgio Buttazzo, Hard Real-Time Computing Systems: Predictable Scheduling Algorithms and Applications, Springer, 2011.
- Heinz Wörn, Uwe Brinkschulte, Echtzeitsysteme, Springer Verlag, Berlin/Heidelberg, 2005
- Uwe Brinkschulte, Theo Ungerer, Mikrocontroller und Mikroprozessoren, Springer Verlag, Heidelberg, dritte Auflage 2010

Assigned Courses:

Real-Time Systems (lecture)
*(in attendance) **

Part of the Module: Echtzeitsysteme (Übung)

Mode of Instruction: exercise course
Language: German
Frequency: irregular (usu. winter semester)
Contact Hours: 2,00

Assigned Courses:

Exercise for Real-Time Systems (exercise course)
*(in attendance) **

Examination

Echtzeitsysteme
written exam / length of examination: 90 minutes, graded
Test Frequency:
this semester

Module INF-0316: Machine Learning and Computer Vision *Machine Learning and Computer Vision*	8 ECTS/LP

Version 1.0.0 (since SoSe19)
Person responsible for module: Prof. Dr. Rainer Lienhart

Learning Outcomes / Competences:
After successful participation in this module, students possess advanced knowledge of machine learning (decision trees, neural networks and deep neural networks, hypothesis evaluation, instance-based learning, Bayesian learning, learning theory), data reduction (e.g. principal component analysis), advanced image processing and machine vision and are able to apply them. They can analyse, understand and programmatically implement scientifically complex procedures in the field of multimedia data processing, as well as to appropriately apply the principles learned to new problems. They develop skills in logical, analytical and conceptual thinking in the field of digital signal processing and multimedia data processing.

Key qualifications: advanced mathematical-formal logic; implementation of subject-specific solution concepts; interdisciplinary knowledge; development and implementation of solution strategies for complex problems; systematic further development of design methods; ability to solve problems under practical boundary conditions.

Workload:
Total: 240 h
30 h exercise course (attendance)
60 h lecture (attendance)
30 h studying of course content using provided materials (self-study)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using literarture (self-study)

Conditions:		**Credit Requirements:**
none		Passing the Module Exam
Frequency: each summer semester (except for summer term 2026)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Machine Learning and Computer Vision (Lecture)
Mode of Instruction: lecture
Language: German
Frequency: each summer semester
Contact Hours: 4,00

Contents:
The lecture gives a good overview of all aspects of machine learning and machine extraction of information from multimedia data (e.g. "Google Image Search", "Google Goggles"). The learned concepts will be practised, analysed, and evaluated in the exercises using successful examples from practice. At the end of the semester, advanced topics such as object detection and object recognition of faces and people will be covered. The contents of the lecture include: Machine Learning (Decision Tree Learning, Artificial Neural Networks, Bayesian Learning, Discrete Adaboot), Data Reduction (Quantization (K-Means Clustering, Affinity Propagation), Dimensionality Reduction Techniques (PCA, NMF, Random Projection, MDS)) and Image Processing & Computer Vision (Salient Feature Points and Feature Descriptors, Object Detection (Face/Car/People Detection), Object Recognition (Face Recognition), Image Search with pLSA).

Literature:
Literature references will be announced at the beginning of the semester.

Part of the Module: Machine Learning and Computer Vision (Tutorial)
Mode of Instruction: exercise course
Language: German
Frequency: each summer semester
Contact Hours: 2,00

Examination
Machine Learning and Computer Vision
written exam / length of examination: 120 minutes, graded
Test Frequency:
each semester
Description:
The examination can be taken every semester during the examination period.

Module INF-0367: Advanced Machine Learning and Computer Vision

Advanced Machine Learning and Computer Vision

5 ECTS/LP

Version 1.0.0 (since WS20/21)
Person responsible for module: Prof. Dr. Rainer Lienhart

Learning Outcomes / Competences:
After successful participation in this module, students have in-depth advanced knowledge of machine learning (support vector machines and deep neural networks and their basic building blocks) and machine vision (deep neural network architectures and systems) and can apply these. They can analyse, understand and programmatically implement scientifically complex procedures in the field of image, text, video and signal processing, as well as to appropriately apply the principles learned to new problems. They develop skills in logical, analytical and conceptual thinking in the field of machine learning and vision.

Key qualifications: advanced mathematical-formal logic; critical reading and analysis of scientific publications; implementation of technical solution concepts; interdisciplinary knowledge; development and implementation of solution strategies of complex problems; systematic further development of design methods; skills in solving problems under practical boundary conditions

Workload:
Total: 150 h
30 h lecture (attendance)
60 h studying of course content through exercises / case studies (self-study)
30 h exercise course (attendance)
15 h studying of course content using literarture (self-study)
15 h studying of course content using provided materials (self-study)

Conditions:	**Credit Requirements:**
"Knowledge of Machine Learning and Computer Vision" (Master's lecture INF-0092 "Multimedia II" or INF-0316 "Machine Learning and Computer Vision")	Passing the module examination

Frequency: each winter semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Machine Learning and Computer Vision (Lecture)
Mode of Instruction: lecture
Language: German
Frequency: each winter semester
Contact Hours: 2,00

Contents:

The lecture gives an in-depth insight into all aspects of machine learning and machine vision. The concepts learned will be practiced, analyzed and evaluated in the exercises using successful real-world examples. The contents of the lecture include: support vector machines, basic building blocks of deep neural networks (layer structures, normalization, attention mechanisms), as well as current reference architectures and systems for image, text, video processing and their combination with further sensor signals.

Literature:

Will be announced at the beginning of the semester.

Assigned Courses:

Advanced Machine Learning and Computer Vision (lecture)
**(online/digital) **

Part of the Module: Advanced Machine Learning and Computer Vision (Tutorial)
Mode of Instruction: exercise course
Language: German
Frequency: each winter semester
Contact Hours: 2,00

Assigned Courses:

Übung zu Advanced Machine Learning and Computer Vision (exercise course)
**(in attendance) **

Examination
Advanced Machine Learning and Computer Vision (Examination)
written exam / length of examination: 90 minutes, graded
Test Frequency:
each semester
Description:
The examination can be taken every semester during the examination period.

Module INF-0368: Embedded Hardware

Embedded Hardware

5 ECTS/LP

Version 1.2.0 (since WS20/21)
Person responsible for module: Prof. Dr. Sebastian Altmeyer

Learning Outcomes / Competences:
The lecture provides basic and advanced knowledge of hardware components (e.g. GPIO, hardware timer, ...) as they are found in almost all embedded systems. Furthermore, the functional principles of different sensors and actuators are presented. A special focus will be on their use to interact with the physical world and on particularities of their application. The theoretical foundations will be based on the current state of research and will allow students to further engage with the topic of embedded hardware at a scientific level.

The lecture will provide students with the ability to distinguish and classify different embedded systems based on their hardware requirements. Students will learn to apply current component programming methods, compare them, and critically analyze them for efficient use. This includes selecting and evaluating hardware components relevant to the system, as well as developing a configuration of components optimized for an existing problem. The lecture will also cover various sensors and actuators, and will go into more detail about the conversion between an analog, physical quantity and a digital, electrical quantity. Here, students will be able to classify physical quantities based on their properties and make a decision about the sensors, actuators, and hardware components needed for the conversion.

The subject matter is exemplified by means of case studies, e.g. from the automotive field, and applied by the students using a simple embedded system.

Key qualifications: Analytical-methodical competence, consideration of approaches to solutions, presentation of solutions to exercise problems; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; quality awareness, meticulousness; self-reflection; responsible action against the background of inadequacy and conflicting interests.

Workload:
Total: 150 h
15 h studying of course content using provided materials (self-study)
15 h studying of course content using literarture (self-study)
60 h studying of course content through exercises / case studies (self-study)
30 h lecture (attendance)
30 h exercise course (attendance)

Conditions:
none

Frequency: irregular (usu. winter semester)	**Recommended Semester:** 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Embedded Hardware (Vorlesung)
Mode of Instruction: lecture
Language: German / English
Frequency: irregular (usu. winter semester)
Contact Hours: 2,00

Contents:

- Modeling of sensors and actuators
- Basics in electronics
- Hardware components of embedded processors and SoC
- Serial interfaces
- Sensors and input devices
- Actuators and output devices

Literature:

- Yifeng Zhu, Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C, E-Man Press LLC, 2017
- Edward Ashford Lee, Sanjit Arunkumar Seshia, Introduction to Embedded Systems - A Cyber-Physical Systems Approach, MIT Press, 2017
- Elecia White, Making Embedded Systems, O'Reilly Media, 2012
- John Catsoulis, Designing Embedded Hardware, O'Reilly Media, 2005
- Rüdiger R. Asche, Embedded Controller: Grundlagen und praktische Umsetzung für industrielle Anwendungen, Springer, 2016
- Hermann Winner, Stephan Hakuli, Felix Lotz, Christina Singer Hrsg., Handbuch Fahrerassistenzsysteme: Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort, Springer, 2015
- Bernhard Grimm, Gregor Häberle, Heinz Häberle, u.a., Fachkunde Industrieelektronik und Informationstechnik, Europa Lehrmittel, 2003

Part of the Module: Embedded Hardware (Übung)

Mode of Instruction: exercise course

Language: German / English

Frequency: irregular (usu. winter semester)

Contact Hours: 2,00

Examination

Embedded Hardware

written exam / length of examination: 60 minutes, graded

Test Frequency:

when a course is offered

Module INF-0381: Embedded Systems - Advanced Course

Embedded Systems - Vertiefung

5 ECTS/LP

Version 1.3.0 (since SoSe21)
Person responsible for module: Prof. Dr. Sebastian Altmeyer

Learning Outcomes / Competences:
The lecture provides in-depth knowledge on changing focus topics in embedded systems, which are used in nearly all areas of industry—such as automotive, aerospace, and robotics—as well as in everyday life. The focus topics are selected from the field of developing and analyzing safe, reliable, and high-performance embedded systems. In particular, current research questions are addressed, and discussions are held on how embedded systems might be developed and analyzed in the future.

