Module Handbook

for the

Master Programme “Artificial Intelligence”

at

Rheinischen Friedrich-Wilhelms-Universität Bonn

revised version: May 14, 2026

Contents

1 Compulsory Modules

MA-INF 0401 Master Thesis

Workload	Credit points	Duration	Frequency
900 h	30 CP	1 semester	every semester

Module coordinator	Lecturer(s)
The Examination Board	All lecturers of computer science

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Compulsory	4.

Learning goals: technical skills

Ability to solve a well-defined, significant research problem under supervision, but in principle independently

Learning goals: soft skills

Ability to write a scientific documentation of considerable length according to established scientific principles of form and style, in particular reflecting solid knowledge about the state-of-the-art in the field

Contents

Topics of the thesis may be chosen from any of the areas of computer science represented in the curriculum

Prerequisites

Required:
By the examination regulations of 2023, the Master's thesis project can only commence after 60 credits in other modules of the programme have been obtained. Before you start on the project, you must obtain the approval of the exam committee and register the starting date of the project. Please check the website of the examination office for forms and procedures.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Independent preparation of a scientific thesis with individual coaching		0	900 S	30

T = face-to-face teaching
S = independent study

Graded exams

Master Thesis

Ungraded coursework (required for admission to the exam)

None

Literature

Individual bibliographic research required for identifying relevant literature (depending on the topic of the thesis)

MA-INF 0402 Master Seminar

Workload	Credit points	Duration	Frequency
60 h	2 CP	1 semester	every semester

Module coordinator	Lecturer(s)
The Examination Board	All lecturers of computer science

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Compulsory	4.

Learning goals: technical skills

Knowledge of the state-of-the-art in research in the respective area and how the thesis results relate to that.

Learning goals: soft skills

Ability to identify the most relevant content for a knowledgeable scientific audience; ability to present and defend one's work in a presentation with visual media in a way that adheres to academic standards; ability to anticipate, accept and answer critical questions.

Contents

Topic, scientific context, and results of the master thesis

Prerequisites

Required:
The Master Seminar accompanies the Master Thesis project, see MA-INF 0401 for prequisites.

Recommended:
None

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar		2	30 T / 30 S	2

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation of final results

Ungraded coursework (required for admission to the exam)

None

Literature

Individual bibliographic research required for identifying relevant literature (depending on the topic of the thesis)

MA-INF 4111 Principles of Machine Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr.-Ing. Christian Bauckhage	Prof. Dr.-Ing. Christian Bauckhage

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Compulsory	1.

Learning goals: technical skills

Upon successful completion of this module, students should be able to describe fundamental methods, algorithms, and use cases of machine learning. Students acquire knowledge about supervised and unsupervised learning; based on the knowledge and skills acquired, students should be able to

- Implement, algorithms for optimization and parameter estimation in model training and machine learning tasks.
- Adopt the fundamental methods they learned about to a wide range of problems in automated intelligent data analysis.

Learning goals: soft skills

In the exercises, students can put their knowledge about theoretical concepts, mathematical methods, and algorithmic approaches into practice and realize small projects involving the implementation and evaluation of machine learning algorithms. This requires teamwork; upon successful completion of the module, students should be able to

- draft and implement basic machine learning algorithms for various practical problem settings
- prepare and give oral presentations about their work in front of an audience

Contents

Fundamental machine learning models for classification and clustering, model training via minimization of loss functions, fundamental optimization algorithms, model regularization, kernel methods for supervised and unsupervised learning, probabilistic modeling and inference, dimensionality reduction and latent factor models, the basic theory behind neural networks and neural network training; This course is intended to lay the foundation for more advanced courses on modern deep learning and reinforcement learning.

Prerequisites

Recommended:
Linear algebra, statistics, probability theory, calculus, python programming

Remarks

At most 150 participants.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture	150	2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to five students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions once.

Forms of media

- lecture slides / lecture notes are made available online
- notebooks with programming examples are made available online

Literature

- D.J.C MacKay: Information Theory, Inference and Learning Algorithms, Cambridge University Press, 2003
- C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006
- S. Haykin: Neural Networks and Learning Machines, Pearson, 2008

MA-INF 4118 Principles of Deep Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Zorah Lähner	Prof. Dr. Zorah Lähner

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Compulsory	1.

Learning goals: technical skills

At the end of the course, students will

- understand the foundations and principles of deep learning
- understand applications, theoretical use cases and limitations of deep learning
- are able to compare and contrast different implementations of deep learning

Learning goals: soft skills

Students will learn to

- implement deep learning algorithms in new contexts
- describe and contrast different fundamental approaches to deep learning architectures
- understand and handle different knowledge representations in the context of new problems
- understand differences of deep learning and other machine learning techniques

Contents

The course will cover foundations and principles of deep learning and its uses in the wider artificial intelligence literature. Foundational concepts of deep learning are covered, including transformer architecture, neural networks, training and optimization, backpropagation, and generalization.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture	120	2	30 T / 45 S	2.5
Exercises	30	2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work must be done individually. A total of 50% of the points must be achieved.

Literature

Will be announced in the lecture.

2 General Electives

MA-INF 5412 Seminar Sustainable Entrepreneurship and Venturing

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Denise Fischer-Kreer	The teaching persons in the current semester will be announced in time, at the start of the semester.

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-2.

Learning goals: technical skills

Students will learn to

- identify social and environmental problems,
- understand the specifies and requirements of sustainable entrepreneurship,
- develop ideas for solutions using tools from AI,
- analyse and evaluate alternatives,
- develop plans to implement their solution,
- to apply tools for sustainability-oriented idea generation and evaluation,
- have knowledge and skills to identify, develop, evaluate, and determine sustainable business models.

Learning goals: soft skills

After a successful completion of the course, the students

- create the foundations of an entrepreneurial mindset.
- work on projects in a team and an interdisciplinary setting,
- present business models based on their solutions.

Contents

The module "Sustainable Entrepreneurship and Venturing" is designed for students interested in start-ups and how entrepreneurship may help foster urgent sustainability transformations. The module provides an overview of the entrepreneurial process of discovering, evaluating, and implementing new business ideas and models to promote sustainable development. During the course, students will explore the concept of sustainable entrepreneurship, which encompasses the fundamentals of entrepreneurship and sustainable business models as well as entrepreneurial tools for sustainability.

Building on this, sustainable venturing embraces an active role and aims to harness the innovative power of entrepreneurship to solve global social and environmental challenges. In this context, students will work in teams to develop a sustainable business idea. Students are guided through the process of applying entrepreneurial tools to advance their entrepreneurial ideas and turn them into business models. Students are also familiarized with concepts and tools for presenting their business idea.

Prerequisites

none

Remarks

Course offered for students of the Master of Artificial Intelligence from the institute of Agrar-, Forst- und Ernährungswissenschaften, under module number ARTS-BC08 [780750100].

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	25	3	45 T / 135 S	6

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6). Project/lab work

3 Specialization Modules

MA-INF 2113 Foundations of Audio Signal Processing

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
apl. Prof. Dr. Frank Kurth	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-2.

Learning goals: technical skills

• Introduction to basic concepts of analog and digital signal processing: Acquire basic knowledge on modeling and representing audio content; learn fundamental concepts of analog and digital signal processing, in particular mathematical models of signal spaces and apply them to the audio domain; learn methods for analog to digital conversion, frequency analysis, time-frequency analysis and digital filtering.
• Applications in the field of Audio Signal Processing: Learn typical application domains of audio signal processing techniques and how to apply the acquired methods in solving applications problems from those domains. Important examples are basic signal manipulation and filtering.
• Solving basic Signal Processing Problems: Learn basic signal processing algorithms for performing the Fourier Transform and a time-frequency analysis, as well as for performing filter operations and fundamental types of signal manipulations.
• Implementing basic Signal Processing Algorithms using state-of-the-art software frameworks: In the exercises, the introduced methods and algorithms have to be implemented and applied to basic applications problems. Hence knowledge in the practical implementation of digital signal processing methods in standard programming environments such as Python, Matlab or Octave is acquired.

Learning goals: soft skills

Capability to analyze; Time management; Presentation skills; Discussing own solutions and solutions of others, and working in groups.

Contents

Theoretical introduction to analog and digital Signal Processing; Fourier Transforms; Analog to digital Conversion; Digital Filters; Audio Signal Processing Applications; Filter banks; Windowed Fourier Transform; 2D-Signal Processing

Prerequisites

Recommended:
Solid basic knowledge on Linear Algebra and Analysis on the level acquired in Bachelor in Computer Science programmes, including proficiency in using complex numbers.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of two to four students. A total of 50% of the points must be achieved.

Forms of media

Slides, Blackboard, Whiteboard

MA-INF 2201 Computer Vision

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Jürgen Gall	Prof. Dr. Jürgen Gall

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-2.

Learning goals: technical skills

Students will be able to understand and explain mathematical descriptions of methods in publications from Computer Vision. Students will be able to implement the discussed Computer Vision algorithms, apply them, and choose the right approach and hyper-parameters for a given problem.

Learning goals: soft skills

Productive work in small teams, development and realization of individual approaches and solutions, critical reflection of competing methods, discussion in groups.

Contents

The class will cover a number of mathematical methods and their applications in computer vision. For example, linear filters, edges, derivatives, Hough transform, segmentation, graph cuts, mean shift, active contours, level sets, MRFs, expectation maximization, background subtraction, temporal filtering, active appearance models, shapes, optical flow, 2d tracking, cameras, 2d/3d features, stereo, 3d reconstruction, 3d pose estimation, articulated pose estimation, deformable meshes, RGBD vision.

Prerequisites

Recommended:
Basic knowledge of linear algebra, analysis, probability theory, Python programming

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved.

Literature

- R. Hartley, A. Zisserman: Multiple View Geometry in Computer Vision
- R. Szeliski: Computer Vision: Algorithms and Applications
- S. Prince: Computer Vision: Models, Learning, and Inference

MA-INF 2312 Image Acquisition and Analysis in Neuroscience

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Schultz	Prof. Dr. Thomas Schultz

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-2.

Learning goals: technical skills

Students will learn about image acquisition and analysis pipelines which are used in neuroscience. They will understand algorithms for image reconstruction, artifact removal, image registration and segmentation, as well as relevant statistical and machine learning techniques. A particular focus will be on data from Magnetic Resonance Imaging and on mathematical models for functional and diffusion MRI data.

Learning goals: soft skills

Productive work in small teams, self-dependent solution of practical problems in the area of biomedical image processing, presentation of solution strategies and implementations, self management, critical reflection of conclusions drawn from complex experimental data.

Contents

This course covers the full image formation and analysis pipeline that is typically used in biomedical studies, from image acquisition to image processing and statistical analysis.

Prerequisites

Recommended:
Mathematical background (calculus, linear algebra, statistics); imperative programming.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		3	45 T / 45 S	3
Exercises		1	15 T / 75 S	3

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions once.

Literature

- B. Preim, C. Botha: Visual Computing for Medicine: Theory, Algorithms, and Applications. Morgan Kaufmann, 2014
- R.A. Poldrack, J.A. Mumford, T.E. Nichols: Handbook of Functional MRI Data Analysis. Cambridge University Press, 2011
- D.K. Jones: Diffusion MRI: Theory, Method, and Applications, Oxford University Press, 2011

MA-INF 2317 Numerical Algorithms for Visual Computing and Machine Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Florian Bernard	Prof. Dr. Florian Bernard

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-2.

Learning goals: technical skills

• ability to implement basic numerical algorithms, understanding their strengths and shortcomings
• mathematical modelling of computational problems in visual computing and machine learning
• gain an intuition which algorithm is best applied for which problem in visual computing and machine learning, so that practical problems in these areas can be solved

Learning goals: soft skills

• problem solving skills: ability to identify and utilise analogies between new problems and previously seen ones
• analytical and abstract thinking: develop a general intuition of computational problems, being able to adopt different perspectives of particular concepts

Contents

This module focuses on numerical methods that frequently occur in the fields visual computing (VC) and machine learning (ML). In addition to algorithms, this module will also cover modelling aspects that are relevant for solving practical problems in VC and ML. The contents include:

• Error analysis and conditioning of problems
• Linear systems (solvability, algorithms, stability, regularisation), and applications and modelling in VC and ML (e.g. linear regression, image alignment, deconvolution)
• Spectral methods (eigenvalue decomposition, singular value decomposition, respective algorithms), and their applications and modelling in VC and ML (e.g. clustering, Procrustes analysis, point-cloud alignment, principal components analysis)
• Numerical optimisation (gradient-based methods, second-order methods, large-scale optimisation) and applications and modelling in VC and ML.

