# Modulhandbuch

für den Studiengang Master Artificial Intelligence

Fakultät für Informatik und Wirtschaftsinformatik

gültig für das Wintersemester 2024 und Sommersemester 2025

# Inhaltsverzeichnis

# Semester 1

# Applied Computer Vision: From Research to Real-World Implementation (5171524)

*Applied Computer Vision: From Research to Real-World Implementation*

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|---|---|---|---|
| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>1 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Dominik Seuß | | |
| **Dozierende** | Prof. Dr. Dominik Seuß | | |
| **Verwendbarkeit** | | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Subject Knowledge:<br>• Acquire fundamental and advanced knowledge in Computer Vision, including both traditional approaches and modern Deep Learning methods<br>• Understand the strengths and limitations of traditional and modern techniques in different application contexts<br>• Be able to analyze, compare, and evaluate current Computer Vision methods<br>Practical Implementation Skills:<br>• Develop/Adapt and implement solutions to real-world industry problems<br>• Apply theoretical concepts to practical tasks through programming exercises and projects<br>• Adapt existing Computer Vision algorithms and apply them to concrete scenarios<br>Problem-Solving Abilities:<br>• Analyze complex challenges in Computer Vision and develop appropriate solutions<br>• Transfer in-depth theoretical concepts to practical applications and develop pragmatic solutions<br>Linking Theory and Practice:<br>• Understand the connection between research approaches and their real-world applicability<br>• Be able to integrate and utilize both theoretical models and practical implementations of algorithms | | |
| **Modulinhalte** | This seminar provides students with a comprehensive introduction to the field of Computer Vision, encompassing both traditional approaches and modern Deep Learning-based methods. Emphasis is placed on understanding the unique strengths and limitations of each approach, highlighting scenarios where traditional techniques remain highly effective and relevant despite the advancements in Deep Learning.<br>The course is designed to be highly practical and industry-oriented, focusing on current challenges and real-world applications in Computer Vision. Students will explore state-of-the-art methods used to tackle practical problems, with a balance of theoretical insights and hands-on implementation.<br>Throughout the seminar, theoretical foundations are complemented by practical exercises and coding assignments, allowing students to directly apply their knowledge. Participants will not only learn to understand cutting-edge algorithms but also implement and adapt them to solve specific problems. This hands-on approach strengthens both technical expertise and problem-solving skills, preparing students for real-world scenarios in academic or industrial settings. | | |
| **Literatur** | Literature will be provided separately for each topic | | |

# Artificial Intelligence and Machine Learning (5171020)

*Artificial Intelligence and Machine Learning*

| **Art des Moduls** | **Sprache** | **SWS** | **ECTS** |
|---|---|---|---|
| Pflichtmodul | Englisch | 4 | 5 |
| **Häufigkeit** | **Dauer** | **Studiensemester** | **Lehr- und Lernformen** |
| Jedes Sommersemester | 1 Semester | 1 | Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr. Andreas Lehrmann | | |
| **Dozierende** | Prof. Dr. Andreas Lehrmann | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt* | *Präsenzzeit* | *Selbststudium* |
| | 150 | 60 | 90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: Basic knowledge in programming (Python) and mathematics (linear algebra, calculus). | | |
| **Prüfung** | *Art der Prüfung*: Schriftliche Prüfung<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Upon completion of this module the students have a broad understanding of machine learning and its subfields, including the following:<br>• They can independently collect/analyze data and take the necessary steps to prepare them for learning and inference tasks.<br>• They are familiar with a variety of supervised/unsupervised models and understand their principles and properties.<br>• They can select an appropriate model for a given task and design, implement, optimize, run, and analyze the corresponding machine learning pipeline.<br>• They understand the balance between expressiveness and generalization. They are able to employ selection, regularization, and meta-learning techniques to maximize model performance. | | |
| **Modulinhalte** | This course provides a comprehensive introduction to the field of machine learning. Starting from basic principles, we are going to develop a data-driven framework that allows us to express representation and prediction tasks as learning problems, either supervised or unsupervised.<br>In both cases, our discussion of the relationship between data and model will lead to a broad spectrum of approaches with different properties: linear vs. non-linear, parametric vs. non-parametric, deterministic vs. non-deterministic, and classification vs. regression. We are going to explore how these models are formulated, how they can be optimized, and how they can be applied to new data.<br>In a parallel track, we are going to explore theoretical properties of machine learning models, including their robustness, complexity, and meta-level behaviour.<br>In particular, the course covers the following topics:<br>• Data: collection & representation<br>• Data: statistical & visual exploration<br>• (Linear/Probabilistic/Non-parametric) classification<br>• (Linear/Non-Linear/Robust) regression<br>• Meta learning: ensembling & boosting<br>• Clustering<br>• Outlier Detection<br>• (Stochastic) gradient descent<br>• (Feature/Model) selection<br>• Regularization<br>• Convolutions<br>• Kernel Trick | | |

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| | • Maximum likelihood & maximum a-posteriori<br>• Principal component analysis<br>• Gaussian processes<br>• Multi-dimensional scaling<br>• Neural networks & deep learning |
| **Literatur** | 1. Bishop, Christopher M.: Pattern Recognition and Machine Learning. Springer, 2006.<br>2. Murphy, Kevin P.: Probabilistic Machine Learning: An Introduction. The MIT Press, 2022.<br>3. Hastie, Trevor and Tibshirani, Robert and Friedman, Jerome: The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Springer, 2009. |