Students will, on the one hand, be enabled to identify and justify the specific requirements of embedded systems. On the other hand, they will learn to apply various development techniques and analysis methods for embedded systems to examples, and to evaluate and classify them with respect to reliability and practicality. Furthermore, the lecture imparts the ability to independently analyze scientific theses related to the focus topics, formulate their own theses, evaluate them, and, if necessary, refute them. The focus topics will be aligned with the current state of research and will enable students to further engage with the subject of embedded systems on a scientific level.

Key qualifications: Analytical-methodical competence, scientific methodology; principles of good scientific practice; skill in presenting and documenting results in a comprehensible manner; independent work with English-language specialist literature; ability to independently expand existing knowledge; analytical-methodological competence; skill in clear and confident oral presentation of (practical or theoretical) ideas, concepts, and results.

Workload:
Total: 150 h
30 h studying of course content using provided materials (self-study)
60 h studying of course content using literarture (self-study)
30 h exercise course (attendance)
30 h lecture (attendance)

Conditions:
none

Frequency: irregular (usu. summer semester)	**Recommended Semester:** 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Embedded Systems - Advanced Course (Vorlesung)
Mode of Instruction: lecture
Language: German / English
Frequency: irregular (usu. summer semester)
Contact Hours: 2,00

Contents:
- Development and analysis of safe, reliable, and high-performance embedded systems
- Non-functional properties of embedded systems
- Current research questions and topics in the field of embedded systems

Literature:
- Selected literature and current scientific articles on embedded systems (varies each semester)

Part of the Module: Embedded Systems - Vertiefung (Übung)
Mode of Instruction: exercise course
Language: German / English
Frequency: irregular (usu. summer semester)
Contact Hours: 2,00

Examination
Embedded Systems - Advanced Course
oral exam / length of examination: 20 minutes, graded
Test Frequency:
when a course is offered

Module INF-0409: Cyber Security *Cyber Security*	6 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Bernhard Bauer	

Learning Outcomes / Competences:

Students can create (K3), evaluate (K6), and document security aspects in the software development process and software architectures.
To this end, they can transfer technical solution concepts into development processes and IT architectures and know methods for developing secure software. They can describe the advantages and disadvantages of security alternatives (K4) and evaluate them in the respective application context (K6). Problems can be identified independently (K4) and solutions systematically designed (K5) and implemented (K3). Furthermore, they have developed skills for analyzing and structuring the problems of security architectures and know the concepts and procedures for creating such architectures. Students can name practice-relevant issues in security architectures and secure software development processes (K1). They can select suitable methods for
They can select and safely apply suitable methods for creating and evaluating security architectures. The students know concepts and technologies for developing secure software and security architectures. They have the competence to recognize significant technical developments.

Key qualification: Competence to network different subject areas; team and
ability to communicate; ability to expand existing knowledge independently; quality awareness; ability to present and document results understandably; practical experience and professional aptitude.

Workload:

Total: 180 h
23 h studying of course content using literarture (self-study)
22 h studying of course content using provided materials (self-study)
60 h studying of course content through exercises / case studies (self-study)
45 h lecture (attendance)
30 h exercise course (attendance)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each winter semester SoSe 25 danach WiSe 26-27	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 5,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Cyber Security (Vorlesung)

Mode of Instruction: lecture
Language: German / English
Frequency: each summer semester
Contact Hours: 3,00

Contents:

The lecture content includes security standards, secure software development lifecycles, as well as security architectures, and their evaluation in respective technology contexts. and the evaluation of security architectures.

Literature:

- Slides
- A. Deane, A. Kraus: The Official (ISC)2 CISSP CBK Reference
- Further literature in the lecture on specific topics

Part of the Module: Cyber Security (Übung)
Mode of Instruction: exercise course
Language: German / English
Frequency: each summer semester
Contact Hours: 2,00

Examination
Cyber Security
oral exam / length of examination: 30 minutes, graded
Test Frequency:
when a course is offered

Module INF-0425: Cyber Security 2 *Cyber Security 2*	6 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Bernhard Bauer	

Learning Outcomes / Competences:
Students can create (K3), evaluate (K6), and document security aspects in the software development process and software architectures.
To this end, they can transfer technical solution concepts into development processes and IT architectures and know methods for developing secure software. They can describe the advantages and disadvantages of security alternatives (K4) and evaluate them in the respective application context (K6). Problems can be identified independently (K4) and solutions systematically designed (K5) and implemented (K3). Furthermore, they have developed skills for analyzing and structuring the problems of security architectures and know the concepts and procedures for creating such architectures. Students can name practice-relevant issues in security architectures and secure software development processes (K1). They can select suitable methods for
They can select and safely apply suitable methods for creating and evaluating security architectures. The students know concepts and technologies for developing secure software and security architectures. They have the competence to recognize significant technical developments.

Key qualification: Competence to network different subject areas; team and
ability to communicate; ability to expand existing knowledge independently; quality awareness; ability to present and document results understandably; practical experience and professional aptitude.

Workload:
Total: 180 h
30 h exercise course (attendance)
45 h lecture (attendance)
60 h studying of course content through exercises / case studies (self-study)
23 h studying of course content using literarture (self-study)
22 h studying of course content using provided materials (self-study)

Conditions: none		
Frequency: each summer semester erst wieder ab SoSe 26	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 5,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Cyber Security 2 (Vorlesung)
Mode of Instruction: lecture
Language: German
Frequency: each winter semester
Contact Hours: 3,00

Contents:
The lecture content includes security standards, secure software development lifecycles, as well as security architectures, and their evaluation in respective technology contexts. and the evaluation of security architectures.

Literature:
- Slides
- A. Deane, A. Kraus: The Official (ISC)2 CISSP CBK Reference
- Further literature in the lecture on specific topics

Part of the Module: Cyber Security 2 (Übung)
Mode of Instruction: exercise course
Language: German
Frequency: each winter semester
Contact Hours: 2,00

Examination
Cyber Security 2
oral exam / length of examination: 30 minutes, graded
Test Frequency:
when a course is offered

Module INF-0432: Isabelle-Lab *Isabelle-Lab*	8 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Kirstin Peters	
Contents: The general idea of interactive theorem proving is introduced and the tool Isabelle/HOL is discussed. Several common features of Isabelle/HOL are studied: e.g. basic concepts such as data structures and functions, modelling mechanisms such as locales, proof techniques such as structural induction, and the proof language Isar.	
Learning Outcomes / Competences: **Knowledge:** Students will get to know the key concepts, definitions, and techniques of interactive theorem proving with Isabelle/HOL. They will get insights and practical knowledge about the design of models in Isabelle/HOL such as the conception of data structures and functions or the abstraction of concepts into a locale. They will learn strategies to tackle complex and technically very detailed proofs. They will learn about automated reasoning mechanisms as well as interactive proof tactics; their respective advantages and typical areas of application. Finally, students learn about the guarantees provided by machine checked proofs and the additional complexity that comes with such projects. **Skills:** Students will be familiar with the basic concepts of modelling and proving in Isabelle/HOL. Students will be able to formally and correctly model applications and concepts in Isabelle/HOL. They are able to select appropriate proof methods and carry out complex proofs with the assistance of Isabelle/HOL. They understand the hints provided by the proof assistance, can analyse the current state of a proof and its proof obligations, and can carry out the next relevant steps. They understand under which circumstances the automatic proof methods are useful and how to apply them. Moreover, they are able to plan and carry out a project and meet the time restrictions that come with such a project. Finally, they will practice logical and conceptual thinking as well as the abstraction and formalisation of concepts in a stringent mathematical framework. **Competences:** Students are prepared to work on verification projects. Students are able to plan and carry out the modelling as well as the proof obligations of such a project in an interactive theorem prover. They understand the nature of the correctness guarantees provided by machine checked proofs, but also the additional complexity that is necessary to carry out such proofs. Furthermore, they know how to characterise and judge on the quality and suitability of existing models and theories in Isabelle/HOL. More abstractly, they are able to reason more concretely about the correctness of a formalisation and proofs. **Key skills:** Formal methods; Knowledge of advantages and disadvantages of different design alternatives in modelling; Ability to carry out very detailed proofs; Ability to work on and organise projects; Ability to work autonomously; Quality awareness; Scientific working.	
Workload: Total: 240 h 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literarture (self-study) 60 h exercise course (attendance) 30 h lecture (attendance)	
Conditions: none	**Credit Requirements:** Bestehen der Modulprüfung

Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Isabelle-Lab (Vorlesung)
Mode of Instruction: lecture
Language: English
Frequency: each winter semester
Contact Hours: 2,00

Contents:

We discuss the basic design of Isabelle and how to work with this interactive theorem prover. In particular we study:

- higher-order logic (HOL)
- isabelle syntax and semantics
- proof strategies
- induction and induction principles
- formalisation of theories in Isabelle/HOL
- proof support (proof tactics and external assistance)
- proof language Isar

Literature:

https://isabelle.in.tum.de/documentation.html

Assigned Courses:

Isabelle-Lab (lecture)
*(in attendance) *

Part of the Module: Isabelle-Lab (Übung)
Mode of Instruction: exercise course
Language: English
Frequency: each winter semester
Contact Hours: 4,00

Assigned Courses:

Übung zu Isabelle-Lab (exercise course)
*(in attendance) *

Examination
Isabelle-Lab
practical exam, graded
Test Frequency:
when a course is offered

Module INF-0440: Quantum Algorithms

Quantum Algorithms

5 ECTS/LP

Version 1.0.0 (since SoSe23)
Person responsible for module: Prof. Dr. Jakob Siegfried Kottmann

Contents:

Foundations of Quantum Information Processing:

- qubits and their representation
- BraKet notation and necessary structures from linear algebra
- operations on qubits: circuits and gates

Quantum Algorithms

- quantum search and amplitude amplification
- quantum fourier transform and it's applications
- quantum simulation
- variational quantum algorithms
- differentiable quantum algorithmic procedures
- quantum heuristics
- usecases from current day research

Learning Outcomes / Competences:

Students acquire basic knowledge of quantum algorithms and are able to explain fundamental principles and describe their use in algorithmic structures. They can describe established algorithmic structures from the field of quantum algorithms, such as search, Fourier transform, and phase estimation, and determine and compare potential areas of application. After attending the course, they will be able to construct quantum algorithmic approaches and translate them into discrete operations on qubit systems. Students will have a sound basic knowledge of fundamental quantum algorithmic structures and variational heuristics. They will be able to identify, analyze, and evaluate quantum algorithmic elements in current literature.