Prerequisites

Recommended:
Participants are expected to have a high level of mathematical maturity (in particular, a good working knowledge of linear algebra and calculus/analysis is essential). A basic understanding of mathematical optimisation is advantageous.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved.

MA-INF 4114 Robot Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Prof. Dr. Sven Behnke, Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-2.

Learning goals: technical skills

This lecture is one of two introductory lectures on Robotics of the intelligent systems track. Creating autonomous robots that can learn to assist humans in situations of daily life is a fascinating challenge for machine learning. The lecture covers key ingredients for a general robot learning approach to get closer towards human-like performance in robotics, such as reinforcement learning, learning models for control, learning motor primitives, learning from demonstrations and imitation learning, and interactive learning.

This module complements MA-INF 4113 and can be taken before or after that module.

Learning goals: soft skills

Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems)

Contents

Reinforcement learning, Markov decision processes, dynamic programming, Monte Carlo methods, temporal-difference methods, function approximation, liear quadratic regulation, differential dynamic programming, partially observable MDPs, policy gradient methods, inverse reinforcement learning, imitation learning, learning kinematic models, perceiving and handling of objects.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved.

Literature

• R. Sutton and A. Barto: Reinforcement Learning, MIT-Press, 1998.
• O. Sigaud and J. Peters (Eds.): From Motor Learning to Interaction Learning in Robots. Springer, 2010.

MA-INF 4115 Introduction to Natural Language Processing

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Lucie Flek	Prof. Dr. Lucie Flek

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-2.

Learning goals: technical skills

This class provides a technical perspective on NLP methods for building computer software that understands and manipulates human language. Contemporary data-driven approaches are emphasized, focusing on machine learning techniques. The covered applications vary in complexity, including for example Entity Recognition, Argument Mining, or Emotion Analysis.

Learning goals: soft skills

Group work during programming exercises will allow students to work on real-world NLP application projects. The final project offers you the chance to apply your newly acquired skills towards an in-depth application using different frameworks such as PyTorch and spaCy and present it in a poster session.

Contents

Through lectures, exercises, and a final project, you will gain a thorough introduction to cutting-edge research in NLP, from the linguistic basis of computational language methods to recent advances in deep learning and large language models. This course provides:

• An overview of NLP goals, challenges, and applications
• Text representation (Words, sentences, paragraphs, documents), word embeddings, word2vec, BERT, word similarity
• Machine learning / deep learning algorithms for text classification, Transformers
• Basics of neural language modeling
• Basics of computational linguistics

- Transforming words to their base forms (tokenization, stemming, lemmatization)

- Syntactic analysis (part of speech tagging, chunking, and parsing)

- Techniques for extracting meaning from text (semantic analysis), use of lexical resources in NLP

• NLP applications and projects (e.g., Sentiment Analysis, Named Entity Recognition, Question Answering, Summarization, Fake news detection, Plagiarism detection, Abusive language detection, Opinion mining...)

Prerequisites

Recommended:
• Basics of statistics recommended.
• Basic programming knowledge in Python is of advantage.
• Basics of machine learning are of advantage.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		3	45 T / 45 S	3
Exercises		1	15 T / 75 S	3

T = face-to-face teaching
S = independent study

Graded exams

Written exam (60 %); Project work (40 %)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work must be done individually. A total of 50% of the points must be achieved.

Forms of media
• Lecture slides • Exercise slides • Notebooks with programming examples

Literature
• J. Eisenstein: Introduction to Natural Language Processing • Jurafsky, Daniel, and James H. Martin. "Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition." • S. Bird, E. Klein, E. Loper; Natural Language Processing with Python

MA-INF 4228 Foundations of Data Science

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Lucie Flek	Prof. Dr. Lucie Flek

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-2.

Learning goals: technical skills

Knowledge: Peculiarities of high dimensional spaces in geometry and probabilities. Singular vector decomposition. Basics in machine learning and clustering.

Skills: Understanding of mathematical tools.

Competences: Application to data science problems and ability to assess similar methods.

Learning goals: soft skills

Oral presentation (in tutorial groups), written presentation (of exercise solutions), team collaboration in solving homework problems, critical assessmen

Contents

Data science aims at making sense of big data. To that end, various tools have to be understood for helping in analyzing the arising structures.

Often data comes as a collection of vectors with a large number of components. To understand their common structure is the first main objective of understanding the data. The geometry and the linear algebra behind them becomes relevant and enlightning. Yet, the intuition from low-dimensional space turns out to be often misleading. We need to be aware of the particular properties of high-dimensional spaces when working with such data. Fruitful methods for the analysis include singular vector decomposition from linear algebra and supervised and unsupervised machine learning.

Prerequisites

Recommended:
Basic skills in linear algebra and stochastics.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions twice.

Literature

Avrim Blum, John Hopcroft, and Ravindran Kannan (2018+). Foundations of Data Science.

4 Advanced Modules

MA-INF 2114 Foundations of 4D/6D Object Capture for Virtual Environments

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Reinhard Klein	Prof. Dr. Reinhard Klein, Dr. Patrick Stotko

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

• Knowledge about 3D/4D/6D data capturing and how to apply state-of-the art models and scene representations to effectively process these data
• Make proper use and integrate solutions in game engines like Unity and Unreal Engine and standard tools like Blender for practical applications
• Development and realization of individual state-of-the-art graphics and vision approaches

Learning goals: soft skills

• Communicative Skills: Written and oral presentation of solutions, discussing ideas in small teams, and preparing structured written documents.
• Self-Competences: include time management, goal-oriented work, the ability to analyze problems theoretically, and finding practical solutions
• Social Skills: involves effective teamwork, collaborating with others, accepting and formulating criticism, and critical examination of research results
• Practical Skills: ability to implement practical solutions, present and defend design decisions, and prepare readable documentation of software or projects

Contents

This intensive course offers an overview of the latest techniques and trends in 3D/4D/6D visual data processing and demonstrates how these basic concepts can be applied to game engines and standard graphics tools. The covered topics will be:

• Foundations of Computer Graphics and Vision
• Use of Deep Learning techniques in visual data processing
• Data acquisition techniques for Graphics and Vision
• Human model representations
• Motion data processing
• Geometry processing techniques
• Differentiable rendering for 3D/4D/6D reconstruction and model optimization
• Neural Radiance Fields and Gaussian Splatting as efficient scene representations
• Dynamic scene representations

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		4	60 T / 45 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam in three parts

Ungraded coursework (required for admission to the exam)

Successful participation in the exercise requires a minimum of 50% correct unit tests for the programming assignments in each 5-day period

Literature
Supplemental readings will be provided before the lecture starts.

MA-INF 2206 Seminar Vision

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Jürgen Gall	Prof. Dr. Jürgen Gall

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers.

Prerequisites

Recommended:
MA-INF 2201 – Computer Vision or MA-INF 2213 - Advanced Computer Vision

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 2208 Seminar Audio

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
apl. Prof. Dr. Frank Kurth	apl. Prof. Dr. Frank Kurth, Dr. Michael Clausen

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers in the area of audio signal processing.

Prerequisites

Recommended:
MA-INF 2113 - Audio Signal Processing

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 2212 Pattern Matching and Machine Learning for Audio Signal Processing

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
apl. Prof. Dr. Frank Kurth	apl. Prof. Dr. Frank Kurth

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

• Introduction into selected topics of digital signal processing: Acquire basic knowledge on representing and manipulating 1D-time series. Learn basic methods for time-frequency analysis and signal processing methods for feature extraction.
• Applications in the field of Audio Signal Processing: Learn typical application domains of audio signal processing techniques and how to apply the acquired methods in solving applications problems. Important examples are filtering, signal/object detection and classification tasks.
• Methods of Automatic Pattern Recognition and Machine Learning: Learn methods for Feature Extraction, Automatic Pattern Recognition and Machine Learning for the context of Audio Signal Processing. Be able to apply those fundamental methods (method list: see "Contents" section) in particular for solving applications tasks.

Learning goals: soft skills

Audio Signal Processing Applications; Extended programming skills for signal processing applications; Capability to analyze; Time management; Presentation skills; Discussing own solutions and solutions of others, and working in groups.

Contents

The lecture is presented in modular form, where each module is motivated from the application side. The presented topics are: Windowed Fourier transforms; Audio Identification; Audio Matching; Signal Classification; Applications of ML/DL concepts, in particular HMMs, SVMs and Neural Networks to Audio Signal processing tasks.

Prerequisites

Recommended:
Solid basic knowledge on Linear Algebra, Analysis and Stochastics, including proficiency in using complex numbers.

Having attended MA-INF 2113 Foundations of Audio Signal Processing is highly recommended, as fundamental material from (Digital) Signal Processing and Audio Processing are introduced there in depth.

Basic knowledge in time series data analysis is helpful but not mandatory.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of two to four students. A total of 50% of the points must be achieved.

Forms of media

Slides, Blackboard, Whiteboard

MA-INF 2213 Advanced Computer Vision

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Jürgen Gall	Prof. Dr. Jürgen Gall

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Students will be able to implement the discussed machine learning algorithms for Computer Vision, apply them, and choose the right approach and hyper-parameters for a given problem.

Learning goals: soft skills

Productive work in small teams, development and realization of individual approaches and solutions, critical reflection of competing methods, discussion in groups.

Contents

The class will cover a number of computer vision applications. For example, image classification, object detection, action recognition, pose estimation, face analysis, tracking, image synthesis, vision-language models.

Prerequisites

Recommended:
MA-INF 2201 – Computer Vision

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		3	45 T / 45 S	3
Exercises		1	15 T / 75 S	3

T = face-to-face teaching
S = independent study

Graded exams

Oral exam (20 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved.

MA-INF 2216 Lab Visual Computing

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Florian Bernard	Prof. Dr. Florian Bernard

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

- Getting into a selected topic of visual computing
- Implementation and practical application of current visual computing methods
- Experimental evaluation and visualisation of results
- Scientific research and writing

Learning goals: soft skills

- self-organisation
- ability to analyze problems theoretically and to find creative and practical solutions
- critical thinking: examine one's solutions and results critically
- to classify own results into the state-of-the-art of the respective area
- to prepare readable documentation of software and research results
- to present, defend and discuss design decisions and results in the team/group and to other students clearly and in accordance with academic standards

Contents

This lab introduces visual computing methods and applications. You will get a chance to study the methods in depth by implementing them and running experiments. At the end of the semester, you will present the method, give a short demonstration and hand in a report describing the method and experimental outcomes. Potential topics include deep learning (e.g. graph neural networks, unsupervised learning, 3D deep learning), mathematical optimization (e.g. linear/convex/non-convex programming, graph-based algorithms) and other methods involving mathematical modeling of visual computing problems.

Prerequisites

Recommended:
Basic knowledge in mathematics (e.g. linear algebra, calculus, optimization) and programming (e.g. python, in particular pytorch or tensorflow, C++, or Matlab). In addition:

- MA-INF 2317: Numerical Algorithms for Visual Computing and Machine Learning, or
- MA-INF 2225: Discrete Models for Visual Computing

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 2219 Seminar Visualization and Medical Image Analysis

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Schultz	Prof. Dr. Thomas Schultz

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Enhanced and in-depth knowledge in specialized topics in the area of visualization and medical image analysis.

Learning goals: soft skills

Acquire the competence to independently search for and study state-of-the-art scientific literature in depth, read critically, identify the most relevant content, and assess research results in the context of the corresponding research area; to discuss research results with a knowledgeable scientific audience; to present prior work by others in writing and in presentations with visual media in a way that adheres to academic standards, that is well-structured and didactically effective, and that motivates the audience to participate; to formulate and accept criticism; to manage one's time with relatively open assignments and long-ranging deadlines.

Contents

Recent research topics in visualization and medical image analysis based on journal and conference publications. Relevant journals include Medical Image Analysis, IEEE Transactions on Medical Imaging, IEEE Transactions on Visualization and Computer Graphics; relevant conferences include Medical Image Computing and Computer-Assisted Intervention (MICCAI), IEEE/CVF Computer Vision and Pattern Recognition (CVPR) IEEE VIS, EuroVis.

Prerequisites

Recommended:
At least one of the following:

- MA-INF 2222 – Visual Data Analysis
- MA-INF 2312 – Image Acquisition and Analysis in Neuroscience

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 2220 Lab Visualization and Medical Image Analysis

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Schultz	Prof. Dr. Thomas Schultz

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Students acquire a deep understanding of a specific problem in visualization and medical image analysis, and technical knowledge about state-of-the-art algorithmic approaches to solving it. This involves problem identification; data processing; selection, design, implementation, and application of suitable algorithms; communication of results.