# Artificial Neural Networks and Cognitive Models (5171030)

*Artificial Neural Networks and Cognitive Models*

| **Art des Moduls** | **Sprache** | **SWS** | **ECTS** |
|---|---|---|---|
| Pflichtmodul | Englisch | 4 | 5 |
| **Häufigkeit** | **Dauer** | **Studiensemester** | **Lehr- und Lernformen** |
| Jedes Sommersemester | 1 Semester | 1 | Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr. Magda Gregorová | | |
| **Dozierende** | Prof. Dr. Magda Gregorová | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt* | *Präsenzzeit* | *Selbststudium* |
| | 150 | 60 | 90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Upon completion of the module students:<br>• can place artificial neural networks within the broader area of machine learning, understand their major advantages and disadvantages, and are aware of major applications of ANN as well as selected advanced models under research and their fundamental ideas<br>• understand and assess the critical differences between the basic ANN architectures (MLP, CNN, RNN), can implement them in standard deep learning software packages, and can train, test, and evaluate the ANN models over real data<br>• building on the experience of working with their own ANN implementations, can reuse publicly available implementations of more complex models to carry out experiments over real datasets, can compare the<br>performance of these across various models and their hyperparameter setups<br>• understand the importance of transparency and reproducibility in deep learning experimentation and can present in written as well as oral their learning and evaluation pipeline including relevant description of the selected software and hardware configuration<br>• are aware of the ethical and societal impacts of machine learning and deep learning and can critically assess deep learning reports along these lines | | |
| **Modulinhalte** | • Artificial neural networks (ANN) in machine learning (ML)<br>• Basic concepts of learning algorithms and typical tasks<br>• Model development workflow, hyperparameter tunning, performance measures and model selection<br>• Ethical and societal aspects (open access, data governance, fairness, transparency, reproducibility, safety and robustness, interpretability and human oversight/trust, ecological footprint)<br>• Basic ANN architectures<br>• Multilayer perceptron (feed forward)<br>• Convolutional neural networks<br>• Recurrent neural networks<br>• ANN model regularization<br>• Norm penalties<br>• Data augmentation<br>• Early stopping<br>• Dropout<br>• ANN model optimization<br>• (Stochastic) gradient descent<br>• Backpropagation<br>• Momentum methods | | |

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| | • Learning rate scheduling<br>• Major ANN applications and selected advanced models<br>• Computer vision (object detection, image classification, style transfer)<br>• Natural language processing (word2vec, BERT)<br>• Autoencoders<br>• Generative models<br>• Deep learning software packages (one of these)<br>• PyTorch<br>• Tensorflow |
| **Literatur** | 1. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. Deep Learning. MIT Press, 2016<br>2. Zhang, Aston, Zachary C. Lipton, Mu Li, and Alexander J. Smola. Dive into Deep Learning. https://d2l.ai/, 2021 |

# Introduction to Deep Learning (5173030)

*Introduction to Deep Learning*

| **Art des Moduls** | **Sprache** | **SWS** | **ECTS** |
|---|---|---|---|
| Pflichtmodul | Englisch | 4 | 5 |
| **Häufigkeit** | **Dauer** | **Studiensemester** | **Lehr- und Lernformen** |
| Jedes Sommersemester | 1 Semester | 1 | Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr. Magda Gregorová | | |
| **Dozierende** | Prof. Dr. Magda Gregorová | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt* | *Präsenzzeit* | *Selbststudium* |
| | 150 | 60 | 90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Upon completion of the module students:<br>• can place artificial neural networks within the broader area of machine learning, understand their major advantages and disadvantages, and are aware of major applications of ANN as well as selected advanced models under research and their fundamental ideas<br>• understand and assess the critical differences between the basic ANN architectures (MLP, CNN, RNN), can implement them in standard deep learning software packages, and can train, test, and evaluate the ANN models over real data<br>• building on the experience of working with their own ANN implementations, can reuse publicly available implementations of more complex models to carry out experiments over real datasets, can compare the<br>performance of these across various models and their hyperparameter setups<br>• understand the importance of transparency and reproducibility in deep learning experimentation and can present in written as well as oral their learning and evaluation pipeline including relevant description of the selected software and hardware configuration<br>• are aware of the ethical and societal impacts of machine learning and deep learning and can critically assess deep learning reports along these lines | | |
| **Modulinhalte** | • Artificial neural networks (ANN) in machine learning (ML)<br>• Basic concepts of learning algorithms and typical tasks<br>• Model development workflow, hyperparameter tunning, performance measures and model selection<br>• Ethical and societal aspects (open access, data governance, fairness, transparency, reproducibility, safety and robustness, interpretability and human oversight/trust, ecological footprint)<br>• Basic ANN architectures<br>• Multilayer perceptron (feed forward)<br>• Convolutional neural networks<br>• Recurrent neural networks<br>• ANN model regularization<br>• Norm penalties<br>• Data augmentation<br>• Early stopping<br>• Dropout<br>• ANN model optimization<br>• (Stochastic) gradient descent<br>• Backpropagation<br>• Momentum methods | | |

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|---|---|
| | • Learning rate scheduling<br>• Major ANN applications and selected advanced models<br>• Computer vision (object detection, image classification, style transfer)<br>• Natural language processing (word2vec, BERT)<br>• Autoencoders<br>• Generative models<br>• Deep learning software packages (one of these)<br>• PyTorch<br>• Tensorflow |
| **Literatur** | 1. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. Deep Learning. MIT Press, 2016<br>2. Zhang, Aston, Zachary C. Lipton, Mu Li, and Alexander J. Smola. Dive into Deep Learning. https://d2l.ai/, 2021 |

# Mathematical Foundations of AI (5172010)

*Mathematical Foundations of AI*

| **Art des Moduls**<br>Pflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Sommersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>1 | **Lehr- und Lernformen**<br>Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr. Martin Storath | | |
| **Dozierende** | Prof. Dr. Martin Storath | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Schriftliche Prüfung<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | • Students refresh and develop further their knowledge and skills on the necessary mathematical foundations for understanding and developing algorithms for AI; in particular, linear algebra, calculus, probability.<br>• Students understand the principles of continuous optimization (constrained and unconstrained), are able to select appropriate approaches and they apply them for problems in AI.<br>• Students are able to apply and evaluate the principles of probabilistic modelling and inference, and they create probabilistic models for frequently occurring kinds of data.<br>• Students use the acquired mathematical skills to design and create frequently occurring building blocks of AI systems, such as linear regression, PCA, Gaussian mixture models and support vector machines. | | |
| **Modulinhalte** | 1. Advanced Vector Calculus<br>• Multivariate derivatives and chain rule<br>• Backpropagation and automatic differentiation<br>• Linearization and multivariate Taylor series<br>2. Advanced Linear Algebra<br>• Eigenvalues and eigenvectors<br>• Singular value decomposition<br>• Matrix approximation<br>3. Continuous Optimization<br>• Gradient descent<br>• Constrained optimization and Lagrange multipliers<br>• Convex Optimization<br>4. Models and Data<br>• Change of variables<br>• Empirical risk minimization<br>• Parameter estimation<br>• Probabilistic modelling and inference<br>• Model selection | | |
| **Literatur** | 1. M. P. Deisenroth, A. A. Faisal, Cheng Soon Ong: Mathematics for Machine Learning, Cambridge University Press, 2020<br>2. C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006<br>3. G. James, D. Witten, T. Hastie, R. Tibshirani: An Introduction to Statistical Learning, Second Edition, Springer, 2021 | | |