Workload:

Total: 150 h
60 h studying of course content through exercises / case studies (self-study)
15 h studying of course content using literarture (self-study)
15 h studying of course content using provided materials (self-study)
30 h exercise course (attendance)
30 h lecture (attendance)

Conditions:		**Credit Requirements:**
Linear Algebra (basics)		Passing the exam
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Quantum Algorithms (Vorlesung)
Mode of Instruction: lecture
Language: English / German
Frequency: each summer semester
Contact Hours: 2,00

Contents:

Foundations of Quantum Information Processing:

- qubits and their representation
- BraKet notation and necessary structures from linear algebra
- operations on qubits: circuits and gates

Quantum Algorithms

- quantum search and amplitude amplification
- quantum fourier transform and it's applications
- quantum simulation
- variational quantum algorithms
- differentiable quantum algorithmic procedures
- quantum heuristics
- usecases from current day research

Literature:

Basics of Quantum Information/Quantum Computation:

- Michal Nielsen; Isaac Chuang: Quantum Computation and Quantum Information

Basics of quantum mechanics:

- Richard P. Feynman; Robert B. Leighton; Matthew Sands: Feynman-Vorlesungen über Physik: Band III, Quantenmechanik
- original scripts are online: https://www.feynmanlectures.caltech.edu/info/

Overview over variational quantum algorithms:

- https://doi.org/10.1103/RevModPhys.94.015004
- https://doi.org/10.1038/s42254-021-00348-9

More on quantum algorithms:

- http://theory.caltech.edu/~preskill/ph229/ (chapter 5 provides a good summary of the well-known "traditional" quantum algorithms)

Part of the Module: Quantum Algorithms (Übung)

Mode of Instruction: exercise course

Language: English

Frequency: each summer semester

Contact Hours: 2,00

Examination

Quantum Algorithms

oral exam / length of examination: 25 minutes, graded

Test Frequency:

when a course is offered

Module INF-0462: Embedded Hardware Lab

Embedded Hardware Lab

8 ECTS/LP

Version 1.1.0 (since WS23/24)
Person responsible for module: Prof. Dr. Sebastian Altmeyer

Learning Outcomes / Competences:
Over the course of the semester, students develop a complete embedded system as a coherent semester assignment. A core task of the course is to analyse the characteristics and recognize the functionality of microcontrollers and peripherals based on data sheets and specifications. The students will have the opportunity to assemble the components needed for an assignment and to define suitable interfaces. Due to the required development and implementation on a microcontroller, the students apply the concepts learned directly in practice. The focus is on the interaction with sensors and actuators as well as on the communication with other parts of the system. To this end, they will identify and apply different types of flow control. During the lab, students learn to plan complex assignments, design solutions and test and evaluate their functionality. The exchange among the students aimed at during the course enables them to appropriately compare and discuss the results achieved.
Students acquire competencies in the following areas at an advanced, practice-oriented, but scientific level: independent work with microcontrollers, data sheets and specifications, interfacing of analog and digital peripherals, design and modelling of embedded software with state charts and their implementation in code. Further focus is on the configuration of sequential interfaces as well as scheduling and task-based programming.

Key Qualifikations: Ability to understand and document ideas, concepts and results; Consciousness of quality, meticulousness; Project-related work and time management; selection and correct application of appropriate methods; ability to expand existing knowledge independently; Self-reflection

Workload:
Total: 240 h
60 h exercise course (attendance)
30 h lecture (attendance)
120 h studying of course content through exercises / case studies (self-study)
15 h studying of course content using literarture (self-study)
15 h studying of course content using provided materials (self-study)

Conditions:		**Credit Requirements:**
Module Foundations of Technical Computer Science (INF-0138) - recommended		Passing the module exam
Frequency: irregular (usu. summer semester)	**Recommended Semester:** 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Embedded Hardware Lab (Lecture)
Mode of Instruction: lecture
Language: English / German
Frequency: irregular
Contact Hours: 2,00

Contents:

The practical course "Embedded Hardware Lab" aims to learn the challenges of programming embedded systems. The central platform is a development board that offers a microcontroller as well as various sensors, actuators, displays and interfaces for further peripherals. The programming is done in C without the application of hardware abstraction layers and the created programs are supposed to read out different sensors and set corresponding actuators. In particular, the challenges of embedded systems, such as the timing of the software as well as working with data sheets, are to be learned. Towards the end of the course, the basic knowledge acquired at the beginning will be deepened and already existing sub-components will be assembled into a more complex embedded system.

Literature:

- Zhu, Yifeng: Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C, Third Edition, E-Man Press LLC, 2017
- White, Elecia: Making Embedded Systems, O'Reilly Media Inc., 2012
- Marwedel, Wehmeyer: Eingebettete Systeme, Springer Verlag, Heidelberg, 2007

Part of the Module: Embedded Hardware Lab (Exercise)

Mode of Instruction: exercise course

Language: English / German

Frequency: irregular

Contact Hours: 4,00

Examination

Embedded Hardware Lab

practical exam, graded

Test Frequency:

when a course is offered

Module INF-0472: Management of Communication Networks *Management von Kommunikationsnetzen*	5 ECTS/LP
Version 1.1.0 (since WS23/24) Person responsible for module: Prof. Dr. Michael Seufert	

Learning Outcomes / Competences:

The lecture provides students with knowledge and skills in the field of management of communication networks.
The module covers various aspects of the efficient and secure operation of communication networks and prepares students to successfully plan, implement, and manage complex network infrastructures.
Students gain a solid understanding of the fundamentals of network management, including the different management levels, protocols, and tools. They understand the significance of network management for the effective utilization of communication networks.
The module provides students with comprehensive knowledge and skills to effectively manage network elements, deploy management systems, configure devices, and perform troubleshooting. Additionally, topics such as measurements in communication networks, active and passive network monitoring, Quality of Service (QoS)/Quality of Experience (QoE), automation of network management, virtualization and softwarization of communication networks, network security, and network neutrality are addressed.
Students develop a deeper understanding of the relationships between theoretical concepts in network management and their practical application. They can analyze complex management challenges and develop solution strategies. Students can interpret performance data from communication networks, identify potential bottlenecks, and apply diagnostic procedures to analyze and resolve network issues.
Students will be able to assess the effectiveness of network management solutions and analyze their impact on the performance and security of communication networks. They will be able to compare and evaluate different approaches and technologies in order to make informed decisions and provide recommendations for improvements.
Students will be empowered to develop new approaches and concepts in the field of network management. They will be able to design innovative solutions that go beyond traditional methods and address the current challenges of network management. They will be capable of researching new management strategies and techniques and applying them in practice.
Students will be able to assess the impact of network management on organizational goals and business processes. They will be able to quantify the added value of effective network management for businesses and society, and apply appropriate evaluation methods to analyze the costs, risks, and benefits of network management.
The exercises in Management of Communication Networks complement the lecture and provide students with the opportunity to apply their acquired knowledge in practical scenarios within real or simulated environments. The exercises include practical tasks, case studies, and projects that allow students to further develop their skills in network management and strengthen their problem-solving capabilities.

Key qualifications: subject-specific specialization; knowledge of the approaches and terminology of application-relevant disciplines; understanding of the application domain as well as the advantages and disadvantages of alternative technologies and their evaluation in the respective context; competence in identifying significant technological developments; ability to select and confidently apply appropriate concepts and methods; capacity to implement discipline-specific solution strategies; proficiency in solving problems under practice-oriented conditions; ability to present and document results clearly; competence in effective teamwork.

Workload:

Total: 150 h
30 h lecture (attendance)
30 h exercise course (attendance)
15 h studying of course content using literarture (self-study)
60 h studying of course content through exercises / case studies (self-study)
15 h studying of course content using provided materials (self-study)

Conditions:	**Credit Requirements:**
• Basics of communication systems and networking • Familiarity with ISO/OSI layers 1–4	Passing the module exam

• Knowledge of IP, routing, TCP/UDP and protocols for popular Internet applications (web browsing, video streaming) • Basics of network performance and network security		
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Management of Communication Networks (Lecture)
Mode of Instruction: lecture
Language: English / German
Frequency: each summer semester
Contact Hours: 2,00

Contents:

- Definitions and Models for Network Management
- Network Elements and Management Systems
- Configuration of Network Elements and Troubleshooting
- Active and Passive Network Measurements
- Quality of Service (QoS)
- Data Models for and Automation of Network Management
- Virtualization and Softwarization of Communication Networks
- Network Security
- Quality of Experience (QoE)
- Network Neutrality

Literature:

- Clemm A.: Network Management Fundamentals, Cisco Press, 2006
- Claise B., Wolter R.: Network Management: Accounting and Performance Strategies, Cisco Press, 2007
- Edelman J, Lowe S. S., Oswalt M.: Network Programmability and Automation, O'Reilly, 2018
- Capobianco J. W.: Automate Your Network, 2019
- Garrett J.: Data Analytics for IT Networks, Cisco Press, 2019
- Claise B., Clarke J., Lindblad J.: Network Programmability with YANG, Addison-Wesley, 2019
- Chou E.: Mastering Python Networking, Packt, 2020
- Kurose J.W., Ross K.W.: Computer Networking - A Top-Down Approach, 7th edition, Pearson, 2016
- Göransson P., Black C., Culver T.: Software Defined Networks: A Comprehensive Approach, 2nd edition, Morgan Kaufmann, 2017

Part of the Module: Management of Communication Networks (Exercise)
Mode of Instruction: exercise course
Language: English / German
Frequency: each summer semester
Contact Hours: 2,00

Examination
Management of Communication Networks
portfolio exam, graded
Test Frequency:
when a course is offered

Module INF-0476: Computer Vision for Intelligent Systems

Computer Vision für Intelligente Systeme

5 ECTS/LP

Version 1.1.0 (since WS23/24)
Person responsible for module: Prof. Dr. Jörg-Dieter Stückler

Learning Outcomes / Competences:
Students will understand the following methodological foundations of computer vision for intelligent systems at an in-depth scientific level and will be able to implement appropriate algorithms for advanced problems: Image formation, two-view geometry, deep learning basics for images and point clouds, image motion estimation and optical flow, keypoints and point correspondences, factor graphs and probabilistic state estimation, visual odometry and visual simultaneous localization and mapping, 3D object detection, 3D mapping. Participants understand the advantages and disadvantages of different methods and can analyze and select them for applications and apply them to new problems. Students have developed skills for analyzing and structuring machine vision problems for intelligent systems and know concepts and approaches for implementing algorithms for these problems. In addition, they have the competence to recognize significant technical developments.