Learning goals: soft skills

Ability to analyze problems theoretically and to find creative and practical solutions; to examine one's solutions and results critically; to classify one's own results into the state-of-the-art of the

respective area; to prepare readable documentation of software and research results; to present, defend and discuss design decisions and results in the team/group and to other students clearly and in accordance with academic standards; to collaborate constructively with others in small teams over a longer period of time; to aim at long-range goals under limited resources.

Contents

The students will carry out a practical task (project) in the context of data visualization and visual analytics or medical image analysis, including test and documentation of the implemented software/system. Projects are often based on journal and conference publications. Relevant journals include Medical Image Analysis, IEEE Transactions on Medical Imaging, IEEE Transactions on Visualization and Computer Graphics; relevant conferences include Medical Image Computing and Computer-Assisted Intervention (MICCAI), IEEE/CVF Computer Vision and Pattern Recognition (CVPR) IEEE VIS, EuroVis.

Prerequisites

Recommended:
At least one of the following:

- MA-INF 2222 – Visual Data Analysis
- MA-INF 2312 – Image Acquisition and Analysis in Neuroscience.

A solid background in programming is required, preferably in Python. Most projects also require basic knowledge in linear algebra, calculus, probability theory, and/or numerical algorithms.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 2221 Seminar Visual Computing

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
Prof. Dr. Florian Bernard	Prof. Dr. Florian Bernard

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers.

Prerequisites

Required:
No formal requirements. Participants are expected to have some previous exposure to at least one of the following:
- visual computing (e.g. computer vision, computer graphics, 3D shape analysis, image analysis, etc.),
- mathematical optimisation (e.g. combinatorial/continuous, convex/non-convex, etc.), or
- machine learning.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 2222 Visual Data Analysis

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Schultz	Prof. Dr. Thomas Schultz

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Ability to design, implement, and make proper use of systems for visual data analysis. Knowledge of algorithms and techniques for the visualization of multi-dimensional data, graphs, as well as scalar, vector, and tensor fields.

Learning goals: soft skills

Productive work in small teams, self-dependent solution of practical problems in the area of visual data analysis, critical reflection on visualization design, presentation of solution strategies and implementations, self management

Contents

This class provides a broad overview of principles and algorithms for data analysis via interactive visualization. Specific topics include perceptual principles, color spaces, visualization analysis and design, integration of visual with statistical data analysis and machine learning, as well as specific algorithms and techniques for the display of multidimensional data, dimensionality reduction, graphs, geospatial data, neural networks, as well as scalar, vector and tensor fields.

Prerequisites

Recommended:
Students are recommended to have a basic knowledge in linear algebra and calculus, as well as proficiency in programming.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions once.

Literature

- A.C. Telea, Data Visualization: Principles and Practice. CRC Press, Second Edition, 2015
- M. Ward et al., Interactive Data Visualization: Foundations, Techniques, and Applications. CRC Press, 2010
- T. Munzner, Visualization Analysis and Design, A K Peters, 2015

MA-INF 2225 Discrete Models for Visual Computing

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Florian Bernard	Prof. Dr. Florian Bernard

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

• Ability to implement basic visual computing algorithms, understanding their strengths and shortcomings
• Mathematical modelling of computational problems in visual computing
• Gain an intuition which algorithm is best applied for which problem in visual computing, so that practical problems in these areas can be solved

Learning goals: soft skills

• Problem solving skills: ability to identify and utilise analogies between new problems and previously seen ones
• Analytical and abstract thinking: develop a general intuition of computational problems, being able to adopt different perspectives of particular concepts

Contents

This module focuses on discrete models that frequently occur in the field of visual computing (VC). In addition to algorithms, this module will also cover modelling aspects that are relevant for solving practical problems in VC. The contents include:

• Graph-based models (e.g. linear and quadratic assignment, network flows, product graph formalisms, dynamic programming and their application)
• Continuous algorithms for discrete problems (e.g. convex & spectral relaxations, projection methods, path-following and their application)
• Deep Learning for discrete domains (e.g. differentiable programming, graph neural networks, deep learning on meshes)

Prerequisites

Recommended:
Participants are expected to have a high level of mathematical maturity (in particular, a good working knowledge of linear algebra and calculus/analysis is essential). A basic understanding of graph theory is advantageous.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved.

MA-INF 2226 Lab Geometry Processing

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Jun. Prof. Dr. Zorah Lähner	Prof. Dr. Zorah Lähner

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Ability to handle complex geometric data types; to extract implementation details from research publications; to implement and visualize geometric data.

Learning goals: soft skills

Ability to analyze problems theoretically and to find creative and practical solutions; to examine one's solutions and results critically; to classify one's own results into the state-of-the-art of the respective area; to prepare readable documentation of software and research results; to present, defend and discuss design decisions and results in the team/group and to other students clearly and in accordance with academic standards; to collaborate constructively with others in small teams over a longer period of time.

Contents

Mesh deformation, point cloud meshing, pytorch3D, shape correspondence, reconstruction, 2D-to-3D transfer. This lab introduces methods and applications in the field of geometry processing. You will get a chance to study the methods in depth by implementing them and running experiments. At the end of the semester, you will present the method, give a short demonstration and hand in a report describing the method and experimental outcomes.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 2228 Seminar Vision and Graphics (Role-Based)

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Jun. Prof. Dr. Zorah Lähner	Prof. Dr. Zorah Lähner

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

- reading and understanding of research publications in the area of computer vision and computer graphics
- learning about different roles in the research community and taking their point of view

Learning goals: soft skills

- Critical thinking: ability to put research into wider context and analyze it from different perspectives
- Communication: oral and written presentation of scientific content, high level discussion about a new topic
- Self-Competence: time management, focusing on essential aspects , creativity

Contents

Students will study a variety of publications in the area of computer vision and graphics, and will be assigned a specific role which determines how to interact with the work.

The roles include but are not limited to:

- Scientific Peer Reviewer
- Academic Researcher
- Archaeologist (putting the paper into context regarding previous and subsequent work)
- Industry Practitioner

Prerequisites

Recommended:
A background in visual computing through lectures from the Graphics, Vision, Audio subfield is highly recommended.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6). Participation in each type of assigned role in-presence at least once.

MA-INF 2229 Seminar Recent Advances in Geometry Processing

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Jun. Prof. Dr. Zorah Lähner	Prof. Dr. Zorah Lähner

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

This module examines recent topics in geometry processing. The students learn to do independent, in-depth study of state-of-the-art scientific literature, discuss them with their peers and present in a form suited for a scientific audience.

Learning goals: soft skills

Communication skills: oral and written presentation of scientific content

Self-competence: the ability to analyze problems, time management, creativity

Contents

Algorithmic and learning-based methods for geometry processing, including typical applications like shape correspondence, 3D reconstruction, geometry evaluation, differential geometry, statistical modeling as well differences for methods using implicit and explicit geometry representations.

Prerequisites

Recommended:
MA-INF 2310 Advanced Topics in Computer Graphics II

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 2307 Lab Vision

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Jürgen Gall	Prof. Dr. Jürgen Gall

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

The students will carry out a practical computer vision task (project).

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Computer Vision: research topics and applications

Prerequisites

Required:
Good C++ or Python programming skills

Recommended:
MA-INF 2201 – Computer Vision or MA-INF 2213 - Advanced Computer Vision

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 2309 Lab Audio

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
apl. Prof. Dr. Frank Kurth	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Proficiency in implementing signal processing concepts introduced in selected scientific publications or research reports. Proficiency in collecting and maintaining data sets, in particular signals and corresponding metadata, and performing scientific evaluations of signal processing methods based on data sets and implemented algorithms.

Learning goals: soft skills

Ability to analyze problems theoretically and to find creative and practical solutions; to examine one's solutions and results critically; to classify one's own results into the state-of-the-art of the respective area; to prepare readable documentation of software and research results; to present, defend and discuss design decisions and results in the team/group and to other students clearly and in accordance with academic standards; to collaborate constructively with others in small teams over a longer period of time; to pursue long-range goals under a given resource budget.

Contents

In the lab a medium-sized programming project related to digital audio signal processing has to be solved during the period of one semester. For this, initial literature, usually in form of one or two scientific papers or reports, will be provided at the beginning of the lab. Also, resources regarding the audio signal data to be used, are given. Typical programming tasks consist of implementing either general signal processing algorithms such as fundamental frequency estimation or of implementing algorithms for solving application problems such as speaker detection or classification. For participants with interest in topics of pattern recognition, machine and deep learning, programming projects from those areas, with application to audio processing, can be selected.

Prerequisites

Recommended:
Solid basic proficiency in imperative programming (e.g. knowledge of C/C++, Java, Python). Knowledge of the material from MA-INF 2113 Foundations of Audio Signal Processing is highly recommended. Knowledge of material from MA-INF 2212 Pattern Matching and Machine Learning for Audio is helpful but not necessary.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 4112 Algorithms for Data Science

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Stefan Wrobel	Dr. Tamas Horvath, Prof. Dr. Stefan Wrobel

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

In this module the students will learn algorithms for data science as well as implement and practice selected algorithms from this field. The module concentrates on basic algorithms in association rule mining, graph mining, and data streams. At the end of the module, students will be capable of analyzing formal properties of this kind of algorithms and choosing appropriate pattern discovery and data stream algorithms.

Learning goals: soft skills

Communicative skills (oral and written presentation of solutions, discussions in teams), self-competences (ability to accept and formulate criticism, ability to analyse, creativity in the context of an "open end" task), social skills (effective team work and project planning).

Contents

The module is offered every year, each time concentrating on one or more specific issues, such as frequent, closed and maximal frequent itemset mining, frequent subgraph mining algorithms for forests and for other graph classes beyond forests, frequent items and frequency moments in data streams, and graph stream algorithms.

Prerequisites

Recommended:
Knowledge of standard notions and results from complexity theory, propositional logic, hashing, probability theory, and calculus, all on the bachelor level, are required.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to five students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions once.

Forms of media

lectures, exercises

Literature

- Avrim Blum, John Hopcroft, Ravindran Kannan: Foundations of Data Science. Cambridge University Press, 2020.
- Jiawei Han, Micheline Kamber, Jian Pei: Data Mining: Concepts and Techniques. Morgan Kaufmann Publishers, 2012.
- David J. Hand, Heikki Mannila and Padhraic Smyth: Principles of Data Mining. The MIT Press, 2001.

MA-INF 4117 Mining Media Data I

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Rafet Sifa	Prof. Dr. Rafet Sifa, Dr. Lorenz Sparrenberg

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2. or 3.

Learning goals: technical skills

By the end of this course, students will be able to:

- Analyze and extract meaningful relationships from large-scale media datasets using advanced data mining techniques.
- Develop and implement predictive and descriptive models for applications such as recommender systems, trend analysis, and outlier detection.
- Apply mathematical optimization methods to create interpretable and efficient machine learning models.
- Integrate theoretical concepts with practical tools to address challenges in digital forensics, behavioral profiling, and marketing strategy design.

Learning goals: soft skills

Contents

This course provides a comprehensive exploration of advanced data mining techniques tailored for media data analysis. Students will delve into methods like affinity mining, latent pattern mining, neural networks, and archetypal analysis to uncover insights in behavioral profiling, recommender systems, and outlier detection. Emphasis is placed on theoretical understanding and practical application through mathematical optimization, interpretable models, and real-world case studies, enabling participants to harness data for impactful digital marketing, fraud detection, and content personalization.

Prerequisites

Recommended:
Basic knowledge of data science, machine learning, and pattern recognition; programming skills; linear algebra.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		1	15 T / 30 S	1.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes) or oral exam.

Ungraded coursework (required for admission to the exam)

(i) The completion of regularly provided exercise sheets. The work can be done in groups of up to five students. A total of 50% of the points must be achieved. (ii) The completion of a programming project. The work is done in groups of up to five students. The results of the programming project must be presented in class.

Literature

- Rafet Sifa (2019). Matrix and Tensor Factorization for Profiling Player Behaviour. Independently pressed.
- Jiawei Han, Jian Pei, Micheline Kamber (2012). Data Mining: Concepts and Techniques. 3rd Ed., Elsevier Inc.
- Christopher Manning, Prabhakar Raghavan, Hinrich Schütze (2008). Introduction to Information Retrieval. Cambridge University Press.
- Michael Negnevitsky (2019), Artificial Intelligence: A Guide to Intelligent Systems. 3rd Ed., Pearson.
- Ian Goodfellow, Yoshua Bengio, Aaron Courville (2016). Deep Learning. MIT Press..
- Lecture notes of the instructors.

MA-INF 4119 Data, Knowledge, and Context in Machine Learning and AI

Workload	Credit points	Duration	Frequency
60 h	2 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Brendan Balcerak Jackson	The lecturers will be announced in time before the start of the semester.