# Mathematical and Theoretical Foundations of AI (5171010)

*Mathematical and Theoretical Foundations of AI*

| **Art des Moduls**<br>Pflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Sommersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>1 | **Lehr- und Lernformen**<br>Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr. Frank-Michael Schleif | | |
| **Dozierende** | Prof. Dr. Martin Storath, Prof. Dr. Kai Diethelm | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Schriftliche Prüfung<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | • Students refresh and develop further their knowledge and skills on the necessary mathematical foundations for understanding and developing algorithms for AI; in particular, linear algebra, calculus, probability.<br>• Students understand the principles of continuous optimization (constrained and unconstrained), are able to select appropriate approaches and they apply them for problems in AI.<br>• Students are able to apply and evaluate the principles of probabilistic modelling and inference, and they create probabilistic models for frequently occurring kinds of data.<br>• Students use the acquired mathematical skills to design and create frequently occurring building blocks of AI systems, such as linear regression, PCA, Gaussian mixture models and support vector machines. | | |
| **Modulinhalte** | 1. Advanced Vector Calculus<br>• Multivariate derivatives and chain rule<br>• Backpropagation and automatic differentiation<br>• Linearization and multivariate Taylor series<br>2. Advanced Linear Algebra<br>• Eigenvalues and eigenvectors<br>• Singular value decomposition<br>• Matrix approximation<br>3. Continuous Optimization<br>• Gradient descent<br>• Constrained optimization and Lagrange multipliers<br>• Convex Optimization<br>4. Models and Data<br>• Change of variables<br>• Empirical risk minimization<br>• Parameter estimation<br>• Probabilistic modelling and inference<br>• Model selection<br>5. Basic Applications for AI systems<br>• Linear Regression<br>• Dimensionality Reduction with Principal Component Analysis (PCA)<br>• Density Estimation with Gaussian Mixture Models | | |
| **Literatur** | 1. M. P. Deisenroth, A. A. Faisal, Cheng Soon Ong: Mathematics for Machine Learning, Cambridge University Press, 2020 | | |

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|---|---|
| | 2. C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006<br>3. G. James, D. Witten, T. Hastie, R. Tibshirani: An Introduction to Statistical Learning, Second Edition, Springer, 2021 |

# Parallel Programming (5171510)

*Parallel Programming*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>1 | **Lehr- und Lernformen**<br>Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr. Kai Diethelm | | |
| **Dozierende** | Prof. Dr. Kai Diethelm | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: Fundamental knowledge in programming in a higher programming language, e.g. C or C++. | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Students have a firm knowledge of the concepts and methods of parallel programming. They are aware of the capabilities and limitations of these concepts. They can select appropriate approaches for given applications and apply them to the problems at hand. | | |
| **Modulinhalte** | The module will address the following topics:<br>• Basic ideas of parallel computing<br>• Hardware concepts for parallel computers (shared memory systems, distributed memory systems, GPU-based systems)<br>• Amdahl's law<br>• SISD, SIMD and MIMD software<br>• Introduction to the programming paradigms OpenMP, MPI and CUDA<br>• Code performance analysis and optimization (bottlenecks etc.)<br>All parts of the module are accompanied by a significant amount of practical work on a high performance compute cluster that provides all the required hardware. | | |
| **Literatur** | 1. Thomas Rauber and Gudula Rünger: Parallel Programming for Multicore and Cluster Systems, 2nd ed. Springer, Heidelberg, 2013<br>2. Timothy G. Mattson, Yun (Helen) He and Alice E. Koniges: The OpenMP Common Core. MIT Press, Cambridge, 2019<br>3. David Kirk and Wen-mei W. Hwu: Programming Massively Parallel Processors – A Hands-on Approach, 3rd ed. Morgan Kaufmann, Waltham, 2016<br>4. William Gropp, Ewing Lusk and Anthony Skjellum: Using MPI, 3rd ed. MIT Press, Cambridge, 2014<br>5. Georg Hager and Gerhard Wellein: Introduction to High Performance Computing for Scientists and Engineers. CRC Press, Boca Raton, 2011 | | |

# Project Module 1 (5172050)

*Project Module 1*

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| **Art des Moduls**<br>Pflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
| **Häufigkeit**<br>Jedes Semester | **Dauer**<br>1 Semester | **Studiensemester**<br>1 | **Lehr- und Lernformen**<br>Projekt |
| **Modulverantwortung** | Prof. Dr. Magda Gregorová | | |
| **Dozierende** | Prof. Dr. Arndt Balzer, Prof. Dr. Magda Gregorová | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Students can methodically process and solve comprehensive tasks. The students can develop and implement suitable solution strategies in a team. They know how team processes work and can assess how to<br>contribute their own personality. The students can independently set up, implement, accompany and present a small AI project in a team. They can select and use appropriate development technologies and test and document their code. | | |
| **Modulinhalte** | The students will work in groups to solve projects using AI techniques (supervised by at least one professor). The topics are provided by professors of the FIW, other faculties or external partners. In general the project will contain a software development (potentially accompanied by a technical solution) and a respective documentation or other form or presentation. | | |
| **Literatur** | 1. Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, A.Geron, O'Reilly, 2019<br>2. The Data Science Design Manual, S. Skiena, Springer, 2017<br>3. Deep Learning, I. Goodfellow, MIT Press, 2016<br>Further literature will be given based on the respective project tasks. | | |

# Project Module 2 (5172060)

*Project Module 2*

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|---|---|---|---|
| **Art des Moduls**<br>Pflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
| **Häufigkeit**<br>Jedes Semester | **Dauer**<br>1 Semester | **Studiensemester**<br>1 | **Lehr- und Lernformen**<br>Projekt |
| **Modulverantwortung** | Prof. Dr. Magda Gregorová | | |
| **Dozierende** | Prof. Dr. Arndt Balzer, Prof. Dr. Magda Gregorová | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Students can methodically process and solve comprehensive tasks. The students can develop and implement suitable solution strategies in a team. They know how team processes work and can assess how to<br>contribute their own personality. The students can independently set up, implement, accompany and present a small AI project in a team. They can select and use appropriate development technologies and test and document their code. | | |
| **Modulinhalte** | The students will work in groups to solve projects using AI techniques (supervised by at least one professor). The topics are provided by professors of the FIW, other faculties or external partners. In general the project will contain a software development (potentially accompanied by a technical solution) and a respective documentation or other form or presentation. | | |
| **Literatur** | 1. Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, A.Geron, O'Reilly, 2019<br>2. The Data Science Design Manual, S. Skiena, Springer, 2017<br>3. Deep Learning, I. Goodfellow, MIT Press, 2016<br>Further literature will be given based on the respective project tasks. | | |