Key qualifications: Ability to think logically, analytically and conceptually; selection and confident application of appropriate methods; independent work with textbooks; implementation of technical solution concepts in programs and models; knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context; ability to make scientifically meaningful assessments using appropriate methods. Comprehensible presentation of results; ability to work in teams.

Workload:
Total: 150 h
15 h studying of course content using provided materials (self-study)
15 h studying of course content using literarture (self-study)
60 h studying of course content through exercises / case studies (self-study)
30 h lecture (attendance)
30 h exercise course (attendance)

Conditions:
- Basic programming knowledge in Python
- Advantageous: Basic knowledge in Deep Learning

Credit Requirements:
Passing the module exam

Frequency: irregular (usu. winter semester)

Recommended Semester:
from 1.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
4,00

Repeat Exams Permitted:
according to the examination regulations of the study program

Parts of the Module

Part of the Module: Computer Vision for Intelligent Systems (Lecture)
Mode of Instruction: lecture
Language: English / German
Contact Hours: 2,00

Contents:

This lecture teaches basic methods and algorithms for computer vision for intelligent systems. The lecture covers the following topics:

- Image formation, geometric primitives and transformations.
- Two-view geometry
- Basics of deep learning for images and point clouds
- Motion estimation in images and optical flow
- Keypoints, descriptors and point correspondences
- Camera motion estimation from images
- Factor graphs and probabilistic state estimation
- Visual simultaneous localization and mapping
- 3D object detection
- 3D mapping

Literature:

Lecture slides will be provided. Additional literature will be provided in lecture and exercises.
Recommended textbooks:

- Yi Ma, Stefano Soatto, Jana Kos Košecká, S. Shankar Sastry. An Invitation to 3-D Vision
- R. Szeliski. Computer vision: algorithms and applications
- K. Murphy. Machine Learning: A Probabilistic Perspective
- Goodfellow, Bengio and Courville. Deep Learning. https://www.deeplearningbook.org

Assigned Courses:

Computer Vision for Intelligent Systems (Computer Vision für Intelligente Systeme) (lecture)
**(in attendance) **

Part of the Module: Computer Vision for Intelligent Systems (Exercises)
Mode of Instruction: exercise course
Language: English / German
Contact Hours: 2,00

Assigned Courses:

Exercises for Computer Vision for Intelligent Systems (Übungen zu Computer Vision für Intelligente Systeme) (exercise course)
**(in attendance) **

Examination
Computer Vision for Intelligent Systems
written exam / length of examination: 90 minutes, graded
Test Frequency:
when a course is offered

Module INF-0499: Foundation Models in Deep Learning

Foundation Models in Deep Learning

5 ECTS/LP

Version 1.0.0 (since SoSe24)
Person responsible for module: Prof. Dr. Rainer Lienhart

Learning Outcomes / Competences:
After successful participation in this module, participants understand basics and in-depth issues and algorithms of robotics (e.g. recursive state estimation, Gaussian and non-parametric filters, Kalman filters, motion and localisation, perception, mapping, SLAM) from a probabilistic point of view and can apply learned concepts to complex, practice-relevant tasks. Students can analyse and evaluate problems in this context. Participation in this module promotes skills in logical, analytical and conceptual thinking in the field of probabilistic robotics. Students can select suitable methods from the concepts learned in a targeted manner, apply them confidently and transfer them to new problems, including those from other disciplines. The module imparts competencies for recognising current research and significant technological developments in this field.

Key qualifications: advanced mathematical-formal logic; implementation of subject-specific solution concepts; interdisciplinary knowledge; development and implementation of solution strategies for complex problems; systematic further development of design methods; ability to solve problems under practical boundary conditions.

Workload:
Total: 150 h
30 h exercise course (attendance)
30 h lecture (attendance)
15 h studying of course content using provided materials (self-study)
60 h studying of course content through exercises / case studies (self-study)
15 h studying of course content using literarture (self-study)

Conditions:	**Credit Requirements:**
Knowledge in machine learning and machine vision (Master lecture INF-0092 "Multimedia II" or INF-0316 "Machine Learning and Computer Vision")	Passing the module examination

Frequency: each summer semester except summer semester 2026	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Probabilistic Robotics (Lecture)
Mode of Instruction: lecture
Language: German
Frequency: each summer semester außer im SoSe 2026
Contact Hours: 2,00

Contents:

1. Introduction to Probabilistic Robotics
2. Recursive State Estimation
3. Gaussian Filters
4. Nonparametric Filters
5. Robot Motion
6. Robot Perception
7. Mobile RobotLocalization: Markow and Gaussian
8. Mobile Robot Localization: Grid and MonteCarlo
9. Occupancy Grid Mapping
10. SLAM

Literature:

References will be announced at the beginning of the semester.

Part of the Module: Probabilistic Robotics (Tutorial)

Mode of Instruction: exercise course

Language: German

Frequency: each summer semester außer im SoSe 2026

Contact Hours: 2,00

Examination

Probabilistic Robotics (Examination)

oral exam / length of examination: 30 minutes, graded

Test Frequency:

each semester

Description:

The examination can be taken every semester during the examination period.

Module INF-0504: Medical Monitoring and Advanced Sensor Data Processing

8 ECTS/LP

Medical Monitoring and Advanced Sensor Data Processing

Version 1.3.0 (since SoSe24)
Person responsible for module: Prof. Dr. Sebastian Zaunseder

Learning Outcomes / Competences:
Subject-related competences:

After successful participation, students have knowledge and competences with regard to the field of medical monitoring. Students have basic knowledge on the background of medical monitoring and common technical solutions for clinical and out-of-hospital use. They are familiar with the functional principles of various methods relevant to medical monitoring and their interpretation. Students can also contribute to the (further) development of monitoring applications.

Methodological competencies:

Students are able to deal independently with solutions to medical monitoring. In particular, they are able to process medical data using common script languages such as Python, to document their solutions and to interpret processing results appropriately. In addition, Students have basic competencies in the handling of monitoring data and devices for monitoring.

Interdisciplinary Competencies:

The students are able to apply the acquired knowledge in any area of study that deals with (medical) data. In addition, the module teaches essential problem-solving skills, whereby an abstract way of thinking as well as a structured approach to problem solving are learned.

Key skills:

Ability to think logically, analytically and conceptually; ability to present and document results in a comprehensible manner; ability to communicate orally and in writing in a way that is appropriate to the situation and specific to the target group; ability to work together in teams; ability to solve problems under practical boundary conditions; ability to expand existing knowledge independently; quality awareness.

Workload:
Total: 150 h
60 h studying of course content using provided materials (self-study)
60 h exercise course (attendance)
90 h studying of course content through exercises / case studies (self-study)
30 h lecture (attendance)

Conditions:	**Credit Requirements:**
basic math skills; basic programming skills; basic knowledge on handling digital signals	Passing the module exam

Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Medical monitoring and advanced sensor data processing (Lecture)
Mode of Instruction: lecture
Language: English / German
Frequency: irregular
Contact Hours: 2,00

Contents:

The lecture deals with the fundamentals, implementations and applications of medical monitoring. The following topics, all of them elaborate with respect and in close connection to medical monitoring, are covered:

- Fundamentals of medical monitoring (basic ideas, history, current solutions, trends)
- Fundamentals of sensor data fusion
- Preprocessing approaches (e.g. denoising by conventional filters, Kalman filters and autoencoders)
- Dimension reduction and source separation (e.g. principal component analysis and independent component analysis)
- Feature extraction by functional transforms (e.g. time-frequency transforms)
- Basic detection/classification approaches

Literature:

- S. Bernhard, A. Brensing, and K.-H. Witte, *Biosignalverarbeitung*. De Gruyter, 2019. doi: 10.1515/9783110442434.

Part of the Module: Medical Monitoring and Advanced Sensor Data Processing (Exercise)

Mode of Instruction: exercise course

Language: English / German

Frequency: irregular

Contact Hours: 4,00

Contents:

The exercise teaches practical skills with relevance to the field of medical monitoring. The focus is handling and processing data from/for monitoring applications. The following contents are covered:

- Familiarization with techniques of data acquisition and handling data
- Denoising of data of variable origin
- Application of feature extraction and dimension reduction techniques
- Prediction/detection of (patho)physiological states
- Techniques for visualization and interpretation of sensor data

Examination

Medical Monitoring and Advanced Sensor Data Processing

portfolio exam, graded

Test Frequency:

when a course is offered

Module INF-0509: Embodied Artificial Intelligence *Embodied Artificial Intelligence*	8 ECTS/LP
Version 1.0.0 (since SoSe24) Person responsible for module: Prof. Dr. Jörg-Dieter Stückler	

Learning Outcomes / Competences:
Students will understand fundamental and contemporary methods of embodied artificial intelligence (robot learning, reinforcement learning, visual scene perception, foundation models for robotics) at a scientific level and will gain practical experience by implementing appropriate algorithms for advanced problems in team projects. Participants understand the advantages and disadvantages of different methods and can analyze and select them for applications and apply them to new problems. Students have developed skills for analyzing and structuring problems in embodied artificial intelligence and know concepts and approaches for implementing algorithms for these problems. In addition, they have the competence to recognize significant scientific and technical developments.