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-3.

Learning goals: technical skills

Upon successful completion of the module, students should be able to describe the fundamental concepts and methods of triangular AI and can describe paradigm use cases. Students acquire knowledge about methods for integrating machine-learning systems with knowledge representations and contextual awareness. Students should be able to transfer these methods to new problems and areas of application. Students acquire a differentiated awareness of ethical issues and trustworthiness in AI research.

Learning goals: soft skills

Students learn to put their knowledge of theoretical concepts and methods into practice to realize small projects, both on their own and by successfully working as part of a team. Students should be able to prepare and give oral presentations about their work in front of an audience.

Students learn about the different fundamental approaches to artificial intelligence offered at the institute, helping them guide and structuring their further course of study.

Contents

The course focuses on cutting-edge research in "triangular AI," which combines a data-intensive approach with expert knowledge and context as two additional powerful sources of intelligence. Methods are examined for integrating knowledge from various sources such as previous experience, informed simulations, mathematical descriptions of physical laws, and explicit knowledge provided by humans. The course also explores methods for exploiting the resources of the open, variable contexts in which the system operates, such as active sensing, experimentation and dynamic multimodal interaction with humans. The course surveys several core areas of research in triangular AI, including hybrid and resource-aware machine learning and human-centered and embodied AI. It also surveys triangular approaches in several application areas, including natural language processing, physics and the life sciences, and industry and logistics. The course also examines the potential of triangular AI for achieving AI that is ethically informed and trustworthy for human users.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 30 S	2

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

none

MA-INF 4201 Artificial Life

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Detailed understanding of the most important approaches and principles of artificial life. Knowledge and understanding of the current state of research in the field of artificial life. The students can judge and explain if an Artificial Life approach is feasible for a given class of problems. They can estimate the necessary effort to implement and shape the Artificial Life paradigm w.r.t. the task, and can give an educated estimation of the possible outcome and forseeable limitations of the approach. They can implement the basic fundamental Artificial Life paradigms.

Learning goals: soft skills

Capability to identify the state of the art in artificial life, and to present and defend the found solutions within the exercises in front of a group of students. Critical discussion of the results of the homework.

Contents

Foundations of artificial life, cellular automata, Conway's "Game of Life"; mechanisms for structural development; foundations of nonlinear dynamical systems, Lindenmeyer-systems, evolutionary methods and genetic algorithms, reinforcement learning, artificial immune systems, adaptive behaviour, self-organising criticality, multi-agent systems, and swarm intelligence, particle swarm optimization.

Prerequisites

Recommended:
Basic knowledge of linear algebra, analysis, logic, automata, and complexity analysis of deterministic and randomised algorithms.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (100 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to four students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions twice.

Forms of media

Pencil and paper work, explain solutions in front of the exercise group, implementation of small programs, use of simple simulation tools.

Literature

- Christoph Adami: Introduction to Artificial Life, The Electronic Library of Science, TELOS, Springer-Verlag
- Eric Bonabeau, Marco Dorigo, Guy Theraulaz: Swarm Intelligence: From Natural to Artificial Systems, Oxford University Press, Santa Fe Institute Studies in the Science of Complexity.
- Andrzej Osyczka: Evolutionary Algorithms for Single and Multicriteria Design Optimization, Studies in Fuzzyness and Soft Computing, Physica-Verlag, A Springer-Verlag Company, Heidelberg

MA-INF 4208 Seminar Vision Systems

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Prof. Dr. Sven Behnke, Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

• Knowledge in advanced topics in the area of technical vision systems, such as image segmentation, feature extraction, and object recognition.
• Ability to understand new research results presented in original scientific papers and to present them in a research talk as well as in a seminar report.

Learning goals: soft skills

Self-competences (time management, literature search, self-study), communication skills (preparation and clear didactic presentation of research talk, scientific discussion, structured writing of seminar report), social skills (ability to formulate and accept criticism, critical examination of research results).

Contents

Current research papers from conferences and journals in the field of vision systems covering fundamental techniques and applications.

Prerequisites

Recommended:
At least one of the following:

- MA-INF 2201 - Computer Vision
- MA-INF 4111 – Principles of Machine Learning
- MA-INF 4204 – Technical Neural Nets

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

- R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010.
- C. M. Bishop: Pattern Recognition and Machine Learning, Springer 2006.
- D. A. Forsyth and J. Ponce: Computer Vision: A Modern Approach, Prentice Hall, 2003.

MA-INF 4209 Seminar Principles of Data Mining and Learning Algorithms

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Stefan Wrobel	Prof. Dr. Stefan Wrobel, PD Dr. Michael Mock, Dr. Florian Seiffarth, Dr. Tamas Horvath

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Enhanced and in-depth knowledge in specialized topics in the area of machine learning and data mining.

Learning goals: soft skills

Acquire the competence to independently search for and study state-of-the-art scientific literature in depth, read critically, identify the most relevant content, and assess research results in the context of the corresponding research area; to discuss research results with a knowledgeable scientific audience; to present prior work by others in writing and in presentations with visual media in a way that adheres to academic standards, that is well-structured and didactically effective, and that motivates the audience to participate; to formulate and accept criticism; to manage one's time with relatively open assignments and long-ranging deadlines.

Contents

Theoretical, statistical and algorithmical principles of data mining and learning algorithms. Search and optimization algorithms. Specialized learning algorithms from the frontier of research. Fundamental results from neighbouring areas.

Prerequisites

Recommended:
Knowledge of basic notions and algorithms from machine learning and data mining. It is recommend to first take at least one of the following modules:

- MA-INF 4111 – Principles of Machine Learning
- MA-INF 4112 – Algorithms for Data Science

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Forms of media

Scientific papers and websites, interactive presentations.

Literature

The relevant literature will be announced towards the end of the previous semester.

MA-INF 4211 Seminar Cognitive Robotics

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Prof. Dr. Sven Behnke, Dr. Raphael Memmesheimer

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Knowledge in advanced topics in the area of cognitive robotics, such as robot perception, action planning, and robot learning.

Ability to understand new research results presented in original scientific papers and to present them in a research talk as well as in a seminar report.

Learning goals: soft skills

Self-competences (time management, literature search, self-study), communication skills (preparation and clear didactic presentation of research talk, scientific discussion, structured writing of seminar report), social skills (ability to formulate and accept criticism, critical examination of research results).

Contents

Current research papers from conferences and journals in the field of cognitive robotics covering fundamental techniques and applications.

Prerequisites

Recommended:
At least 1 of the following:
- MA-INF 4113 – Cognitive Robotics
- MA-INF 4114 – Robot Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.
- Selected papers.

MA-INF 4213 Seminar Humanoid Robots

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Maren Bennewitz	Prof. Dr. Maren Bennewitz

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Enhanced and in-depth knowledge in specialized topics in the area of humanoid robotics, such as perception, state estimation, navigation, manipulation, and motion planning.

Learning goals: soft skills

Self-competences (time management, literature search, self-study), communication skills (preparation of the talk, clear didactic presentation of techniques and experimental results, scientific discussion, structured writing of summary), social skills (ability to formulate and accept criticism, critical examination of algorithms and experimental results).

Contents

Current research papers from conferences and journals in the field of humanoid robotics covering fundamental techniques and applications.

Prerequisites

Recommended:
At least 1 of the following:

- MA-INF 4215 – Humanoid Robotics
- MA-INF 4113 – Cognitive Robotics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics
- K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer
- Selected papers.

MA-INF 4214 Lab Humanoid Robots

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Maren Bennewitz	Prof. Dr. Maren Bennewitz

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Design and implementation of perception, state estimation, navigation, manipulation, and motion planning techniques for humanoid robots.

Learning goals: soft skills

Ability to analyze problems theoretically and to find creative and practical solutions; to examine one's solutions and results critically; to prepare readable documentation of software and research results; to present, defend and discuss design decisions and results in the team/group and to other students clearly and in accordance with academic standards; to collaborate constructively with others in small teams over a longer period of time;

Contents

Robot middleware, perception, state estimation, navigation, manipulation, and motion planning for humanoid robots.

Prerequisites

Recommended:
At least 1 of the following:

- MA-INF 4215 – Humanoid Robotics
- MA-INF 4113 – Cognitive Robotics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics
- K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer
- Selected papers.

MA-INF 4215 Humanoid Robotics

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Maren Bennewitz	Prof. Dr. Maren Bennewitz

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

This lecture covers techniques for humanoid robots such as perception, navigation, and motion planning. After the lecture, the students will be able to understand and implement techniques that enable humanoid robots to autonomously navigate in human environments as well as perceive, represent, and manipulate objects.

Learning goals: soft skills

Communicative skills (oral and written presentation of solutions, discussions in small teams), ability to analyze problems.

Contents

Sensing and perception, environment representations, active perception, inverse kinematics, motion planning, grasping, balance control, walking, and footstep planning.

Prerequisites

Recommended:
MA-INF 4113 – Cognitive Robotics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (90 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 50% of the points must be achieved.

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics
- K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer
- Selected research papers.

MA-INF 4216 Biomedical Data Science and AI

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Holger Fröhlich	Dr. Holger Fröhlich

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	

Learning goals: technical skills

- understanding and knowledge of fundamental data mining and machine learning methods
- understanding of their application in bioinformatics

Learning goals: soft skills

- communication: oral and written presentation of solutions to exercises
- self-competences: ability to analyze application problems and to formulate possible solutions
- practical skills: ability to practically implement solutions
- social skills: working in a small team with other students

Contents

This lecture gives a broad overview about frequently used statistical techniques as well as data mining and machine learning algorithms in bioinformatics. The use of the respective methods to solve problems in bioinformatics is explained. The goal is to understand the explained methods, being able to apply them correctly and partially implement them. More detailed, the following topics are covered in the context of their application in bioinformatics:

- Short introduction to Bioinformatics and Biomedicine
- Statistical Basics: Probability distributions and Bayesian inference, statistical hypothesis testing, linear models, logistic regression, Principal Component Analysis
- Clustering
- Hidden Markov Models
- Supervised Machine Learning
- Elastic Net

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

(i) The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions once. (ii) Participation in an achievement test. On the test, at least 50% of the points much be achieved.

Literature

T. Hastie, R. Tibshirani, J. Friedman, The Elements of Statistical Learning, Springer, 2008

S.Boslaugh, P. Watters, Statistics in a Nutshell, O'Reilly, 2008

N. Jones, P. Pevzner, An Introduction to Bioinformatics Algorithms, MIT Press, 2004

MA-INF 4217 Seminar Machine Learning Methods in the Life Sciences

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Holger Fröhlich	Dr. Holger Fröhlich

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

- understanding and knowledge of machine learning methods and their application in modern life sciences, e.g. biomedicine

Learning goals: soft skills

- communication: oral scientific presentation of a defined topic
- self-competences: ability to identify relevant literature for a given topic; ability to read, understand and analyze scientific publications
- social skills: ability to discuss a scientific topic with other students and the staff

Contents

Machine learning techniques play a crucial role in modern life sciences, including biomedicine. The goal of this seminar is to discuss a variety of machine learning techniques in the context of their application to solve real-world problems in biomedicine.

Topics will be selected from the following areas:

- Ensemble learning
- Survival and disease progression models
- Bayesian Networks
- Stochastic processes, e.g. Gaussian Proceses, Dirichlet Process Mixture Models
- MCMC methods
- Deep learning methods, e.g. DNNs, CNNs, Deep Belief Networks
- feature selection and non-linear embedding methods
- multi-modal data fusion techniques

Attendees will be asked to perform research about their topic in a self-responsible manner.

Prerequisites

Recommended:
MA-INF 4216 – Data Mining and Machine Learning Methods in Bioinformatics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Forms of media

powerpoint

Literature

selected journal and conference papers

MA-INF 4230 Advanced Methods of Information Retrieval

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Prof. Dr. Elena Demidova

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

This module introduces the students to the advanced methods, data structures, and algorithms of information retrieval for structured and semi-structured data (including, for example, knowledge graphs, relational data, and tabular data).

At the end of the module, the students will be capable of choosing appropriate data structures and retrieval algorithms for specific applications and correctly apply relevant statistical and machine learning-based information retrieval procedures.

Learning goals: soft skills

Communication skills: oral and written presentation and discussion of solutions.

Self-competences: ability to analyse and solve problems.

Contents

The module topics include data structures, ranking methods, and efficient algorithms that enable end-users to effectively obtain the most relevant search results from structured, heterogeneous, and distributed data sources. Furthermore, we will study the corresponding evaluation techniques as well as novel applications.