# Reasoning and Decision Making under Uncertainty (5171040)

*Reasoning and Decision Making under Uncertainty*

| **Art des Moduls** | **Sprache** | **SWS** | **ECTS** |
|---|---|---|---|
| Pflichtmodul | Englisch | 4 | 5 |
| **Häufigkeit** | **Dauer** | **Studiensemester** | **Lehr- und Lernformen** |
| Jedes Sommersemester | 1 Semester | 1 | Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr. Frank Deinzer | | |
| **Dozierende** | Prof. Dr. Frank Deinzer | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt* | *Präsenzzeit* | *Selbststudium* |
| | 150 | 60 | 90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | • Students develop further knowledge and skills on the necessary mathematical foundations for understanding and developing algorithms for AI.<br>• Students can apply the principles of Reinforcement Learning algorithms<br>• Students can use the principles of modelling gents, environments and rewards.<br>• Students understand the necessity of function approximations in learning.<br>• Students understand the concepts of statiscal sensor fusion<br>• Students can realize sensor fusion applications<br>• Students build on their acquired knowledge to master learning problems. | | |
| **Modulinhalte** | The course is composed of 2 thematic blocks.<br>Block A: Reinformcement Learning<br>1. Basic Reinforcement Learning Concepts<br>• Actions and States<br>• Goals, Rewards, Returns and Episodes<br>• Policies and Value Functions<br>2. Basic Reinforcement Learning Methods<br>• Finite Markov Decision Processes<br>• Dynamic Programming<br>• Monte Carlo Methods<br>3. Advanced tabular learning Methods<br>• Temporal-Difference Learning<br>• Bootstrapping Methods<br>4. Learning in Continuous State and Action Spaces<br>• On-Policy Approximation<br>• Value-function Approximation<br>• Off-Policy Approximation<br>• Approximate Eligibility Traces<br>5. Value Function Approximation Case Studies<br>• Computer Vision: Action planning<br>• Mastering Games: Backgammon, Go<br>6. Applications and Exercises<br>Block B: Sensor Fusion<br>1. Using Bayes for Sensor Data Fusion<br>• Modeling and Estimation of Densities<br>• Sensor Fusion over Time<br>2. Hidden Markov Models and Viterbi Algorithm<br>3. Recursive State Estimation | | |

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| | • Gaussian Filters<br>• Nonparametric Filters<br>4. Applications |
| **Literatur** | 1. Sutton, Barto. Reinforcement Learning - An Introduction. Bradford Books, 2018<br>2. Thorp. Beat the Dealer. Random House. 1966<br>3. Mitchell. Data Fusion: Concepts and Ideas. Springer. 2014<br>4. Thrun, Burgard, Fox: Probabilistic Robotics. MIT Press. 2005<br>5. Johnson, Freund, Miller. Miller & Freund's Probability and Statistics for Engineers. Pearson<br>Further specialized literature will be announced in the course. |

# Scientific seminar (5171110)

*Scientific seminar*

| **Art des Moduls**<br>Pflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Sommersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>1 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Magda Gregorová | | |
| **Dozierende** | Prof. Dr. Magda Gregorová, Dr. Maryam Bagheri | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: ME/OE | | |
| **Lernergebnisse** | Upon completion of the seminar students:<br>• can write English academic texts on AI topics taking into account the expected format (using appropriate mathematical typographical software - LaTex), structure, and the target audience; can adapt the language and visual support accordingly (article vs. presentation, etc.).<br>• understand the importance of good academic conduct, the boundaries and consequences of plagiarism, and the benefits of open science, transparency and reproducibility, they can design their communication strategy accordingly (open access / open source, experimental documentation, etc.)<br>• can conduct relevant literature search, analyze the quality of texts, can create and maintain a relevant bibliography in standard software tools and correctly reference previous work in their academic outputs<br>• are aware of selected recent trends in AI research and main opportunities and challenges in transferring them to practical applications<br>• can critically analyse academic text and provide constructive feedback, can interact with senior researchers in an informed discussion | | |
| **Modulinhalte** | Practical research and scientific work skills and principles of good scientific conduct.<br>• Academic writing on AI topics in English (for non-native speakers)<br>• Standard structure of academic texts – theses, technical reports, research articles, academic CV<br>• Specific grammar features and word choices of English academic text and common pitfalls for non-native speakers<br>• Good conduct in academic writing (citations, acknowledgments, plagiarism), open science, transparency, reproducibility<br>• Literature review (dblp, google scholar, journals and conferences, predatory publishers)<br>• Visual support of technical text (visual display of quantitative data, visual communication), academic presentations and poster design<br>• Analysis of academic text, critical evaluation, peerreview process and principles<br>• Academic and research support software tools and bibliography systems (Zotero, Mendeley, …)<br>• Academic talk structure, audience targeting, academic exchange of knowledge and experience, constructive feedback and academic research discussion | | |
| **Literatur** | To be defined in seminar | | |