Key qualifications: Ability to think logically, analytically and conceptually; selection and confident application of appropriate methods; independent work with textbooks; implementation of technical solution concepts in programs and models; knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context; ability to make scientifically meaningful assessments using appropriate methods. Comprehensible presentation of results; ability to work in teams.

Workload:
Total: 240 h
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)
30 h lecture (attendance)
60 h exercise course (attendance)

Conditions:	**Credit Requirements:**
• Basic programming knowledge in Python • Basic knowledge in Deep Learning	Passing the module exam

Frequency: irregular (usu. summer semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Embodied Artificial Intelligence (Lecture)
Mode of Instruction: lecture
Language: English
Frequency: irregular (usu. summer semester)
Contact Hours: 2,00

Contents:

Embodied artificial intelligence is about intelligent robots which learn to solve tasks that require perception and interaction with the environment through the agent's embodiment (sensors and actuators). More specifically, the course will cover state-of-the-art methods for robot learning and perception.

The course consists of a lecture part, which teaches theoretical basics and contempory methods in embodied artificial intelligence, and an exercise part, which deepens the contents of the lecture in the exercises in practical team projects. The course includes the following topics:

1. Introduction to deep learning
2. Robot kinematics
3. Transformer and diffusion models
4. Model-free reinforcement learning
5. Model-based reinforcement learning
6. Imitation learning
7. Vision-language-action models
8. Object perception
9. Localization and mapping
10. Imitation learning

Literature:

Lecture slides will be provided. Additional references to literature will be provided in the lecture.

Recommended textbooks:

- Sutton and Barto. Reinforcement Learning. Second Edition. MIT Press 2018
- Bishop. Deep Learning - Foundations and Concepts. Springer, 2023

Part of the Module: Embodied Artificial Intelligence (Exercises)

Mode of Instruction: exercise course
Language: English
Frequency: irregular (usu. summer semester)
Contact Hours: 4,00

Examination

Embodied Artificial Intelligence

portfolio exam, graded

Test Frequency:

when a course is offered

Module INF-3037: Graph Algorithms

Graph Algorithms

8 ECTS/LP

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr. Pascal Lenzner

Learning Outcomes / Competences:
The goal of the lecture is to use suitably chosen examples to give a broad overview over the field of Graph Algorithms. The students will learn how to design and analyse graph algorithms for various settings . They will be able to understand and explain different graph-theoretic concepts as well as their application in different domains.
They will also be able to understand and apply several practical algorithms for computing shortest paths, flows, matchings, cuts, and embeddings. For this we will formally analyze the efficiency and other properties of the employed algorithms. Moreover, the students will learn how to evaluate the impact of graph properties on complexity of graph problems.

Key skills: Advanced mathematical-formal methodology, subject-specific specializations, quantitative aspects of computer science, ability to analyze and structure complex computer science problems, ability to develop and implement solution strategies for complex problems, knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context, Ability to think logically, analytically and conceptually, selection and reliable application of suitable methods, ability to work in teams, knowledge of practical tasks, ability to present and document results in a comprehensible manner, ability to expand existing knowledge independently, quality awareness, meticulousness

Workload:
Total: 240 h
30 h studying of course content using provided materials (self-study)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using literarture (self-study)
30 h exercise course (attendance)
60 h lecture (attendance)

Conditions:	**Credit Requirements:**
No fixed prerequisites, but basic knowledge in the design and analysis of algorithms as well in compexity theory from the Bachelor studies will be assumed.	Passing the module exam

Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Graph Algorithms (Lecture)
Mode of Instruction: lecture
Language: English / German
Frequency: each winter semester
Contact Hours: 4,00

Contents:

Graphs play a central role in the world of algorithms. For example, navigation devices use an algorithm to compute shortest paths on a graph to answer a route query. Many planning and assignment problems can also be easily modeled as problems on graphs. In principle, it is true that a great many problems can be thought of as graph problems, so designing efficient algorithms for such problems is an important subfield of theoretical computer science.

In this lecture we will enter the world of graph algorithms. On the one hand, we will learn about important algorithmic problem classes on graphs and efficient algorithms to solve them. Among other things, we will look at finding shortest paths, flows, cuts, separators, and matchings in graphs. Algorithms for these problems have a wide variety of applications, making them an important and useful tool for any algorithmicist. On the other hand, we will also study how constraints on the graphs at hand affect the complexity of the problems and their algorithmic solution. For example, many algorithmic problems are more efficiently solvable on trees and planar graphs (i.e., graphs that can be embedded in the plane without intersection) than on general graphs. We will also explore some properties of graphs that we can exploit specifically for designing efficient algorithms. For example, trees and planar graphs have small separators (sets of nodes whose removal causes the graphs to decompose into multiple context components), which helps design efficient divide & conquer algorithms.

The goal of the lecture is the development and training of a structured approach to algorithmic problems on graphs. In doing so, we will jointly develop efficient graph algorithms with appropriate data structures, prove their correctness, and analyze their resource requirements (runtime and memory). In addition, the lecture will highlight special graph classes and other important concepts in graph theory and their impact on the world of algorithms.

Part of the Module: Graph Algorithms (Exercise)

Mode of Instruction: exercise course

Language: English / German

Frequency: each winter semester

Contact Hours: 2,00

Examination

Graph Algorithms

oral exam / length of examination: 30 minutes, graded

Test Frequency:

when a course is offered

Module INF-3815: Advanced Biomedical Systems Modeling and Data Science *Advanced Biomedical Systems Modeling and Data Science*	5 ECTS/LP

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr. Andreas Raue

Learning Outcomes / Competences:
This interdisciplinary course provides advanced-level knowledge of computational techniques in systems modeling and data science applied to complex biomedical challenges.

Students will expand their expertise in mathematical modeling, machine learning, and biological data analysis. The course emphasizes both theoretical understanding and practical application through project-based learning.

A solid background in biology, mathematics (calculus, linear algebra, differential equations), and programming (Python) is required.

The goal of this course is to prepare students for a career path as scientists in biomedical, biotechnology or pharmaceutical industry, or for continuing their academic training and research by acquiring a PhD degree.

Objectives:

- Deepen understanding of systems modeling and data science principles.
- Develop expertise in handling complex datasets and applying advanced models and methods.
- Enhance proficiency in interpreting and presenting biomedical data using advanced models.
- Strengthen project design and critical evaluation skills for scientific research.

Workload:
Total: 150 h
15 h studying of course content using literarture (self-study)
60 h studying of course content through exercises / case studies (self-study)
15 h studying of course content using provided materials (self-study)
30 h lecture (attendance)
30 h exercise course (attendance)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each semester	**Recommended Semester:** 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Biomedical Systems Modeling and Data Science (Lecture)
Mode of Instruction: lecture
Language: English / German
Frequency: each semester
Contact Hours: 2,00

Contents:

Part 1: Data Science

- Statistical Theory & Applications
- Machine Learning Techniques
- Omics Data Integration
- Artificial Ground Truth

Part 2: Systems Modeling

- Dynamical Systems & Modeling Concepts
- Model Development & Analysis
- Experimental Design
- Advanced Model Classes

Note: The syllabus may be adjusted based on class progress and instructor discretion.

Literature:

- "Introduction to System Biology" by Edda Klipp
- "A First Course in Systems Biology" by Eberhard O. Voit
- "Introduction to Machine Learning" by Ethem Alpaydin
- "Machine Learning" by Tom M. Mitchell

For further reading, not a blueprint for this lecture!

Additional research papers and online resources will be provided throughout the course.

Assigned Courses:

Advanced Biomedical Systems Modeling and Data Science (lecture)
**(in attendance) **

Part of the Module: Advanced Biomedical Systems Modeling and Data Science (Computer Exercise)
Mode of Instruction: exercise course
Language: English / German
Frequency: each semester
Contact Hours: 2,00

Contents:

- We will apply the concepts covered in each week's lecture to relevant biomedical data
- Exercises will be posted as Python Jupyter Notebooks that include tasks that need to be completed
- A virtual environment will be provided, but students are also encouraged to use their own setups

Assigned Courses:

Übung zu Advanced Biomedical Systems Modeling and Data Science (exercise course)
**(in attendance) **

Examination
Introduction to Biomedical Systems Modeling and Data Science
portfolio exam, graded
Test Frequency:
when a course is offered
Description:
The portfolio exam will consist of two parts:

- Practice/homework coding tasks: You will be able to largely complete those during the computer practice or at home.
- Written exam: Questions will cover the comprehension of the contents of the lectures.

Module INF-0042: Project Module Software Methodologies for Distributed Systems

Projektmodul Softwaremethodiken für verteilte Systeme

10 ECTS/LP

Version 1.0.0 (since SoSe13)
Person responsible for module: Prof. Dr. Bernhard Bauer

Learning Outcomes / Competences:
After participating in the project module, students understand problems of higher complexity in the field of software methodologies for distributed systems and have in-depth specialist knowledge and skills there. They are able to develop concepts, methods, procedures, techniques, and technologies of the mentioned field in research projects and are able to apply innovative approaches in solving problems. This enables them to link up with international research and make their scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the area, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.

Key qualifications: Ability to think logically, analytically, and conceptually; Independent work with literature; Understandable, confident, and convincing presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill of working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology;

Workload:
Total: 300 h
15 h seminar (attendance)
285 h internship / practical course (self-study)

Conditions:
none

Frequency: each semester	**Recommended Semester:** 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Projektmodul Softwaremethodiken für verteilte Systeme
Mode of Instruction: internship
Language: German / English
Frequency: each semester
Contact Hours: 1,00

Contents:
Current research topics at the Software Methodology for Distributed Systems Lab

Literature:
Provided for the respective topics.