Prerequisites

Recommended:
Basic knowledge of data science and machine learning; programming skills. Recommended reading:

- Sarah Boslaugh. Statistics in a Nutshell. A Desktop Quick Reference, O'Reilly Media, Inc., 2nd Edition, (2012).
- Ethem Alpaydin. Machine Learning. The MIT Press (2021).

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three, four or five students, depending on the total number of students taking the course. A total of 50% of the points must be achieved. For 80% of the exercise sheets, 40% of the points must be achieved for each sheet. Each student must present a solution to an exercise in the exercise sessions once.

Literature
Selected chapters from: • Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze, Introduction to Information Retrieval, Cambridge University Press. 2008. • Bhaskar Mitra and Nick Craswell (2018), "An Introduction to Neural Information Retrieval ", Foundations and Trendső in Information Retrieval: Vol. 13: No. 1, pp 1-126. • Ridho Reinanda, Edgar Meij and Maarten de Rijke (2020), "Knowledge Graphs: An Information Retrieval Perspective", Foundations and Trendső in Information Retrieval: Vol. 14: No. 4, pp 289-444. • Jeffrey Xu Yu, Lu Qin, Lijun Chang. Keyword Search in Databases. Synthesis Lectures on Data Management. Morgan & Claypool Publishers. 2009. Further references to relevant material will be provided during the lecture.

MA-INF 4231 Seminar Advanced Topics in Information Retrieval

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Prof. Dr. Elena Demidova

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Enhanced and in-depth knowledge in specialized topics in the area of information retrieval, including understanding of information retrieval process, specialized data representation methods, advanced retrieval methods, evaluation techniques, and domain-specific applications.

Learning goals: soft skills

Acquire the competence to independently search for and study state-of-the-art scientific literature in depth, read critically, identify the most relevant content, and assess research results in the context of the corresponding research area; to discuss research results with a knowledgeable scientific audience; to present prior work by others in writing and in presentations with visual media in a way that adheres to academic standards, that is well-structured and didactically effective, and that motivates the audience to participate; to formulate and accept criticism; to manage one's time with relatively open assignments and long-ranging deadlines.

Contents

Statistical and machine learning-based information retrieval methods, including typical steps of the information retrieval process: data collection, feature extraction, indexing, retrieval, ranking, and evaluation. Specialized data representation and retrieval methods for selected data types and applications in specific domains.

Prerequisites

Recommended:
MA-INF 4230 - Advanced Methods of Information Retrieval.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

Selected chapters from:

- Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze, Introduction to Information Retrieval, Cambridge University Press. 2008.
- Bhaskar Mitra and Nick Craswell (2018), "An Introduction to Neural Information Retrieval ", Foundations and Trendső in Information Retrieval: Vol. 13: No. 1, pp 1-126.

Further relevant literature will be announced at the beginning of the seminar.

MA-INF 4232 Lab Information Retrieval in Practice

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Dr. Rajjat Dadwal

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

This module concentrates on practical experience in information retrieval. Participants acquire basic knowledge and practical experience in designing and implementing information retrieval systems for specific data types and applications.

Learning goals: soft skills

Communication skills: the ability to work in teams.

Self-competences: the ability to analyse problems and find practical solutions. Time management, creativity, presentation of results.

Contents

Practical application of information retrieval methods to solve retrieval problems on real-world data and evaluate proposed solutions.

Prerequisites

Recommended:
MA-INF 4230 - Advanced Methods of Information Retrieval

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

Selected chapters from:

- Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze, Introduction to Information Retrieval, Cambridge University Press. 2008.
- Bhaskar Mitra and Nick Craswell (2018), "An Introduction to Neural Information Retrieval ", Foundations and Trendső in Information Retrieval: Vol. 13: No. 1, pp 1-126.

Further references to relevant material will be provided during the lab.

MA-INF 4235 Reinforcement Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every 2 years

Module coordinator	Lecturer(s)
Prof. Dr.-Ing. Christian Bauckhage	Prof. Dr.-Ing. Christian Bauckhage

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Upon successful completion of this module, students should be able to describe fundamental methods, algorithms, and use cases of reinforcement learning. Students acquire knowledge about underlying mathematical models and corresponding algorithms; based on the knowledge and skills acquired, students should be able to:

- implement algorithms for reinforcement learning problems;
- adopt the fundamental methods they learned about to a wide

range of problems in policy optimization.

Learning goals: soft skills

In the exercises, students can put their knowledge about theoretical concepts, mathematical methods, and algorithmic approaches into practice and realize small projects involving the implementation and evaluation of search- and policy learning algorithms. This requires teamwork; upon successful completion of the module, students should be

able to:

- draft and implement basic reward functions and policy learning algorithms for various practical problem settings;
- prepare and give oral presentations about their work in front of an audience.

Contents

State space models, tree search algorithms, Monte Carlo tree search,

Markov chain models, Markov decision processes, value functions,

reward functions, Bellman equations, policy learning, TD learning Q

learning, deep Q learning

Prerequisites

Required:
Linear algebra, statistics, probability theory, python programming

Remarks

At most 150 participants.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to six students. Each student must present a solution to an exercise in the exercise sessions once. There is one mid-term test where a total of 50% of the credits must be achieved.

Forms of media

- lecture slides / lecture notes are made available online
- notebooks with programming examples are made available online

Literature
R.S. Sutton and A.G. Barto: Reinforcement Learning, 2nd ed., MIT Press, 2018

MA-INF 4237 Lab Natural Language Processing

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Lucie Flek	Prof. Dr. Lucie Flek

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

The Natural Language Processing (NLP) Lab course provides students with a detailed look at the recent advancements in NLP, covering various aspects such as large language models (LLMs), conversational systems, and computational social science. The course emphasizes a practical approach and offers you the opportunity to gain hands-on experience in developing NLP-based systems, allowing you to deepen your understanding of NLP technologies and apply theoretical knowledge to real-world scenarios.

Learning goals: soft skills

Through tutorials and a final project, you will gain practical skills in NLP techniques and have this chance to apply this knowledge to a various interesting project. Students will collaborate in small teams (a group of two students) and implement NLP applications over the course of the term. Each team is advised by one researcher of the CAISA Lab.

Contents

The course emphasizes a practical approach and offers you the opportunity to gain hands-on experience in developing NLP-based systems, allowing you to deepen your understanding of NLP technologies and apply theoretical knowledge to real-world scenarios.

Prerequisites

Required:
MA-INF 4115: Introduction to Natural Language Processing

Recommended:
- Basic programming knowledge in Python and Machine Learning
- Basics of Machine Learning
- Basic knowledge of Python Libraries for ML (NumPy, Scikit-Learn, Pandas)
- Basics of Probability, Linear Algebra and Statistics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 4240 Lab Hybrid Learning and Applications

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Rafet Sifa	Prof. Dr. Rafet Sifa, Dr. Lorenz Sparrenberg

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

- Studying a self-selected research topic
- Reproducing important results
- Elaborating findings based on own research
- Applying theoretical knowledge to real-world problems
- Familiarity with external research work

Learning goals: soft skills

- Own idea generation
- Project completion within self-defined scope and timeline
- Adapting relevant aspects to own projects
- Communication skills through structured presentations

Contents

This lab offers a comprehensive introduction to using hybrid learning, merging machine learning and deep learning techniques to address complex problems. By integrating foundation models with downstream tasks using various machine learning methods, students explore a range of fascinating applications. They are encouraged to select and research their own project topics, gaining hands-on experience in data preprocessing, model building, evaluation, and optimization. This course is designed to equip students with practical skills to design and implement effective hybrid learning solutions.

Schedule:

1. organization meeting
2. presentation of the research idea and its application (1 week later)
3. midterm presentation of results
4. final presentation
5. Student paper

Prerequisites

Required:
- Independent work required

Recommended:
- A basic understanding of machine learning is helpful
- Students should bring their own ideas.

Remarks

Due to the limit of 10 participants, students must send their participation request and a few sentences about their research idea to amllab@bit.uni-bonn.de before the first appointment. Places will be allocated according to the date of receipt and the quality of the idea submitted.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

- Topic dependent and specified or researched by the student
- Lecture notes of the instructor (Advanced methods for text mining by Prof. Dr. Rafet Sifa, SS24)

MA-INF 4241 Lab Cognitive Modelling of Biological Agents

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Dr. Dominik Bach	Prof. Dr. Dr. Dominik Bach

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

- Cognitive modelling workflow in computational neuroscience.
- Analysis of real-life cognitive tasks.
- Reasoning about different problem solutions.
- Understanding constraints of biological systems.

Learning goals: soft skills

Ability to analyze problems theoretically and to find creative and practical solutions; to examine one's solutions and results critically; to classify one's own results into the state-of-the-art of the respective area; to prepare readable documentation of software and research results; to present, defend and discuss design decisions and results in the team/group and to other students clearly and in accordance with academic standards; to collaborate constructively with others in small teams over a longer period of time; to aim at long-range goals under limited resources; to work under pressure.

Contents

The goal of cognitive modelling in computational neuroscience is to reverse-engineer how a real neural system solves a given cognitive task, often using reinforcement learning theory as a starting point. This lab covers the entire cognitive modelling workflow as used in computational neuroscience. Students will address an interesting cognitive problem by (a) developing rational solutions drawing on reinforcement learning, or descriptive solutions drawing on cognitive science and mathematical psychology, (b) derive behavioural signatures of this solution by mathematical analysis or computational simulation, (c) design efficient experiments to disambiguate these solutions from real behaviour, and (d) potentially analyse existing data sets. The course emphasises a practical, application-focused approach. Students collaborate in teams of 2, each supervised by a CAIAN researcher.

Prerequisites

Recommended:
One out of:

- MA-INF 4113 Cognitive Robotics
- MA-INF 4114 Robot Learning
- MA-INF 4215 Humanoid Robotics
- MA-INF 4235 Reinforcement Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 4242 Self-supervised Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
JProf. Dr. Hermann Blum	JProf. Dr. Hermann Blum

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2. or 3.

Learning goals: technical skills

Students can list and explain different fundamental unsupervised, self-supervised machine learning models and can justify a choice of model for a given problem. Students can list and explain different techniques of self-supervision and semi-supervision. For a given data source and task, they can evaluate if a technique is applicable and implement it based on established software frameworks.

Learning goals: soft skills

Communicative skills (discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems).

Contents

The course covers a broad range of methods to learn from unlabelled data with a focus on deep neural networks and hybrid methods.

Models: Nearest Neighbors, Clustering, Autoencoders, (pretrained) Neural Networks, Generative Models

Self-Supervision Techniques: Denoising, Masking, Pre-text Tasks, Distillation, Cycleconsistency, Contrastive Learning, Pseudo-Labelling, System-level Self-Supervision.

Prerequisites

Recommended:
It is recommended that the students have:

- knowledge of foundations of artifical intelligence and deep learning.

It is recommended to first complete the following module:

- MA-INF 4111 Principles of Machine Learning.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 min)

Ungraded coursework (required for admission to the exam)

none

Literature

- scikit-learn User Guide.
- I. Goodfellow, Y. Bengio and A. Courville: Deep Learning. MIT Press, 2016.
- Balestriero et al.: A Cookbook of Self-Supervised Learning, 2023.

MA-INF 4243 Mining Media Data II

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Rafet Sifa	Prof. Dr. Rafet Sifa, Dr. Lorenz Sparrenberg

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2. or 3.

Learning goals: technical skills

By the end of the course, students will be able to:

- Understand and implement advanced data mining techniques for predictive and prescriptive analytics.
- Employ large language models and transformer-based architectures for tasks like text analysis, classification, and summarization.
- Apply knowledge distillation techniques to optimize and deploy machine learning models in resource-constrained environments.
- Analyze media data effectively to derive insights and support decision-making in real-world applications, including digital marketing and fraud detection.
- Address challenges in media analytics, such as ethical considerations, model interpretability, and efficient resource use.

Learning goals: soft skills

Contents

This course explores advanced techniques in data mining, emphasizing predictive and prescriptive methods applied to media data. Students will learn to analyze large and complex datasets using state-of-the-art machine learning methodologies, including behavioral prediction, knowledge distillation, and large language models (LLMs). The curriculum includes foundational concepts, text representation learning, transformer architectures, and practical applications in media analytics, such as recommendation systems and information extraction. The course combines theoretical instruction with hands-on exercises to develop both technical and analytical skills relevant to industry and research.

Prerequisites

Recommended:
Basic knowledge of data science, machine learning, and pattern recognition; programming skills; linear algebra.

Completion of MA-INF 4117 - Mining Media Data I is recommended but not mandatory.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		1	15 T / 30 S	1.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 min) or oral exam.