# Semester 1,2

# Cloud Native (5171512)

*Cloud Native*

| **Art des Moduls** | **Sprache** | **SWS** | **ECTS** |
|---|---|---|---|
| Wahlpflichtmodul | Englisch | 4 | 5 |
| **Häufigkeit** | **Dauer** | **Studiensemester** | **Lehr- und Lernformen** |
| Unregelmäßig | 1 Semester | 1,2 | Seminar |
| **Modulverantwortung** | Prof. Dr.-Ing. Pascal Meißner | | |
| **Dozierende** | Dr. Harald Philipp Gerhards | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt* | *Präsenzzeit* | *Selbststudium* |
| | 150 | 60 | 90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: Basic skills in programming are needed | | |
| **Prüfung** | *Art der Prüfung*: Schriftliche Prüfung<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Upon completion of the module, students will:<br>• have an overview of the evolution of cloud computing and new architectures.<br>• Be able to understand the architectural patterns of cloud native platforms and applications.<br>• Be able to develop applications for container platforms on behalf of containerization principles.<br>• Be able to understand vertical and horizontal scaling of applications.<br>• Be able to maintain and configure monitoring and security components of Kubernetes platforms.<br>• Be able to critically access approaches to versioning software artifacts and develop appropriate strategies for agile software projects.<br>• Know the concepts of asynchronous communication using Apache Kafka.<br>• Have solidified their knowledge on cloud native tools like Docker, Kubernetes, Helm, Apache Kafka and Git | | |
| **Modulinhalte** | Main Concepts of Cloud Computing<br>• Definition of \\"cloud native\\"<br>• Historical background<br>• Cloud Native and Open Source<br>• Major players (CNCF, Linux Foundation, Apache Foundation)<br>Cloud Native Architecture<br>• Principles and paradigms<br>• Distributed systems<br>• Representation Concepts (C4, UML)<br>Containerization & Virtualization Principles<br>• Container vs. Virtual Machine<br>• Emergence of Docker<br>• Container Images<br>• Image Build<br>• Composing Containers<br>Container Orchestration<br>• Horizontal and vertical scaling<br>• Kubernetes artifacts<br>• Cluster Network<br>• Persistence in Kubernetes<br>• Templating for Kubernetes<br>• Monitoring and Logging<br>• Kubernetes Management | | |

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| | • Service Mesh<br>Pub-Sub-Messaging Concepts<br>• Apache Kafka<br>• Distributed logs<br>• Stream processing<br>Versioning<br>• Commit strategies<br>• Branching strategies<br>Development Operation Principles<br>• DevOps<br>• DevSecOps<br>• CI/CD<br>• GitOps |
| **Literatur** | Literature will be announced in the course. |

# Conversational AI – Virtual Assistants und Chatbots (IBM Watson Chatbot Challenge 2022) (5071062, 5171511)

*Conversational AI – Virtual Assistants and Chatbots (IBM Watson Chatbot Challenge 2022)*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Deutsch/Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>1,2 | **Lehr- und Lernformen**<br>Seminar, Projekt |
| **Modulverantwortung** | Prof. Dr. Christian Bachmeir | | |
| **Dozierende** | Prof. Dr. Christian Bachmeir | | |
| **Verwendbarkeit** | Master Artificial Intelligence, Master Informationssysteme | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Projektarbeit<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | 1) Overall objective<br>• Students can explain conversational systems by using conversational terms such as: entities, intents, utterances, context, slots/parameters, actions, dialogue design, disambiguation, digression, events, response, broadcast/push notifications and fulfilment<br>• Students can describe how knowledge-based systems and knowledge engineering could help to increase the natural language understanding (NLU)<br>• Students can describe how machine learning, intent matching, entity extraction, dialogue design and context can increase the user experience and containment<br>• Students can identify and solve a business case applying the Enterprise Design Thinking methodology, can train and integrate a virtual assistant<br>• Students identify the cost, benefit, flexibility, and risk factors that affect the investment decision, can explain ROI and indicate the PV, NPV<br>2) Objective: Professional skills<br>• Students can execute a requirements elicitation phase for an AI-powered virtual assistant<br>• Students can design and construct a conversational system<br>• Students develop a data model<br>• Students train the virtual assistant with client data<br>• Students can construct and implement a conversational AI prototype, pilot or proof-of-concept<br>• Students can integrate backend services or APIs in the client environment or external webpage<br>• Students can address and integrate virtual assistant systems and other channels<br>• Students solve a client use case<br>3) Objective: Problem-solving and critical thinking<br>Students can identify use case by exercising Enterprise AI<br>Design Thinking<br>• Students should be able to analyze and answer complex<br>questions about the structure and dynamics of<br>conversational flows<br>• Students can justify an overall conversational architecture based on a prior requirements analysis and/or design process<br>• Students should be able to assess the strengths and weaknesses of their work<br>• Students can outline further implementation flavors<br>• Students can identify potential for further enhancements of the virtual assistant depending on the use case (e.g. encorporating further Watson Services, connecting to an IVR system, | | |

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| | adding more user languages, preprocessing the user utterance, process automation, incorporating webservices, etc.)<br>4) Objective: Method skills<br>• Understand and apply the core concepts of conversational analysis by structuring and infusing the data into Watson Assistant<br>• Solve a business case by identifying the appropriate tools and services that support a user-oriented solution<br>5) Objective: Communication skills<br>• Students can communicate best practices for building a conversational AI solution<br>• Students understand the client's requirements and know how to translate those into milestones<br>• Students can manage the client's expectations • Students can demonstrate and explain their solution to a non-technical audience<br>6) Objective: Interpersonal skills<br>• Students can investigate self-directedly further machine learning and/or knowledge engineering methods based on the conversational scenario<br>• Students will work cooperatively within their teams in order to solve the business problem together<br>• Students will take over responsibility and accountability for the work that they have committed themselves |
| **Modulinhalte** | Conversational artificial intelligence (AI) is no longer science fiction, but an increasingly mainstream capability with which consumers interact daily in their homes, workplaces, and on the go.<br>Usually known as bots, chatbots, or virtual assistants, this conversational AI makes up a crowded and confusing enterprise market, leading buyers with many "bot" versions that may not talk to each other effectively.<br>Watson Assistant is IBM's virtual assistant solution that allows users to interact with business systems using natural human language. IBM has married a technically robust conversational platform with developer and line-of-businessfriendly tools with the breadth of the broader Watson portfolio. Enterprises can build and train the AI solution to serve a wide range of use cases across applications, devices, and channels.<br>The module aims are to design enterprise-specific conversational use cases and implement them using state-of- the-art frameworks of IBM Watson Assistant.<br>You will get insights into:<br>• the conversational design,<br>• natural language processing (NLP)<br>• in general and specifically in natural language understanding (NLU) and generation (NLG)<br>• as well as dialogue design.<br>Further, you will get a glimpse into machine learning and knowledge engineering depending on the group project requirements and students preferences.<br>The assessment is a group project focussing in a cross-functional team on a provided or real use case and a prototypical implementation during the course.<br>These virtual assistants aim to create and solve a real business case of real companies.<br>They are presented and evaluated by the companies at a final presentation.<br>In this independent study module, 20% of the classroom time will be coaching;<br>the first two sessions will be classical/ directed input and hands-on lecture;<br>later the learning is self-directed by working on the group work.<br>There will be a mid-term checkpoint to ensure the milestones of the project are on track.<br>Contents<br>1) Motivation and history<br>• Enterprise AI Design Thinking<br>• AI and non-AI Methods for Chatbot/Virtual Assistant<br>• Conversational AI and Bot Lifecycle<br>• Conversational Design and Engineering Process<br>• Use Case Ideation and/or Requirements Gathering<br>• Conversational and User Experience (UX)<br>• General approach to Cognitive Computing - Cognitive Computing flavours<br>• Introduction into Piloting and MVP<br>• Integration of Conversational Channels |