Assigned Courses:

Oberseminar zu Softwaremethodik für verteilte Systeme
**(hybrid/mixed) **

Examination

Project acceptance, presentation, final report

internship, graded

Test Frequency:

when a course is offered

Module INF-0374: Project Module Resource Aware Algorithmics

Projektmodul Resource Aware Algorithmics

10 ECTS/LP

Version 1.0.0 (since WS20/21)
Person responsible for module: Prof. Dr. Tobias Mömke

Learning Outcomes / Competences:
After attending this research module, the students are able to understand algorithmic problems and solutions of medium difficulty in the area of resource aware algorithmics.They have acquired a detailed understanding of up-to-date topics within the area and can actively participate in research projects. Furthermore, they understand some deep concepts, methods, tools and technologies and can apply the acquired knowledge in research projects. Besides the technical abilities, they train their team and communication skills, the ability to perform literature research and to discurss and present technical topics.

Key Qualifications: Ability to perform analytical and logic thinking; self-sufficient work with scientific literature in English language; ability to present results and ideas in form of understandable and inspiring presentations; aim for high-quality results; communication skills; ability to work with a team and to understand team processes; respect for clean scientific practices

Workload:
Total: 300 h
285 h internship / practical course (self-study)
15 h seminar (attendance)

Conditions:		**Credit Requirements:**
none		Bestehen der Modulprüfung
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Projekt Module Resource Aware Algorithmics
Mode of Instruction: internship
Language: German / English
Frequency: each semester
Contact Hours: 1,00

Contents:
Autonome Mitarbeit an aktuelle Forschungsthemen.

Literature:
wissenschaftliche Papiere, Handbücher

Assigned Courses:

Oberseminar Resource Aware Algorithmics
**(in attendance) **

Examination
Projekt Module Resource Aware Algorithmics
portfolio exam, graded
Test Frequency:
when a course is offered

Module INF-0436: Project Module Quantum Algorithms
Projektmodul Quantenalgorithmen

10 ECTS/LP

Version 1.0.0 (since SoSe23)
Person responsible for module: Prof. Dr. Jakob Siegfried Kottmann

Learning Outcomes / Competences:
After participating in the project module, students will understand highly complex problems in the field of quantum algorithms and will have in-depth specialist knowledge and skills in this area. They will be able to develop concepts, methods, procedures, techniques, and technologies in this field in research projects and will be able to apply innovative methods to solve problems. This enables them to connect with international research and make their own scientific contribution in this field. In addition, students will have the teamwork and communication skills, the ability to conduct literature research, and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine, and present interim results and innovative ideas.

Workload:
Total: 300 h
15 h seminar (attendance)
285 h internship / practical course (self-study)

Conditions: none		**Credit Requirements:** Passing the exam
Frequency: as needed	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Projektmodul Quantenalgorithmen
Mode of Instruction: internship
Language: English / German
Frequency: as needed

Contents:
Doing active research and participating on current reserach projects

Literature:
Case dependent

Assigned Courses:

Oberseminar Quantenalgorithmik
**(hybrid/mixed) **

Examination
Projektmodul Quantenalgorithmen
practical exam, graded
Test Frequency:
when a course is offered

Module INF-0481: Project Module Intelligent Perception in Technical Systems *Projektmodul Intelligente Perzeption in Technischen Systemen*	10 ECTS/LP

Version 1.0.0 (since WS23/24)
Person responsible for module: Prof. Dr. Jörg-Dieter Stückler

Learning Outcomes / Competences:
After participating in the project module, students understand problems of higher complexity in the field of intelligent perception in technical systems and have deeper expertise and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.

Key qualifications: Ability to think logically, analytically and conceptually; Independent work with English-language scientific literature; Understandable, confident and convincing presentation of ideas, concepts and results; Quality awareness; Communication skills; Skill of working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology.

Workload:
Total: 300 h
285 h internship / practical course (self-study)
15 h seminar (attendance)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Project Module Intelligent Perception in Technical Systems
Mode of Instruction: internship
Language: English / German
Frequency: each semester
Contact Hours: 1,00

Contents:
Current research topics.

Literature:
Scientific papers, manuals

Assigned Courses:

Oberseminar Intelligente Perzeption in Technischen Systemen
**(in attendance) **

Examination

Project Module Intelligent Perception in Technical Systems

practical exam, graded

Test Frequency:

when a course is offered

Module MTH-4310: Mathematics Project	10 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Contents:
Students can approach any professor in the mathematics department to get a project topic assigned to them. The precise content and task to complete depends on the assigned project topic and will be discussed individually with the professor.

Learning Outcomes / Competences:
After participating in the project module, students understand problems of higher complexity in the selected field of mathematics and have in-depth specialist knowledge and skills there. They are able to develop concepts, methods, procedures, techniques, and technologies of the mentioned field in research projects and are able to apply innovative approaches in solving problems. This enables them to link up with international research and make their scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the area, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.

Key qualifications: Ability to think logically, analytically, and conceptually; Independent work with literature; Understandable, confident, and convincing presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill of working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology;

Workload:
Total: 300 h

Conditions:		**Credit Requirements:**
none		Bestehen der Modulprüfung
Frequency: each semester	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
	Repeat Exams Permitted: according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Mathematics Project for Data Science
Language: English / German

Examination
Mathematics Project for Data Science
portfolio exam, graded

Module MTH-4300: Mathematics Seminar		4 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Contents: Depends on the topic of the seminar, please check in digicampus before the term starts.		
Learning Outcomes / Competences: Through self-study of mathematical topics, talks and scientific discussion, the following goals are to be achieved: Ability to work with scientific literature, skills in formulating and presenting theoretical questions based on the mathematical methods learnt. Integrated acquisition of key qualifications: Working independently with scientific literature, trying out different presentation techniques and presentation media, conducting scientific discussions and communicating problem-solving approaches.		
Workload: Total: 120 h		
Conditions: none		**Credit Requirements:** One needs to pass one of the offered seminars. The precise form of the exam (talk/homework/etc) will be announced in digicampus for the individual seminar before the term starts.
Frequency: each semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Mathematics Seminar
Language: English / German

Assigned Courses:

Seminar zur Numerik (Master) (seminar)
**(online/digital) **

Seminar zur Stochastik (Seminar zur Statistik) Master (seminar)
**(in attendance) **

Examination
Mathematics Seminar Mathematics Seminar
portfolio exam, graded

Module INF-0095: Seminar Multimedia Computing & Computer Vision (MA) *Seminar Multimedia Computing (MA)*	4 ECTS/LP

Version 1.0.0 (since SoSe14)
Person responsible for module: Prof. Dr. Rainer Lienhart

Learning Outcomes / Competences:
After attending the seminar, the students can independently work out and analyse advanced problems, concepts, methods, procedures, techniques, and technologies from the field of multimedia computing and computer vision (e.g. image and video processing, machine learning, and image and video search) and evaluate them in relation to the individual seminar topic.
Participants possess scientific methodology, communication skills, and the ability to present a special topic clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively.
Furthermore, they learn to recognise logical structures of thinking and argumentation and use them in a goal-oriented manner. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a talk that is clear and easy to follow. Additionally, the students know how to focus on essential messages and convey them in a comprehensible way, even with complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to confidently deal with common presentation media and use them interactively. They manage to gear a talk to a specific target group, apply various moderation techniques, and keep their audience engaged even over a longer period.
Key qualifications: Presentation techniques; literature research; principles of good scientific practice; evaluating solution approaches, procedures, techniques, and technologies from different points of view.

Workload:
Total: 120 h
90 h preparation of written term papers (self-study)
30 h seminar (attendance)

Conditions: none		
Frequency: each semester außer im SoSe 2026	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Multimedia Computing (MA)
Mode of Instruction: seminar
Language: German
Frequency: each summer semester außer im SoSe 2026
Contact Hours: 2,00

Contents:
The concrete topic of the seminar from the wide-ranging field of multimedia is determined anew each year and adapted to current trends.

Literature:
current research literature

Assigned Courses:

Seminar über Multimedia und Maschinelles Sehen (Master) (seminar)
**(in attendance) **

Examination

Presentation and written paper

seminar, graded

Test Frequency:

when a course is offered

Module INF-0227: Seminar Database Systems Master *Seminar Datenbanksysteme für Master*	4 ECTS/LP
Version 1.0.0 (since SoSe16) Person responsible for module: Prof. Dr. Peter Michael Fischer	

Learning Outcomes / Competences:
After attending the seminar, students are able to independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of database systems in relation to the individual seminar topic from the mentioned field.
They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic in a clear and understandable manner, both verbally and in writing, and to critically and argumentatively discuss and evaluate scientifically challenging topics from the named field. They will also be able to recognize the logical structures of reasoning and argumentation and use them in a goal-oriented manner.
The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a lecture in a clear and comprehensible way and how to focus the lecture on essential messages and convey them in a comprehensible way, even in the case of complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions.
The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a lecture to a specific target group and to motivate the listener even during longer lecture durations and to apply various moderation techniques.
Key qualifications: Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and for their documentation; Skill in logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness, meticulousness; Communication skills; Time management; Evaluation of approaches, procedures, techniques and technologies from different points of view.

Workload:
Total: 120 h
90 h preparation of written term papers (self-study)
30 h seminar (attendance)

Conditions: Module Database Systems (INF-0073) - recommended		
Frequency: irregular (usu. summer semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Datenbanksysteme für Master
Mode of Instruction: seminar
Language: German / English
Frequency: irregular (usu. summer semester)
Contact Hours: 2,00

Contents:
Current research contributions from the field of "Databases and Information Systems".