Ungraded coursework (required for admission to the exam)

(i) The completion of regularly provided exercise sheets. The work can be done in groups of up to five students. A total of 50% of the points must be achieved. (ii) The completion of a programming project. The work is done in groups of up to five students. The results of the programming project must be presented in class.

MA-INF 4244 Lab Deep Learning for the Physical Sciences

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
JProf. Dr. Zorah Lähner	JProf. Dr. Zorah Lähner, Dr. Alexander Rüttgers

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Ability to apply theoretical knowledge in practical applications (mostly from physical sciences), to extract relevant information from research publications, to read research publications from an interdisciplinary point of view, to implement and visualize experimental setups.

Learning goals: soft skills

Ability to analyze problems theoretically and to find creative and practical solutions; to examine one's solutions and results critically; to classify one's own results into the state-of-the-art of the respective area; to prepare readable documentation of software and research results; to present, defend and discuss design decisions and results in the team/group and to other students clearly and in accordance with academic standards; to collaborate constructively with others in small teams over a longer period of time.

Contents

This lab gives students the opportunity to apply their knowledge on methods of deep learning on real applications drawn from the physical sciences, e.g. astro physics or chemistry. Students will learn about a specific problem from a different field and potential approaches to tackle it, while gaining hands-on experience in data (pre-)processing, model building, evaluation, and optimization, and being encouraged to proposes their own solutions.

Prerequisites

Recommended:
Previous experience with deep learning algorithms is vital, e.g. by

- MA-INF 4333 - Geometric Deep Learning
- BA-INF 153 - Einführung in Deep Learning für Visual Computing

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 4245 Lab AI for Scientific Discovery

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Vahid Babaei	Prof. Dr. Vahid Babaei

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

After successful completion of this lab, you will be able to:

• Explain the fundamental mission of AI for Science, why it is relevant and what is the necessary skill set for successfully applying it to real-world problems.
• Evaluate the impact of AI for Science on different scientific areas, and explain why it has made an impact on some areas and not much on others.
• Review different AI for Science technologies, with a focus on their weaknesses/strengths across disciplines, such as material design and discovery.
• Analyze the potential of AI in real-world experimental settings, such as applying Bayesian optimization for design of experiments.
• Understand necessary components for building generative and predictive AI tools for different scientific questions.

Learning goals: soft skills

Contents

AI for Science is the term loosely used for applying modern artificial intelligence methods to accelerate discovery and deepen understanding in the natural and applied sciences. It uses generative models to suggest new ideas, neural networks to replace slow simulations, and Bayesian optimizers to guide experiments as they progress. Together, these tools greatly reduce the time to advance science and make discoveries. Initial breakthroughs highlight the magnitude of this paradigm shift: AlphaFold 3 now predicts full protein–nucleic acid–ligand complexes with near-atomic accuracy, condensing months of wet-lab crystallography into minutes of GPU time. At the laboratory bench, agentic platforms are beginning to knit simulations, robotic synthesizers and language-model planning into a continuous, self-refining loop of experimentation.

In this lab, you will study these methods in depth by implementing some of them and running different analyses on them. You will evaluate your learnings by presenting the method for the class, giving a short demonstration and delivering a final report.

Prerequisites

Recommended:
The lab requires knowledge in mathematics (e.g., linear algebra, calculus, optimization) and programming (e.g. Python, especially PyTorch). Knowledge related to modern AI and deep learning, especially in the context of visual computing or robotics will help with a smooth experience.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 4304 Lab Cognitive Robotics

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Prof. Dr. Sven Behnke, Dr. Raphael Memmesheimer

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Participants acquire practical experience and in-depth knowledge in the design and implementation of perception and control algorithms for complex robotic systems. In a small group, they analyze a problem, realize a state-of-the-art solution, and evaluate its performance.

Learning goals: soft skills

Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations)

Contents

Robot middleware (ROS), simultaneous localization and mapping (SLAM), 3D representations of objects and environments, object detection and recognition, person detection and tracking, action recognition, action planning and control, mobile manipulation, human-robot interaction.

Prerequisites

Recommended:
At least 1 of the following:

- MA-INF 4113 – Cognitive Robotics
- MA-INF 4114 – Robot Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.
- Selected research papers.

MA-INF 4306 Lab Development and Application of Data Mining and Learning Systems

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Stefan Wrobel	Prof. Dr. Stefan Wrobel

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Students will acquire in-depth knowledge in the design, implementation, and experimental evaluation of machine learning and data mining systems. They learn how to work with existing state-of-the-art machine learning and data mining algorithms and apply them to real-world and synthetic datasets, usually extending them for the requirements of their particular learning/mining task.

Learning goals: soft skills

Ability to analyze problems theoretically and to find creative and practical solutions; to examine one's solutions and results critically; to classify one's own results into the state-of-the-art of the respective area; to prepare readable documentation of software and research results; to present, defend and discuss design decisions and results in the team/group and to other students clearly and in accordance with academic standards; to collaborate constructively with others in small teams over a longer period of time; to aim at long-range goals under limited resources; to work under pressure.

Contents

Design, adaptation, implementation, and systematic experimental evaluation of specialised data mining and learning algorithms, from classical to state-of-the-art, from all areas of machine learning and data mining. Search and optimization algorithms. Common open source libraries for machine learning and data mining.

Prerequisites

Recommended:
Basic notions and algorithms from machine learning and data mining are required. It is recommended to take at least one of the following courses first:

- MA-INF 4111 – Principles of Machine Learning
- MA-INF 4112 – Algorithms for Data Science

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Forms of media

Computer Software, Documentation, Research Papers.

Literature

The relevant literature will be announced towards the end of the previous semester.

MA-INF 4308 Lab Vision Systems

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Prof. Dr. Sven Behnke

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Students will acquire knowledge of the design and implementation of parallel algorithms on GPUs. They will apply these techniques to accelerate standard machine learning algorithms for data-intensive computer vision tasks.

Learning goals: soft skills

Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations)

Contents

Basic matrix and vector computations with GPUs (CUDA). Classification algorithms, such as multi-layer perceptrons, support-vector machines, k-nearest neighbors, linear-discriminant analysis. Image preprocessing and data handling. Quantitative performance evaluation of learning algorithms for segmentation and categorization.

Prerequisites

Recommended:
At least 1 of the following:

MA-INF 2201 - Computer Vision

MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning

MA-INF 4204 – Technical Neural Nets

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

- R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010.
- C. M. Bishop: Pattern Recognition and Machine Learning, Springer 2006.
- NVidia CUDA Programming Guide, Version 4.0, 2011.

MA-INF 4322 Lab Machine Learning on Encrypted Data

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Michael Nüsken	Dr. Michael Nüsken

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of Cryptography, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify one's own results into the state-of-the-art of the resp. area

Contents

With the rise of more and more mechanisms and installations of data science methodology to automatically analyze large amounts of possibly privacy infringing data we have to carefully understand how to protect our data. Also more and more fake data shows up and we have to find ways to distinguish faked from trustable data. At the same time we want to allow insightful research and life-easing analyzes to be possible. This seeming contradiction has lead to various efforts for unifying both: protecting data and allowing analyzes, at least to some extent and possibly under some restrictions.

The target of the lab is to understand how computations on encrypted data may work in one particular application that we are choosing together. Ideally, we can come up with a novel solution for performing an unconsidered algorithm. We study the tasks and tools, select algorithms, find a protocol, prototype an implemention, perform a security analysis, present an evaluation.

Prerequisites

Recommended:
Good knowledge in cryptography is vital, e.g. by one or more modules out of:

- MA-INF 1103 - Cryptography,
- MA-INF 1223 - Privacy Enhancing Technologies, and
- MA-INF 1209 - Seminar Advanced Topics in Cryptography.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 4324 Seminar Advanced Topics in Data Science

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Prof. Dr. Elena Demidova

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Enhanced and in-depth knowledge in specialized topics in the data science, including understanding of the data science process, statistical and machine learning-based data analytics methods, specialized data representation techniques, evaluation methods, and domain-specific applications.

Learning goals: soft skills

Acquire the competence to independently search for and study state-of-the-art scientific literature in depth, read critically, identify the most relevant content, and assess research results in the context of the corresponding research area; to discuss research results with a knowledgeable scientific audience; to present prior work by others in writing and in presentations with visual media in a way that adheres to academic standards, that is well-structured and didactically effective, and that motivates the audience to participate; to formulate and accept criticism; to manage one's time with relatively open assignments and long-ranging deadlines.

Contents

Statistical and machine learning-based methods of data analytics, including typical steps of the data science process: data generation, integration, cleaning, exploration, modelling and evaluation. Specialized data representation and analytics methods for selected data types and applications in specific domains.

Prerequisites

Recommended:
MA-INF 4328 - Spatio-Temporal Data Analytics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

Relevant literature will be announced at the beginning of the seminar

MA-INF 4325 Lab Data Science in Practice

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Dr. Rajjat Dadwal

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

This module concentrates on practical experience in data analytics. Participants acquire basic knowledge and practical experience in the design and implementation of data science workflows for specific data types and applications.

Learning goals: soft skills

• Communication skills: the ability to work in teams.
• Self-competences: the ability to analyse problems and find practical solutions. Time management, creativity, presentation of results.

Contents

Practical application of statistical and machine learning-based methods to solve data analytics problems on real-world datasets and evaluate proposed solutions.

Prerequisites

Recommended:
MA-INF 4328 - Spatio-Temporal Data Analytics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 4326 Explainable AI and Applications

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Rafet Sifa	Prof. Dr. Rafet Sifa, Dr. Lorenz Sparrenberg

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

• Know the dual-model functioning of the human mind, and two main AI paradigms
• Develop white-box neural AI systems
• Understand the problems and limitations of Blackbox Deep-Learning systems, and Know the state-of-the-art Methods for Interpreting Deep-Learning systems (XAI)

Learning goals: soft skills

• Know System 1 and 2 of the mind, prons and cons of symbolic AI and connectionist AI
• Develop neural-geometric systems that have both good features of symbolic AI and connectionist AI
• Know the limitation of famous Deep-Learning systems, such as GPT3, self-driving. Know standard methods to explore the explainability of Deep-Learning systems

Contents

1. Introduction: fates of large Deep-Learning systems, e.g. Watson, GPT, self-driving cars
2. Dual-system theories (System 1 and 2), nine laws of cognition, criteria of semantic models
3. The target and the state-of-art methods of XAI
4. Neural-symbolic AI
5. Cognitive maps, Collages, Mental Spatial Representation, Events
6. Qualitative Spatial Representation and Reasoning
7. Rotating Sphere Embedding: A New Wheel for Neural-Symbolic Unification
8. Neural Syllogistic Reasoning
9. Recognizing Variable Environments
10. Humor Understanding
11. Rotating Spheres as building-block semantic components for Language, Vision, and Action

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to four students. A total of 50% of the points must be achieved.

Literature

- Kahneman, D. (2011). Thinking fast and slow. Farrar, Straus and Giroux.
- Gaedenfors, P. (2017). The Geometry of Meaning. MIT Press.
- Attardo, Hempelmann, Maio (2003). Script Oppositions and Logical Mechanisms: Modeling Incongruities and their Resolutions, HUMOR 15(1)3–46
- Tversky, B. (2019). Mind in Motion. Basic Books, New York.
- Dong, et al. (2020). Learning Syllogism with Euler Neural-Networks. arXiv:2007.07320
- Dong, T. (2021). A Geometric Approach to the Unification of Symbolic Structure and Neural Networks. Springer.
- Knauff and Spohn (2021). Handbook of Rationality. MIT Press, Cambridge, MA, USA.
- Samek et.al. (2019), Explainable AI: Interpreting, Explaining and Visualizing Deep Learning. Springer.
- Greg Dean (2019). Step by Step to Stand-Up Comedy (Revised Edition). ISBN: 978-0-9897351-7-9

MA-INF 4327 Lab Biomedical Data Science

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Holger Fröhlich	Prof. Dr. Holger Fröhlich

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of biomedical data science, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Varying selected topics close to current research in the area of biomedical data science.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 4328 Spatio-Temporal Data Analytics

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Dr. Rajjat Dadwal, Prof. Dr. Elena Demidova

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

This module introduces the students to the advanced methods, data structures, and data analytics algorithms for spatio-temporal data. At the end of the module, the students will be capable of choosing appropriate data representations, data structures and algorithms for specific applications and correctly applying relevant statistical and machine learning-based data analytics procedures.

Learning goals: soft skills

Communication skills: oral and written presentation and discussion of solutions. Self-competences: the ability to analyze and solve problems.

Contents

The module topics include data structures, data representation and analysis methods, and algorithms that enable analyzing spatio-temporal data and building predictive models effectively and effectively. Furthermore, we will study the corresponding evaluation techniques and novel applications.