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| | • Introduction into Watson Assistant<br>2) Core concepts and methods<br>• Fundamental concepts of AI<br>• Provision of service instances in IBM Cloud account<br>• Introduction to Watson Assistant main concepts<br>• Conversational Prototyping and Implementation<br>• Data model (Intents & Entities)<br>• Ground truth (Training Data)<br>• Basic Conversational dialogue design<br>• Designing Multi-turn interactions<br>• Optional: Search Skill<br>• Decision trees and dialog features<br>• Conversational Service Integration and Fulfillment<br>3) Advanced topics<br>• Programing User Interface<br>• REST API calls<br>• Analytics and conversation analysis<br>• Integration (Chat Widget / Webhooks)<br>• Handing over the conversation to an agent (Triage)<br>• Connecting other Watson Services for preprocessing data<br>• Testing methods for accuracy and containment<br>4) Application<br>• Introduction to Watson Conversation concepts<br>• Chatbot Challenge Introduction and description<br>• Client introduction<br>• Instructions (Cooperation with client / Professors)<br>• Criteria's to evaluate each team<br>• Collecting use case requirements<br>• Managing expectation<br>• Defining goals and milestones |
| **Literatur** | • Slides with methodological requirements and optional further readings will be handed out to sTudents at the beginning of the semester.<br>• Online resources:<br>IBM Cloud, Watson Assistant, Watson Discovery |

# Conversational AI – Virtual Assistants und Chatbots (IBM Watson Chatbot Challenge) (5171511)

*Conversational AI – Virtual Assistants and Chatbots (IBM Watson Chatbot Challenge)*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Deutsch/Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>1,2 | **Lehr- und Lernformen**<br>Seminar, Projekt |
| **Modulverantwortung** | Prof. Dr. Christian Bachmeir | | |
| **Dozierende** | Prof. Dr. Christian Bachmeir | | |
| **Verwendbarkeit** | Master Artificial Intelligence, Master Digital Business Systems | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Projektarbeit<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | 1) Overall objective<br>• Students can explain conversational systems by using conversational terms such as: entities, intents, utterances, context, slots/parameters, actions, dialogue design, disambiguation, digression, events, response, broadcast/push notifications and fulfilment<br>• Students can describe how knowledge-based systems and knowledge engineering could help to increase the natural language understanding (NLU)<br>• Students can describe how machine learning, intent matching, entity extraction, dialogue design and context can increase the user experience and containment<br>• Students can identify and solve a business case applying the Enterprise Design Thinking methodology, can train and integrate a virtual assistant<br>• Students identify the cost, benefit, flexibility, and risk factors that affect the investment decision, can explain ROI and indicate the PV, NPV<br>2) Objective: Professional skills<br>• Students can execute a requirements elicitation phase for an AI-powered virtual assistant<br>• Students can design and construct a conversational system<br>• Students develop a data model<br>• Students train the virtual assistant with client data<br>• Students can construct and implement a conversational AI prototype, pilot or proof-of-concept<br>• Students can integrate backend services or APIs in the client environment or external webpage<br>• Students can address and integrate virtual assistant systems and other channels<br>• Students solve a client use case<br>3) Objective: Problem-solving and critical thinking<br>Students can identify use case by exercising Enterprise AI Design Thinking<br>• Students should be able to analyze and answer complex questions about the structure and dynamics of conversational flows<br>• Students can justify an overall conversational architecture based on a prior requirements analysis and/or design process<br>• Students should be able to assess the strengths and weaknesses of their work<br>• Students can outline further implementation flavors<br>• Students can identify potential for further enhancements of the virtual assistant depending on the use case (e.g. encorporating further Watson Services, connecting to an IVR system, | | |

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| | adding more user languages, preprocessing the user utterance, process automation, incorporating webservices, etc.)<br>4) Objective: Method skills<br>• Understand and apply the core concepts of conversational analysis by structuring and infusing the data into Watson Assistant<br>• Solve a business case by identifying the appropriate tools and services that support a user-oriented solution<br>5) Objective: Communication skills<br>• Students can communicate best practices for building a conversational AI solution<br>• Students understand the client's requirements and know how to translate those into milestones<br>• Students can manage the client's expectations • Students can demonstrate and explain their solution to a non-technical audience<br>6) Objective: Interpersonal skills<br>• Students can investigate self-directedly further machine learning and/or knowledge engineering methods based on the conversational scenario<br>• Students will work cooperatively within their teams in order to solve the business problem together<br>• Students will take over responsibility and accountability for the work that they have committed themselves |
| **Modulinhalte** | Conversational artificial intelligence (AI) is no longer science fiction, but an increasingly mainstream capability with which consumers interact daily in their homes, workplaces, and on the go.<br>Usually known as bots, chatbots, or virtual assistants, this conversational AI makes up a crowded and confusing enterprise market, leading buyers with many "bot" versions that may not talk to each other effectively.<br>Watson Assistant is IBM's virtual assistant solution that allows users to interact with business systems using natural human language. IBM has married a technically robust conversational platform with developer and line-of-businessfriendly tools with the breadth of the broader Watson portfolio. Enterprises can build and train the AI solution to serve a wide range of use cases across applications, devices, and channels.<br>The module aims are to design enterprise-specific conversational use cases and implement them using state-of- the-art frameworks of IBM Watson Assistant.<br>You will get insights into:<br>• the conversational design,<br>• natural language processing (NLP)<br>• in general and specifically in natural language understanding (NLU) and generation (NLG)<br>• as well as dialogue design.<br>Further, you will get a glimpse into machine learning and knowledge engineering depending on the group project requirements and students preferences.<br>The assessment is a group project focussing in a cross-functional team on a provided or real use case and a prototypical implementation during the course.<br>These virtual assistants aim to create and solve a real business case of real companies.<br>They are presented and evaluated by the companies at a final presentation.<br>In this independent study module, 20% of the classroom time will be coaching;<br>the first two sessions will be classical/ directed input and hands-on lecture;<br>later the learning is self-directed by working on the group work.<br>There will be a mid-term checkpoint to ensure the milestones of the project are on track.<br>Contents<br>1) Motivation and history<br>• Enterprise AI Design Thinking<br>• AI and non-AI Methods for Chatbot/Virtual Assistant<br>• Conversational AI and Bot Lifecycle<br>• Conversational Design and Engineering Process<br>• Use Case Ideation and/or Requirements Gathering<br>• Conversational and User Experience (UX)<br>• General approach to Cognitive Computing - Cognitive Computing flavours<br>• Introduction into Piloting and MVP<br>• Integration of Conversational Channels |