Literature:
Current research contributions

Assigned Courses:

Seminar Datenbanksysteme für Master (seminar)
*(hybrid/mixed) *

Examination

lecture and written elaboration
seminar, graded

Test Frequency:
when a course is offered

Module INF-0344: Seminar Software Engineering of Distributed Systems (MA) *Seminar Software Engineering verteilter Systeme (MA)*	4 ECTS/LP

Version 1.0.0 (since SoSe20)
Person responsible for module: Prof. Dr. Bernhard Bauer

Learning Outcomes / Competences:
After attending the seminar, students can independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in software engineering for distributed systems about the particular seminar topic from the named field. They have the scientific methodology, communication skills, and ability to use appropriate media to present a specific case clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. Furthermore, they can recognize the logical structures of thinking and argumentation and use them goal-oriented. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a lecture clearly and understandably, focus the study on essential messages, and understandably convey them, even with complex content. They skillfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and confidently deal with joint presentation media and use them interactively. They manage to gear a lecture to a specific target group, motivate the listener even during longer lecture durations, and apply various moderation techniques.

Key qualifications: Literature research; independent work with English-language specialist literature; analytical-methodical competence; scientific methodology; principles of good scientific practice; skills in the understandable, confident, and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts, and results and in documenting them; skills in logical, abstract, analytical and conceptual thinking and formal argumentation; quality awareness, meticulousness; communication skills; time management; evaluation of approaches, procedures, techniques, and technologies from different points of view. Translated with www.DeepL.com/Translator (free version)

Workload:
Total: 120 h
90 h preparation of written term papers (self-study)
30 h seminar (attendance)

Conditions:
The previous course "Seminar on Software Engineering of Distributed Systems (MA)" (INF-0039) must not have been taken due to overlaps.

Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Software Engineering verteilter Systeme (MA)
Mode of Instruction: seminar
Language: German
Frequency: irregular
Contact Hours: 2,00

Contents:
Current software engineering topics from industry and research.

Literature:
Will be presented in the respective kick-off event.

Assigned Courses:

Seminar Software Engineering verteilter Systeme (Master) (seminar)

*(in attendance) *

Examination

Seminar Software Engineering verteilter Systeme (MA)

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-0364: Seminar Software Engineering in Safety- and Security-Critical Systems (MA) *Seminar Software Engineering in sicherheitskritischen Systemen (MA)*	4 ECTS/LP

Version 1.0.0 (since WS20/21)
Person responsible for module: Prof. Dr. Bernhard Bauer

Learning Outcomes / Competences:
After attending the seminar, students can independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in software engineering in safety-critical systems and related disciplines about the particular seminar topic from the named field. They have the scientific methodology, communication skills, and ability to use appropriate media to present a specific case clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. Furthermore, they can recognize the logical structures of thinking and argumentation and use them goal-oriented. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a lecture clearly and understandably, focus on essential messages, and coherently convey them, even with complex content. They skillfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and confidently deal with joint presentation media and use them interactively. They manage to gear a lecture to a specific target group, motivate the listener even during longer lecture durations, and apply various moderation techniques.

Key qualifications: Literature research; independent work with English-language specialist literature; analytical-methodical competence; scientific methodology; principles of good scientific practice; skills in the understandable, confident, and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts, and results and in documenting them; skills in logical, abstract, analytical and conceptual thinking and formal argumentation; quality awareness, meticulousness; communication skills; time management; evaluation of approaches, procedures, techniques, and technologies from different points of view. Translated with www.DeepL.com/Translator (free version)

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions:
none

Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Software Engineering in sicherheitskritischen Systemen (MA)
Mode of Instruction: seminar
Language: German
Frequency: irregular
Contact Hours: 2,00

Contents:
Current software engineering topics from industry and research.

Literature:
Will be presented in the respective kick-off event.

Assigned Courses:

Seminar Software Engineering in sicherheitskritischen Systemen (Master) (seminar)
*(in attendance) *

Examination

Seminar Software Engineering in sicherheitskritischen Systemen (MA)
written/oral exam, graded

Test Frequency:
when a course is offered

Module INF-0439: Seminar Quantum Algorithms (Master) *Seminar Quantum Algorithms (Master)*	4 ECTS/LP

Version 1.0.0 (since SoSe23)
Person responsible for module: Prof. Dr. Jakob Siegfried Kottmann

Contents:
The seminar deepens the content covered in the lecture “Quantum Algorithms.” Attending the lecture at the same time is recommended. Specific topics are based on current research. Application examples and topics covered in the lecture are explored in greater depth, and new topics are introduced. The seminar is suitable as preparation for a thesis in the field of quantum algorithms.

Learning Outcomes / Competences:
After attending the seminar, students will be able to independently develop, analyze, and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in the field of quantum algorithms in relation to the individual seminar topic from the aforementioned field. They will have the scientific methodology, communication skills, and ability to use appropriate media to present a specific topic clearly and comprehensibly in both written and spoken form and to critically discuss and evaluate scientifically demanding topics from the specified field. In addition, they will be able to recognize the logical structures of thinking and argumentation and use them in a goal-oriented manner. Participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a presentation clearly and comprehensibly and, even with complex content, focus the presentation on key messages and convey these in an understandable way. They skillfully apply chains of argumentation and solution strategies in the event of disruptions.
Students know how to present themselves confidently and use common presentation media interactively. They are able to tailor a presentation to a specific target group, motivate the audience even during longer presentations, and apply various moderation techniques.

Workload:
Total: 120 h
90 h preparation of written term papers (self-study)
30 h seminar (attendance)

Conditions: none		**Credit Requirements:** Passing the exam
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Quantum Algorithms (Master)
Mode of Instruction: seminar
Language: English / German
Frequency: each summer semester
Contact Hours: 2,00

Contents:
The topics of the seminar are redefined each time and adapted to current developments.

Literature:
Depends on chosen topic

Assigned Courses:

Seminar Quantenalgorithmen (Bachelor & Master) (seminar)

*(hybrid/mixed) *

Examination

Seminar Quantum Algorithms (Master)

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-0444: Seminar Generative Artificial Intelligence *Seminar Generative Künstliche Intelligenz*	4 ECTS/LP

Version 1.0.0 (since SoSe23)
Person responsible for module: Prof. Dr. Elisabeth André

Learning Outcomes / Competences:
After attending the seminar, students are able to independently work out, analyze and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of "Generative Artificial Intelligence" in relation to the individual seminar topic from the mentioned field. They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic clearly and comprehensibly, both verbally and in writing, and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. They will also be able to recognize the logical structures of reasoning and argumentation and use them in a goal-oriented manner. The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a lecture in a clear and comprehensible way and how to focus the lecture on essential messages and convey them in a comprehensible way, even in the case of complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a lecture to a specific target group and to motivate the listener even during longer lecture durations and to apply various moderation techniques.

Key qualifications: Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and for their documentation; Skill in logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness, meticulousness; Communication skills; Time management.

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions:
none

Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Generative Artificial Intelligence
Mode of Instruction: seminar
Language: German / English
Frequency: each summer semester
Contact Hours: 2,00

Contents:
Topics in the field of "Generative Artificial Intelligence"

Literature:
References will be announced at the preliminary meeting.

Assigned Courses:

Seminar Generative Künstliche Intelligenz (seminar)

*(in attendance) *

Examination

Seminar Generative Artificial Intelligence

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-0468: Seminar Natural Language Understanding (Master) *Seminar Natural Language Understanding (Master)*	4 ECTS/LP

Version 1.0.0 (since WS23/24)
Person responsible for module: Prof. Dr. Annemarie Friedrich

Contents:
The seminar on natural language understanding delves into the fascinating realm of artificial intelligence and linguistics, exploring how machines can comprehend and process human language. Computational semantics is a subfield of natural language processing (NLP) and computational linguistics that focuses on the development of algorithms, models, and systems for understanding and representing the meaning of natural language text in a way that computers can process and manipulate. Exemplary topics discussed in this seminar include: representing word, sentence, or text meaning, semantic role labeling, semantic parsing, discourse and pragmatics.

The number of participants is limited.

Learning Outcomes / Competences:
After attending the seminar, students are able to independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of embedded systems in relation to the individual seminar topic from the named field.

They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic in a clear and comprehensible manner, both verbally and in writing, and to discuss and evaluate scientifically challenging topics from the aforementioned field in a critical and argumentative manner. They will also be able to recognize the logical structures of reasoning and argumentation and use them in a goal-oriented manner.

The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a scientific presentation in a clear and comprehensible way and how to focus the presentation on essential messages and convey them in a comprehensible way, even in the case of complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a presentation to a specific target group and to motivate the listener even during longer presentation durations and to apply various moderation techniques.

Key qualifications: Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and for their documentation; Skill in logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness, meticulousness; Communication skills; Time management; Evaluation of approaches, procedures, techniques and technologies from different points of view.

Remarks:
The course will be taught by Dr. Jakob Prange, who will join the department in October.

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions: none		**Credit Requirements:** Presentation and term paper
Frequency: irregular	**Recommended Semester:** 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Natural Language Understanding (Master)
Mode of Instruction: seminar
Language: German / English
Frequency: irregular
Contact Hours: 2,00

Contents:

In the seminar, topics from the field of embedded systems will be covered. Each seminar participant receives individual literature references, which are then to be supplemented in the course of the seminar by further independently compiled references. The seminar will end with a written paper and a presentation on the topic covered.

Literature:

given individually and self research

Assigned Courses:

Seminar Natural Language Understanding (Master) (seminar)
**(in attendance) **

Examination

Seminar Natural Language Understanding (Master)
written/oral exam, graded
Test Frequency:
when a course is offered

Module INF-0479: Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision *Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision*	4 ECTS/LP

Version 1.0.0 (since WS23/24)
Person responsible for module: Prof. Dr. Jörg-Dieter Stückler

Learning Outcomes / Competences:
After attending the seminar, the students are able to work out, analyze and evaluate further problems, concepts, methods, techniques and technologies in the field of embodied artificial intelligence and computer vision, methods, procedures, techniques and technologies in the field of Embodied Artificial Intelligence and Computer Vision independently, analyze and evaluate them in relation to the individual seminar topic from the mentioned field.
They possess the scientific methodology, communication skills and ability to use appropriate media to present a specific topic in a clear and comprehensible manner, both verbally and in writing, and critically and argumentatively discuss and evaluate scientifically challenging topics from the named field. In addition, they can recognize the logical structures of thought and argumentation and use them in a goal-oriented manner. Participants are able to formulate clearly and comprehensibly and present scientific content freely. They understand how to structure a presentation clearly and comprehensibly and, even with complex content, how to focus the presentation on essential messages and convey them in a comprehensible manner. The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a presentation to a specific target group, to motivate the listener and to apply various moderation techniques.