Prerequisites

Recommended:
Basic knowledge of data science and machine learning; programming skills. Recommended reading:

- Sarah Boslaugh. Statistics in a Nutshell. A Desktop Quick Reference, O'Reilly Media, Inc., 2nd Edition, (2012).
- Ethem Alpaydin. Machine Learning. The MIT Press (2021).

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (90 minutes)

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three, four or five students, depending on the total number of students taking the course. A total of 50% of the points must be achieved. For 80% of the exercise sheets, 40% of the points must be achieved for each sheet. Each student must present a solution to an exercise in the exercise sessions once.

MA-INF 4329 Seminar Biological Intelligence

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Dr. Dominik Bach	Prof. Dr. Dr. Dominik Bach

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Communication skills: oral and written presentation of scientific content. Self-competences: the ability to analyze problems, time management, creativity

Contents

Humans and other animals outperform artificial agents in various tasks and domains. This includes but is not limited to: learning and planning in unstructured domains; learning from sparse data, observation, and play; generalisation and transfer; causal reasoning; intuitive physics and psychology; language use; any time planning; continuous planning; spatial navigation; dynamic memory and active forgetting. This seminar provides background on some of the underlying biological skills, and computational theories that seek to explain them. We will discuss implications for designing and/or constraining artificial agents.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

MA-INF 4330 Lab Explainable AI and Applications

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Rafet Sifa	Prof. Dr. Rafet Sifa, Dr. Lorenz Sparrenberg

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Independent Research: Students will select a research paper focused on representation learning, replicate its findings, and use techniques from the "Explainable AI and Applications" course to deepen their understanding of the concepts and potentially enhance the results. This process also teaches students to manage and complete a project within a defined scope and timeline.

Practical Application: The lab emphasizes the application of theoretical knowledge to real-world problems, encouraging deeper understanding and innovation. Students will become familiar with external research, apply, and adapt the relevant research code to their projects.

Communication Skills: Students will develop their ability to present complex ideas clearly and effectively through structured presentations and written reports. The course also covers scientific writing, literature review, proper citation, and best practices in academic research.

Learning goals: soft skills

Contents

The lab focuses on enhancing students' understanding of Explainable AI and its applications through hands-on exercises and active participation in presentation meetings. Students explore recent research on the topic of latent representations (e. g. text or image embeddings, sentiment analysis) aiming to reproduce existing research. Then, they apply techniques learned in the lecture "Explainable AI and Applications" (e. g. neurosymbolic representation learning) to get a better understanding of these representations. The results will be presented and discussed in a presentation as well as in a student paper (5-8 pages, given template). There is an opportunity to publish excellent ideas that go beyond the state of the art and brilliant experimental results.

Schedule:

1. organization (April)
2. presentation of the research idea and its application (1 week later)
3. midterm presentation of results (June)
4. final presentation (September)
5. Student paper (September)

Prerequisites

Recommended:
Basic knowledge of machine learning, and pattern recognition, Python programming

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Intermediate presentation (25%), final presentation (25%), student paper (50%)

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature
• Topic dependent to be researched by the student. • Lecture notes of the instructors (Explainable AI and Applications by Dr. Tiansi Dong, WS23/24)

MA-INF 4331 Lab Perception and Learning for Robotics

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
JProf. Dr. Hermann Blum	JProf. Dr. Hermann Blum

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Participants learn how to practically approach a robot perception problem. They learn how to critically read a research paper, how to conduct experiments in the context of robot perception, and how to report and present scientific findings.

Learning goals: soft skills

Ability to analyze problems theoretically and to find creative and practical solutions; to examine one's solutions and results critically; to classify one's own results into the state-of-the-art of the respective area; to prepare readable documentation of software and research results; to present, defend and discuss design decisions and results in the team/group and to other students clearly and in accordance with academic standards; to collaborate constructively with others in small teams over a longer period of time; to aim at long-range goals under limited resources; to work under pressure.

Contents

In small groups, students apply their knowledge of robot perception, deep learning, and computer vision to a novel problem. They analyze the problem, read into relevant literature, propose and implement a solution, and empirically test it. They then refine their approach based on an analysis of the experimental outcomes. The course projects are related to one of multiple of the following topics: Robot localization, planning, navigation, manipulation; Practical aspects of Deep Learning; Sensor models, calibration, capture, processing. Software deployment.

Prerequisites

Recommended:
Students are expected to have general programming skills and prior experience with python. Students will need to operate linux terminal systems such as the university's GPU cluster.

It is recommended to first take two of the following modules:

- MA-INF 2201 Computer Vision
- MA-INF 2213 Advanced Computer Vision
- MA-INF 4113 Cognitive Robotics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005
- I. Goodfellow, Y. Bengio and A. Courville: Deep Learning. MIT Press, 2016
- Per-project assigned literature

MA-INF 4332 Seminar Large Language Models

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Lucie Flek	Prof. Dr. Lucie Flek

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

Learning goals: soft skills

Contents

Large Language Models (LLMs), such as GPT-4, Gemini, and their successors, have had an enormous impact on various domains, including natural language processing, machine learning, and artificial intelligence. These models have redefined what's possible in applications such as text generation, translation, summarization, sentiment analysis, and more. The aim of this seminar is to explore cutting-edge research, insights, and trends in the field of LLMs, such as:

- hallucination reduction and factual grounding
- explainability, reasoning, faithfulness
- safety, toxicity, fairness and bias
- social and moral alignment of LLMs
- style control and personalization
- sustainability, compression, model size reduction, knowledge distillation
- multilinguality and multimodality
- LLMs as planning agents
- and more

Prerequisites

none

Remarks

At most 35 participants

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	35	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

- Bommasani, Rishi: On the opportunities and risks of foundation models
- Devlin, Jacob, et al.: Bert: Pre-training of deep bidirectional transformers for language understanding
- Brown, Tom, et al.: Language models are few-shot learners
- WX Zhao, et al.: A survey of large language models
- Yang, Jingfeng, et al.: Harnessing the power of LLMs in practice: A survey on ChatGPT and beyond

MA-INF 4333 Geometric Deep Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Jun. Prof. Dr. Zorah Lähner	Prof. Dr. Zorah Lähner

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

• Understanding advanced topics in the design of neural networks using geometric data
• Mathematical modelling of invariances and non-Euclidean domains in deep learning and guarantees that can be derived from these
• Gain an overview of practical applications in which this theory can be applied

Learning goals: soft skills

• Problem solving skills: ability to identify and utilize analogies between new problems and previously seen ones
• Analytical and abstract thinking: develop a general intuition of computational problems, being able to adopt different perspectives of particular concepts

Contents

This lecture will cover advanced topics in deep learning focusing on theory related to geometric data and the incorporation of invariances in network architectures. Topics include, among others, permutation invariance, differential geometry, the curse of dimensionality, neural fields and physics-informed neural networks. Students will learn how to process a variety of geometric data structures and implement deep learning algorithms on these related to applications in visual computing, physics and graph processing.

Prerequisites

Recommended:
Students are recommended to have basic knowledge about deep learning and computer vision, for example gained in:

• MA-INF 4111 Principles of Machine Learning,
• MA-INF 2201 Computer Vision, or
• MA-INF 2222 Visual Data Analysis,

and proficiency in python.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam (120 minutes)

Ungraded coursework (required for admission to the exam)

none

MA-INF 4334 Computational neuroscience: cognition and behaviour

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Dr. Dominik Bach	Prof. Dr. Dr. Dominik Bach

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2-3.

Learning goals: technical skills

• Conceptual knowledge and mathematical understanding of common behavioural and cognitive models from computational neuroscience
• Knowledge of common experimental methods used to develop and disambiguate such models
• Basic knowledge of fundamentals in neuroscience, cognitive/perceptual psychology and microeconomics
• In the exercises, students will learn to implement models and how to use them as benchmarks for bottom-up computational neuroscience models, and for automatic signature-testing of AI algorithms

Learning goals: soft skills

• Teamwork (exercises)
• Oral presentation in front of audience (exercises)

Contents

The two dominant paradigms in computational neuroscience are bottom-up (starting from the spontaneous behaviour of constituent elements of the nervous system) and top-down (starting from known functions of biological agents). This lecture introduces important topdown models of behaviour and cognition from three perspectives: computational (problem definition and optimal solutions), algorithmic (rational/engineering/descriptive solutions) and implementation (neural hardware). The lecture covers the following domains:

• decision-making with noisy information (value-based, time-integrated, multi-channel, sequential)
• information representation under resource constraints
• memory formation and storage in biological neural networks
• movement planning
• spatial navigation

Prerequisites

Recommended:
Recommended one out of:

• MA-INF 4113 Cognitive Robotics
• MA-INF 4114 Robot Learning
• MA-INF 4215 Humanoid Robotics
• MA-INF 4235 Reinforcement Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to four students. A total of 50% of the points must be achieved. Each group must present a solution to an exercise in the exercise sessions once.

MA-INF 4335 Lab AI Alignment

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Lucie Flek	Prof. Dr. Lucie Flek

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2. or 3.

Learning goals: technical skills

Through tutorials and a final project, you will gain hands-on experience in AI alignment techniques and have this chance to apply this knowledge to various interesting projects. Students will collaborate in small teams (a group of 3-4 students) and implement small research projects over the course of the term, advised by a researcher from the CAISA lab. Students will learn to reproduce important results from the field, study the scientific literature, generate and implement their own research ideas, and present their results as a presentation and as a paper.

Learning goals: soft skills

Contents

As AI systems such as Large Language Models become increasingly capable and start to be used in high-stakes scenarios, ensuring that they act safely is gaining importance. The research field of AI alignment studies methods to align the behavior and values of AI systems with the user and broader society in a robust, scalable, and interpretable way. The aim of this course is to explore cutting-edge research, insights, and trends in the field of AI alignment.

Schedule:

- Week 0: Organization meeting
- Week 1-5: Lectures and programming exercises
- Week 6: Presentation of project ideas
- Week 12: midterm presentation of results
- Final presentation
- Student paper

Concrete research topics are 1) value alignment, 2) emergent misalignment, 3) scalable oversight, and 4) mechanistic interpretability, among others.

Prerequisites

Recommended:
One of the following courses is recommended:

- MA-INF 4115 - Introduction to Natural Language Processing,
- MA-INF 4235 - Reinforcement Learning,
- MA-INF 4204 - Technical Neural Nets.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project work; attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature
• Hendrycks, Dan: Introduction to AI Safety, Ethics, and Society. • Ouyang, Long et al.: Training language models to follow instructions with human feedback. • Bowman, Sam et al.: Measuring Progress on Scalable Oversight for Large Language Models. • Li, Nathaniel et al.: Measuring and Reducing Malicious Use With Unlearning. • Bricken, Trenton et al.: Towards monosemanticity: Decomposing language models with dictionary learning.

MA-INF 4336 Seminar Selected Topics in Natural Language Processing

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Lucie Flek	Prof. Dr. Lucie Flek

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	2. or 3.

Learning goals: technical skills

In this course, students will learn to engage with technical research papers and other material that study the state-of-the-art approaches to Natural Language Processing. They will learn to synthesize, critically assess, and build upon the material by conducting required readings, weekly discussions. In particular:

- to read and examine the scientific literature critically,
- to identify and present examples of relevant real-world application fields of the scientific publication,
- to give a good scientific presentation to peers that is precise, informative, and engaging,
- to summarize and write a concise technical report including a critical discussion of the research paper (with additional literature research).

Learning goals: soft skills

Contents

In this weekly seminar, students will learn about selected research topics in natural language processing and its applications. In addition, it is an introduction to reading scientific papers, learning how to give a good presentation, and how to write a technical report.

To better explore how state-of-the-art research presentations can be constructed, as a part of the seminar students will also have a chance to attend and discuss presentations of researchers on more senior level presenting their papers (e.g. guest speakers).

Prerequisites

Recommended:
One of the following courses is recommended (but not obligatory):

- MA-INF 4115 - Introduction to Natural Language Processing,
- MA-INF 4235 - Reinforcement Learning,
- MA-INF 4204 - Technical Neural Nets.

Remarks

At most 20 participants

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	20	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report.

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6).

Literature

- Jurafsky & Martin, Speech and Language Processing: https://web.stanford.edu/~jurafsky/slp3/ .

5 Interdisciplinary Modules

MA-INF 5301 Interdisciplinary Project (crop production)

Workload	Credit points	Duration	Frequency
300 h	10 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Jürgen Gall	The lecturers will be announced in time.

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	3.