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|---|---|
| | • Introduction into Watson Assistant<br>2) Core concepts and methods<br>• Fundamental concepts of AI<br>• Provision of service instances in IBM Cloud account<br>• Introduction to Watson Assistant main concepts<br>• Conversational Prototyping and Implementation<br>• Data model (Intents & Entities)<br>• Ground truth (Training Data)<br>• Basic Conversational dialogue design<br>• Designing Multi-turn interactions<br>• Optional: Search Skill<br>• Decision trees and dialog features<br>• Conversational Service Integration and Fulfillment<br>3) Advanced topics<br>• Programing User Interface<br>• REST API calls<br>• Analytics and conversation analysis<br>• Integration (Chat Widget / Webhooks)<br>• Handing over the conversation to an agent (Triage)<br>• Connecting other Watson Services for preprocessing data<br>• Testing methods for accuracy and containment<br>4) Application<br>• Introduction to Watson Conversation concepts<br>• Chatbot Challenge Introduction and description<br>• Client introduction<br>• Instructions (Cooperation with client / Professors)<br>• Criteria's to evaluate each team<br>• Collecting use case requirements<br>• Managing expectation<br>• Defining goals and milestones |
| **Literatur** | • Slides with methodological requirements and optional further readings will be handed out to sTudents at the beginning of the semester.<br>• Online resources:<br>IBM Cloud, Watson Assistant, Watson Discovery |

# Entrepreneurship for Engineers (5171514)

*Entrepreneurship for Engineers*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>1,2 | **Lehr- und Lernformen** |
| **Modulverantwortung** | Prof. Dr. Ivan Yamshchikov | | |
| **Dozierende** | Prof. Dr. Ivan Yamshchikov | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | — Students learn how to apply the principles of technological entrepreneurship.<br>— Students can create a Minimal Viable Prototype (MVP) by applying principles of paper prototyping.<br>— Students can create and implement a customer development pipeline can evaluate product market fit and unit economics of the technological product.<br>— Students can create a pitch deck for their project from scratch, evaluate the quality of the early-stage venture capital, and implement a fund-raising plan.<br>— Students understand the overall properties of venture capital markets. | | |
| **Modulinhalte** | The course is structured as a series of shark-tank events with founders, investors and developers that estimate current progress of the team and decide if the team can work further on the current project or has to pivot.<br>As the course progress we cover following topics:<br>1 What is venture capital?<br>— a brief history of venture investment<br>— probabilistic approach to venture investment<br>— venture capital and technological development<br>2 What is a product?<br>— Why is technology not a product?<br>— Paper prototyping and product market fit<br>— Customer development for engineers<br>3 What is a pitch deck?<br>— What are the key structural components of a good pitch?<br>— Unit economics<br>— Storytelling for engineers<br>4 How do you make decisions under stress?<br>— Managing small teams<br>— Trade-off between discipline and creativity<br>— Empathy for engineers<br>5 What is unit economics?<br>— Customer acquisition costs<br>— Lifetime value | | |
| **Literatur** | I. Strebulaev, A. Dang "Venture Mindset"<br>B. Horowitz "The Hard Thing About Hard Things: Building a Business When There Are No Easy Answers"<br>P. Thiel "Zero to One: Notes on Startups, or How to Build the Future" | | |

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| | M. Weber "Protestant Ethic and the Spirit of Capitalism"<br>K.F. Lee "AI Superpowers: China, Silicon Valley and the New Word Order"<br>B. Christian, T. Griffiths "Algorithms to Live By" |

# Ethics and Regulation of AI (5171519)

*Ethics and Regulation of AI*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Sommersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>1,2 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Markus Oermann | | |
| **Dozierende** | Prof. Dr. Markus Oermann | | |
| **Verwendbarkeit** | Master Artificial Intelligence, Master Digital Business Systems | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Participants<br>• have profound insights regarding the central clusters of ethical challenges of AI<br>• know the basic requirements on AI by established ethical guidelines by the UNESCO, the Council of Europe, the G7 etc.<br>• know how to integrate an ethical assessment in professional workstreams/development processes<br>• know the basics of the new legal framework for AI in the EU that will be established by the AI Act<br>• have insights on current legal discussions on the use of copyright protected material as training data and on the protection of AI's output in terms of intellectual property<br>• get insights on the next phase of the EU's regulation of AI which will address the question of liability<br>• are thereby able to better communicate and cooperate with ethical and legal professionals in their future work environment | | |
| **Modulinhalte** | • AI, a dazzling concept - basic definitions of AI by OECD and EU<br>• basics on ethics in general<br>• clusters of ethical challenges related to AI:<br>- power and responsibility<br>- agency and human/machine relation<br>- biases and discrimination<br>- data ownership/data protection<br>- copyright/intellectual property<br>- job displacement/transformation of work<br>• selected established ethical guidelines and their take on these challenges:<br>- UNESCO<br>- Council of Europe<br>- G7<br>- Blechtley Parc Declaration<br>- special sector codes: IEEE, ILO<br>- self regulatory codes: Open AI safety guidelines<br>• approaches and standards on how to integrate ethical assessment in professional workstreams/development of AI and AI applications<br>• overview on the new legal framework for AI by the upcoming EU AI Act<br>• further current legal discussions on AI:<br>- how to deal with the use of copyright protected material as training data<br>- how to deal with AI's output in terms of copyright law | | |