Key qualifications: Literature research; independent work with English-language scientific literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Ability to present comprehensible, confident and convincing (written and oral); presentation of (practical or theoretical) ideas, concepts, and results and to document them; ability to logical, abstract, analytical and conceptual thinking and formal reasoning; quality consciousness, meticulousness; communication skills; time management; evaluation of approaches, procedures, techniques and technologies from different points of view.

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: irregular (usu. winter semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision
Mode of Instruction: seminar
Language: English / German
Frequency: irregular
Contact Hours: 2,00

Contents:

The seminar will cover current research topics in the field of Embodied Artificial Intelligence and Computer Vision. Each seminar participant will be assigned individual literature references, which will then be supplemented in the course of the seminar by further independently compiled references. The seminar will end with a written report and a presentation on the topic covered.

Literature:

Scientific literature announced in the kick-off meeting and self research

Assigned Courses:

Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision (seminar)

**(in attendance) **

Examination

Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-3019: Seminar Data Engineering Master *Seminar Data Engineering Master*	4 ECTS/LP

Version 1.0.0 (since WS24/25)
Person responsible for module: Prof. Dr. Fabian Panse

Learning Outcomes / Competences:
After attending the seminar, students are able to independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of database systems in relation to the individual seminar topic from the mentioned field.
They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic in a clear and understandable manner, both verbally and in writing, and to critically and argumentatively discuss and evaluate scientifically challenging topics from the named field. They will also be able to recognize the logical structures of reasoning and argumentation and use them in a goal-oriented manner.
The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a lecture in a clear and comprehensible way and how to focus the lecture on essential messages and convey them in a comprehensible way, even in the case of complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions.
The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a lecture to a specific target group and to motivate the listener even during longer lecture durations and to apply various moderation techniques.
Key qualifications: Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and for their documentation; Skill in logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness, meticulousness; Communication skills; Time management; Evaluation of approaches, procedures, techniques and technologies from different points of view.

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: irregular (usu. winter semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Data Engineering Master
Language: German / English
Frequency: irregular (usu. winter semester)
Contact Hours: 2,00

Contents:
Current research topics from the field of data engineering, such as data cleaning, schema matching, or entity matching.

Literature:
Current research papers in the field of data engineering, such as data cleaning, schema matching, or entity matching. Will be provided at the beginning of the course.

Assigned Courses:

Seminar Data Engineering Master (seminar)

*(in attendance) *

Examination

Seminar Data Engineering Master

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-3023: Seminar Software Engineering for Artificial Intelligence Systems Master *Seminar Software Engineering for Artificial Intelligence Systems Master*	4 ECTS/LP

Version 1.0.0 (since WS24/25)
Person responsible for module: Prof. Dr. Bernhard Bauer

Learning Outcomes / Competences:
After attending the seminar, the students are able to independently work out, analyze and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in the field of Software Engineering for Artificial Intelligence Systems concerning the particular seminar topic from the named field. They have the scientific methodology, communication skills, and ability to use appropriate media to present a specific case clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. Furthermore, they can recognize the logical structures of thinking and argumentation and use them goal-oriented. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a lecture clearly and understandably, focus the study on important messages, and convey them in a comprehensible way, even with complex content. They skillfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and confidently deal with joint presentation media and use them interactively. They manage to gear a lecture to a specific target group, motivate the listener even during longer lecture durations, and apply various moderation techniques.

Key qualifications: Literature research; independent work with English-language specialist literature; analytical-methodical competence; scientific methodology; principles of good scientific practice; skills in the understandable, confident, and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts, and results and in documenting them; skills in logical, abstract, analytical and conceptual thinking and formal argumentation; quality awareness, meticulousness; communication skills; time management; evaluation of approaches, procedures, techniques, and technologies from different points of view. Translated with www.DeepL.com/Translator (free version)

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Software Engineering for Artificial Intelligence Systems Master
Mode of Instruction: seminar
Language: German / English
Frequency: irregular
Contact Hours: 2,00

Contents:
This seminar will cover the basics of Software Engineering for Artificial Intelligence Systems. Various topics are to be worked on, which are to serve as a basis for a subsequent practical course.

Literature:
Will be presented at the respective kick-off event.

Assigned Courses:

Seminar Software Engineering for Artificial Intelligence Systems Master (seminar)

**(in attendance) **

Examination

Presentation and written paper

written/oral exam, graded

Test Frequency:

when a course is offered

Module PHM-0083: Computational Physics and Materials Science *Computational Physics and Materials Science*	8 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Liviu Chioncel	

Contents:

- Basic Numerical Methods
- Ordinary and Partial Differential Equations
- Density Functional Theory and Molecular Dynamics
- Advanced Methods for Many-Particle Systems
- Monte Carlo Simulations

Learning Outcomes / Competences:

- The students know the numerical methods suitable for solving physical and material science problems, in particular methods for solving ordinary and partial differential equations as well as molecular dynamics and Monte Carlo simulations, are able to implement these methods in practice, and possess the competence to work on theoretical-numerical problems from various areas of physics and materials science under supervision.
- Integrated acquisition of key qualifications: independent work with English-language technical literature, grasp of complex relationships and their model representation with the help of mathematical structures, methodological competence.

Workload:
Total: 240 h
30 h studying of course content using provided materials (self-study)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using literarture (self-study)
90 h lecture and exercise course (attendance)

Conditions: The module requires the contents of the bachelor module "Numerical Methods" (BaPhy-45-01) as well as elementary programming skills (for example Fortran, C/C++, Python, ...).		
Frequency: every 4th semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Computational Physics and Materials Science
Mode of Instruction: lecture
Language: English
Frequency: every 4th semester
Contact Hours: 4,00

Learning Outcome:
siehe Modulbeschreibung

Contents:

- Basic Numerical Methods
  - Programing languages: Fortran, C++, Perl, Python, compilation and execution
  - Differentiation and integration, interpolations and approximations
  - Zeros and extremes of a single-variable function
  - Matrices in physics: Gauss elimination, LU decomposition, Cholesky factorization, recursive algorithm
- Ordinary and Partial Differential Equations
  - The Euler method, the second and fourth order Runge-Kutta method
  - Simple pendulum, double pendulum, Poincare plots, chaotic regime
  - Boundary value and eigen value problems: elastic waves in a vibrating rod, the shooting method
  - One dimensional Schrödinger equation, Numerov algorithm
- Density Functional Theory and Molecular Dynamics
  - Density Functional Theory for solids: the muffin-tin concept
  - Electronic structure calculations with APW, KKR and LMTO methods
  - Molecular dynamics simulations, the Verlet algorithm
  - Structure and dynamics of real materials, ab-initio molecular dynamics
- Advanced Methods for Many-Particle Systems
  - The second quantization and the Hartree-Fock method
  - Models and many body Hamiltonians and their numerical representation
  - Exact diagonalization, the power method, Lanczos method
  - Lehmannn representation, Green functions, dynamic correlations
- Monte Carlo Simulations
  - Random numbers, high dimensional integrals, Importance sampling, Diffusion limited aggregation.
  - Markov chains, Metropolis algorithm, Ising model, Wang-Landau algorithm, simulated annealing, traveling salesman problem
  - Quantum Monte Carlo methods, path integrals and path integral Monte Carlo, QMC on the lattice, Heisenberg model, world-line approach
  - Determinantal QMC, the Hirsch-Fye algorithm, continuous time QMC

Literature:

- Tao Pang, An Introduction to Computational Physics (Cambridge University Press)
- J. M. Thijssen, Computational Physics (Cambridge University Press)
- S. Koonin, D. Meredith, Computational Physics (Addison-Wesley)
- W. H. Press et al., Numerical Recipes (Cambridge University Press) [available on-line at http://www.nr.com/]
- D. C. Rapaport, The Art of Molecular Dynamics Simulation (Cambridge University Press)
- R. H. Landau, M. J. Paez, C. Bordeianu, Computational Physics (Wiley-VCH)

Part of the Module: Computational Physics and Materials Science (Tutorial)
Mode of Instruction: exercise course
Language: English
Frequency: every 4th semester
Contact Hours: 2,00

Learning Outcome:
see module description

Contents:
see module description

Literature:
see corresponding lecture

Examination

Computational Physics and Materials Science

oral exam / length of examination: 30 minutes, graded

Module MTH-2021: Master Thesis with Colloquium *Master Thesis with Colloquium*		30 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Learning Outcomes / Competences: Students are familiar with the current state of research in a specialised field and the relevant literature. They are able to apply modern mathematical methods to the in-depth study of a current research question. They have the competence to independently work on a mathematical problem within a given time frame using scientific methods and to present the scientific basis of the problem and their results in writing. Integrated acquisition of key qualifications: ability to work in a team, perseverance, ability to document one's own scientific results in writing, critical reflection on one's own results in an international scientific context, principles of good scientific practice.		
Workload: Total: 900 h		
Conditions: none		
Frequency: each semester	**Recommended Semester:** 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 0,00	**Repeat Exams Permitted:** once	

Parts of the Module

Part of the Module: Master Thesis with Colloquium

Mode of Instruction: colloquium
Language: German / English
Frequency: each semester
Contact Hours: 0,00
ECTS Credits: 30.0

Contents:

Appropriately chosen topic

Prerequisites: Basic knowledge in most mathematical subdisciplines, in-depth knowledge in a specialised field.

Examination

Master Thesis with Colloquium

Master's thesis / length of examination: 6 months, graded