Learning goals: technical skills

Ability to independently design, analyze, implement, and experimentally evaluate problem solutions using artificial intelligence methods for problems in the field of focus (crop production); gain experience with software development techniques, tools and standards and scientifically clean documentation of the students own work (including a written report and software).

Learning goals: soft skills

- capacity for collaborative team work in an interdisciplinary setting
- Knowledge of scientific approach to problem solving;
- capacity for team work in an interdisciplinary context
- ability to scientifically present solutions and methods to an interdisciplinary audience;
- critical discussion of applied methods and techniques in accordance with academic standards;
- ability to analyze problems theoretically and to find efficient as well as practical solutions;
- to examine one's solutions and results critically;
- to classify new problems into the state-of-the-art of the respective area.

Contents

Students demonstrate that they have acquired the ability to apply AI methods in an interdisciplinary context and have contributed to solving a real-world problem in the adjacent field (biology/agriculture).

Prerequisites

Recommended:
It is recommended that the students have:

- knowledge of foundations of artifical intelligence and deep learning
- experience in using and implementing machine learning algorithms
- fundamental algorithms, algorithmic paradigms, data structures

It is recommended to first complete the following modules:

- MA-INF 4111 Principles of Machine Learning
- MA-INF 5011 Principles of Deep Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 240 S	10

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project/lab work

MA-INF 5302 Interdisciplinary Project (ethics)

Workload	Credit points	Duration	Frequency
300 h	10 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Lucy Flek	The lecturers will be announced in time.

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	3.

Learning goals: technical skills

Ability to independently design, analyze, implement, and experimentally evaluate problem solutions using artificial intelligence methods for problems in the field of focus (ethics); gain experience with software development techniques, tools and standards and scientifically clean documentation of the students own work (including a written report and software).

Learning goals: soft skills

- capacity for collaborative team work in an interdisciplinary setting
- Knowledge of scientific approach to problem solving;
- capacity for team work in an interdisciplinary context
- ability to scientifically present solutions and methods to an interdisciplinary audience;
- critical discussion of applied methods and techniques in accordance with academic standards;
- ability to analyze problems theoretically and to find efficient as well as practical solutions;
- to examine one's solutions and results critically;
- to classify new problems into the state-of-the-art of the respective area.

Contents

Students demonstrate that they have acquired the ability to apply AI methods in an interdisciplinary context and have contributed to solving a real-world problem in the adjacent field (ethics).

Prerequisites

Recommended:
It is recommended that the students have:

- knowledge of foundations of artifical intelligence and deep learning
- experience in using and implementing machine learning algorithms
- fundamental algorithms, algorithmic paradigms, data structures

It is recommended to first complete the following modules:

- MA-INF 4111 Principles of Machine Learning
- MA-INF 5011 Principles of Deep Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 240 S	10

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project/lab work

MA-INF 5303 Interdisciplinary Project (geodesy)

Workload	Credit points	Duration	Frequency
300 h	10 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Petra Mutzel	The lecturers will be announced in time.

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	3.

Learning goals: technical skills

Ability to independently design, analyze, implement, and experimentally evaluate problem solutions using artificial intelligence methods for problems in the field of focus (geodesy); gain experience with software development techniques, tools and standards and scientifically clean documentation of the students own work (including a written report and software).

Learning goals: soft skills

- capacity for collaborative team work in an interdisciplinary setting
- Knowledge of scientific approach to problem solving;
- capacity for team work in an interdisciplinary context
- ability to scientifically present solutions and methods to an interdisciplinary audience;
- critical discussion of applied methods and techniques in accordance with academic standards;
- ability to analyze problems theoretically and to find efficient as well as practical solutions;
- to examine one's solutions and results critically;
- to classify new problems into the state-of-the-art of the respective area.

Contents

Students demonstrate that they have acquired the ability to apply AI methods in an interdisciplinary context and have contributed to solving a real-world problem in the adjacent field (geodesy).

Prerequisites

Recommended:
It is recommended that the students have:

- knowledge of foundations of artifical intelligence and deep learning
- experience in using and implementing machine learning algorithms
- fundamental algorithms, algorithmic paradigms, data structures

It is recommended to first complete the following modules:

- MA-INF 4111 Principles of Machine Learning
- MA-INF 5011 Principles of Deep Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 240 S	10

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project/lab work

MA-INF 5304 Interdisciplinary Project (life and medical sciences)

Workload	Credit points	Duration	Frequency
300 h	10 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Schultz	The lecturers will be announced in time.

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	3.

Learning goals: technical skills

Ability to independently design, analyze, implement, and experimentally evaluate problem solutions using artificial intelligence methods for problems in the field of focus (life and medical sciences); gain experience with software development techniques, tools and standards and scientifically clean documentation of the students own work (including a written report and software).

Learning goals: soft skills

- capacity for collaborative team work in an interdisciplinary setting
- Knowledge of scientific approach to problem solving;
- capacity for team work in an interdisciplinary context
- ability to scientifically present solutions and methods to an interdisciplinary audience;
- critical discussion of applied methods and techniques in accordance with academic standards;
- ability to analyze problems theoretically and to find efficient as well as practical solutions;
- to examine one's solutions and results critically;
- to classify new problems into the state-of-the-art of the respective area.

Contents

Students demonstrate that they have acquired the ability to apply AI methods in an interdisciplinary context and have contributed to solving a real-world problem in the adjacent field (life and medical sciences).

Prerequisites

Recommended:

It is recommended that the students have:

- knowledge of foundations of artifical intelligence and deep learning
- experience in using and implementing machine learning algorithms
- fundamental algorithms, algorithmic paradigms, data structures

It is recommended to first complete the following modules:

- MA-INF 4111 Principles of Machine Learning
- MA-INF 5011 Principles of Deep Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 240 S	10

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project/lab work

MA-INF 5305 Interdisciplinary Project (physics)

Workload	Credit points	Duration	Frequency
300 h	10 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Zorah Lähner	The lecturers will be announced in time.

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	3.

Learning goals: technical skills

Ability to independently design, analyze, implement, and experimentally evaluate problem solutions using artificial intelligence methods for problems in the field of focus (physics); gain experience with software development techniques, tools and standards and scientifically clean documentation of the students own work (including a written report and software).

Learning goals: soft skills

- capacity for collaborative team work in an interdisciplinary setting
- Knowledge of scientific approach to problem solving;
- capacity for team work in an interdisciplinary context
- ability to scientifically present solutions and methods to an interdisciplinary audience;
- critical discussion of applied methods and techniques in accordance with academic standards;
- ability to analyze problems theoretically and to find efficient as well as practical solutions;
- to examine one's solutions and results critically;
- to classify new problems into the state-of-the-art of the respective area.

Contents

Students demonstrate that they have acquired the ability to apply AI methods in an interdisciplinary context and have contributed to solving a real-world problem in the adjacent field (physics).

Prerequisites

Recommended:
It is recommended that the students have:

- knowledge of foundations of artifical intelligence and deep learning
- experience in using and implementing machine learning algorithms
- fundamental algorithms, algorithmic paradigms, data structures

It is recommended to first complete the following modules:

- MA-INF 4111 Principles of Machine Learning
- MA-INF 5011 Principles of Deep Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 240 S	10

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project/lab work

Literature

The relevant literature will be announced in time.

MA-INF 5306 Interdisciplinary Project (neuroscience)

Workload	Credit points	Duration	Frequency
300 h	10 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Dominik Bach	The lecturers will be announced in time.

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	3.

Learning goals: technical skills

Ability to independently design, analyze, implement, and experimentally evaluate problem solutions using artificial intelligence methods for problems in the field of focus (neuroscience); gain experience with software development techniques, tools and standards and scientifically clean documentation of the students own work (including a written report and software).

Learning goals: soft skills

- capacity for collaborative team work in an interdisciplinary setting
- Knowledge of scientific approach to problem solving;
- capacity for team work in an interdisciplinary context
- ability to scientifically present solutions and methods to an interdisciplinary audience;
- critical discussion of applied methods and techniques in accordance with academic standards;
- ability to analyze problems theoretically and to find efficient as well as practical solutions;
- to examine one's solutions and results critically;
- to classify new problems into the state-of-the-art of the respective area.

Contents

Students demonstrate that they have acquired the ability to apply AI methods in an interdisciplinary context and have contributed to solving a real-world problem in the adjacent field (neuroscience).

Prerequisites

Recommended:

It is recommended that the students have:

- knowledge of foundations of artifical intelligence and deep learning
- experience in using and implementing machine learning algorithms
- fundamental algorithms, algorithmic paradigms, data structures

It is recommended to first complete the following modules:

- MA-INF 4111 Principles of Machine Learning
- MA-INF 5011 Principles of Deep Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 240 S	10

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Project/lab work

6 Ethical, legal, and social aspects

MA-INF 5413 Seminar Ethical principles of AI

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr Aimee van Wynsberghe	Prof. Dr. Aimee van Wynsberghe, Prof. Dr. Bert Heinrichs, Other IWE staff or scholars, announced at the start of the semester

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-2.

Learning goals: technical skills

Students will learn to

• identify and analyze ethical problems and considerations of AI systems and in their training
• be aware of the range of views on the relationship between technology development and society, from technology being neutral to technology being value laden to the technology as a socio-technical system,
• have awareness for the role of these concepts and approaches to thinking in the current debate surrounding AI,
• are capable of formulating a position on the ethical issues at stake in current applications of AI.

Learning goals: soft skills

Students will learn about the design and motivation of ethical, socially responsible, and sustainable AI systems. They will learn to engage with multidisciplinary perspectives.

Contents

The course focusses on ehticial consdiderations in the context of AI development and deployment of AI solutions. The course compare and contrast different viewpoints and also have room for discussions among participants and the lecturers.

Prerequisites

Recommended:
Knowledge of key principles behind AI

Remarks

This course is offered by our partners at the Institute for Science and Ethics.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	20	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6). Regular course participation

Literature

Example Reading materials used:

Coeckelbergh, M. (2019). Artificial intelligence: some ethical issues and regulatory challenges. Technology and regulation, 2019, 31-34.

Green, B. (2019, December). ”Good” isn’t good enough. In Proceedings of the AI for Social Good workshop at NeurIPS (Vol. 17).

Van Wynsberghe, A. (2021). Sustainable AI: AI for sustainability and the sustainability of AI. AI and Ethics, 1(3), 213-218.

van Wynsberghe, A., & Robbins, S. (2019). Critiquing the reasons for making artificial moral agents. Science and engineering ethics, 25(3), 719-735.

MA-INF 5421 Seminar Legal and Social Aspects of AI

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Christian Stracke	Dr. Christian Stracke

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-2.

Learning goals: technical skills

The seminar aims to introduce students to some of the social and legal aspects surrounding the development and use of artificial intelligence. Students will develop skills in assessing AI systems, identifying legal questions and social impacts, reasoning through legal and social issues, and communicating their reasoning.

Learning goals: soft skills

Students will learn about the design of AI systems that adhere to legal guidelines for the use of artificial intelligence, while navigating relevant complex ethical and social questions. They will practice engaging with multidisciplinary perspectives from different viewpoints. At the end of the course, students will be able to understand fundamental legal compromises regarding the use and development of AI.

Contents

We study artificial intelligence and the social and legal aspects involved with the research, design, deployment, and interaction with AI systems. Among other things, the course will focus on

- concrete EU regulations that have been drafted for the fair use of AI,
- regulations concerning the ownership of content produced by AI,
- use of private data for the purposes of training AI,
- laws governing the development, deployment and engineering of AI systems in applications.

A typical lecture will involve both current approaches to legal frameworks in context and discussions of the compromises involved.

Prerequisites

Required:
No previous knowledge is required.

Recommended:
Previous classes in machine learning, robotics, data mining, or related subjects.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	45	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6). Regular participation

MA-INF 5422 Seminar Social Ethics of AI

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Matthias Braun	Prof. Dr. Matthias Braun

Programme	Mode	Semester
M. Sc. Artificial Intelligence	Optional	1-2.

Learning goals: technical skills

Students will learn to identify and analyze societal considerations in the development of AI technology in a multidisciplinary setting. The focus is on the ethics of AI in the context of societal problems and implications.

Learning goals: soft skills

Students will learn to

- analyze and appropriately categorize societal considerations in the development and use of AI technologies,
- compare and contrast viewpoints and different focusses in various disciplines in this context.

Contents

The course concentrates on ethical considerations surrounding AI in the context of societal implications, including fairness, biases, and social welfare.

Prerequisites

Recommended:
Knowledge of fundamental principles in AI.

Remarks

This course is offered by the Department of Systematic Theology/chair of (Social-)Ethics at the University of Bonn.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	15	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Attendance in course sessions in accordance with the exam regulations of 2023, § 12(6). Regular participation