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| | - next step of regulation: the planed reform of the liability regime for AI by the European Commission |
| **Literatur** | Coeckelbergh, Mark (2021): AI ethics, Cambridge, MA: MIT Press.<br>Further basic texts will be announced or made available in the first session |

# Explainable AI (5171525)

*Explainable AI*

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| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>1,2 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Magda Gregorová | | |
| **Dozierende** | Prof. Dr. Magda Gregorová | | |
| **Verwendbarkeit** | | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | PLEASE DESCRIBE | | |
| **Modulinhalte** | PLEASE DESCRIBE | | |
| **Literatur** | PLEASE DESCRIBE | | |

# Machine Learning for Dynamical Systems ()

*Machine Learning for Dynamical Systems*

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|---|---|---|---|
| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>1,2 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Andreas Lehrmann | | |
| **Dozierende** | Prof. Dr. Andreas Lehrmann | | |
| **Verwendbarkeit** | | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Mündliche Prüfung<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | PLEASE DESCRIBE | | |
| **Modulinhalte** | PLEASE DESCRIBE | | |
| **Literatur** | PLEASE DESCRIBE | | |

# Project Module (5171060)

*Project Module*

| **Art des Moduls**<br>Pflichtmodul | **Sprache**<br>Englisch | **SWS**<br>8 | **ECTS**<br>10 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Semester | **Dauer**<br>2 Semester | **Studiensemester**<br>1,2 | **Lehr- und Lernformen**<br>Projekt |
| **Modulverantwortung** | Prof. Dr. Frank-Michael Schleif | | |
| **Dozierende** | Prof. Dr. Frank-Michael Schleif | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>300 | *Präsenzzeit*<br>120 | *Selbststudium*<br>180 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Projektarbeit<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Students can methodically process and solve comprehensive tasks. The students can develop and implement suitable solution strategies in a team. They know how team processes work and can assess how to<br>contribute their own personality. The students can independently set up, implement, accompany and present a small AI project in a team. They can select and use appropriate development technologies and test and document their code. | | |
| **Modulinhalte** | The students will work in groups to solve projects using AI techniques (supervised by at least one professor). The topics are provided by professors of the FIW, other faculties or external partners. In general the project will contain a software development (potentially accompanied by a technical solution) and a respective documentation or other form or presentation. | | |
| **Literatur** | 1. Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, A.Geron, O'Reilly, 2019<br>2. The Data Science Design Manual, S. Skiena, Springer, 2017<br>3. Deep Learning, I. Goodfellow, MIT Press, 2016<br>Further literature will be given based on the respective project tasks. | | |

# Rust programming for safety-critical systems (5171513)

*Rust programming for safety-critical systems*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>1,2 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Daniel Kulesz | | |
| **Dozierende** | Prof. Dr.-Ing. Sebastian Biedermann, Prof. Dr. Daniel Kulesz | | |
| **Verwendbarkeit** | Master Artificial Intelligence, Master Digital Business Systems, Master Informationssysteme | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: Für die praktischen Arbeiten sollten Studierende einen eigenen Rechner (Laptop) mit Windows, OS X, Linux oder *BSD mitbringen.<br>*empfohlen*:<br>• Rudimentäre Programmierkenntnisse (mindestens auf dem Level nach Abschluss der Vorlesung 'Programmieren 2')<br>• Praktische Erfahrung in mindestens einem vorangegangenen Programmierprojekt | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | By successful completion of this course, students obtain the following skills:<br>• They internalized that programming in safety-critical domains is fundamentally different from programming in 'regular' domains.<br>• They understand how strict programming langauges can contribute to safe and secure programming.<br>• They can apply basic and advanced concepts of the Rust programming language in practical projects.<br>• They can build robust Rust applications for use in safety-critical domains. | | |
| **Modulinhalte** | Malfunctions of software in safety-critical systems as well as cyberstrikes can lead to severe losses including death and environmental harm. Hence, when building software for such environments the use of safe and secure programming languages is essential. One suitable programming language for this use case is Rust. Moreover, Rust is also continuously gaining popularity and is used in leading open source projects such as the Linux kernel or the Firefox browser. Rust is particularly attractive because it enables both system-level and application-oriented programming while pursuing the goal of making programs safe and secure.<br>The first part of this course will start with an introduction to safety-critical systems. Afterwards, the basics of Rust (syntax,<br>concepts) will be explained and comparisons to other programming languages (e.g. Java or C/C++) will be drawn. Here, the focus will be on memory management without a garbage collector and its implications on safety and security.<br>In the second part of this course, the participants will deepen the theory through practical work on real development projects. The course follows the concept of 'research-based learning' and therefore requires an adequate degree of initiative and willingness to learn. In particular, we expect that students learn independently by means of designated tutorials. | | |
| **Literatur** | “Programming Rust: Fast, Safe Systems Development”, Jim Blandy, Jason Orendorff, Leonora Tindall, 2nd. ed, 2021, O'Reily<br>“Embedded software development for safety-critical systems”, Chris Hobbs, 2nd ed., 2020, CRC Press | | |

# Semester 2

# Artificial Intelligence in Robotics (5171080)

*Artificial Intelligence in Robotics*

| **Art des Moduls**<br>Pflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Wintersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>2 | **Lehr- und Lernformen**<br>Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr.-Ing. Pascal Meißner | | |
| **Dozierende** | Prof. Dr.-Ing. Pascal Meißner | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | By the end of the module students should be able to:<br>• Apply the Bayes (filter) formula and sample from probability density functions<br>• Determine and apply probabilistic sensor and motion models<br>• Discuss the steps and components of realizations of Bayes filters<br>• Implement realizations of Bayes filters and compute location estimates for robots<br>• Build and analyze grid maps<br>• Differentiate between localisation and SLAM systems as well as outline auxiliary techniques for SLAM solutions<br>• Assess and implement components of landmark- and grid-based solutions to the SLAM problem<br>• Differentiate between different path planning techniques and discuss the steps of collision avoidance solutions<br>• Apply and implement graph-search techniques for path planning<br>• Assess the Markov Decision Process definition as well as the concepts of Utility and Policy<br>• Apply dynamic programming on Markov Decision Problems to compute of value functions and optimal policies<br>• Differentiate between different Reinforcement Learning techniques | | |
| **Modulinhalte** | 01. Introduction – Nomenclature, history, state of the art, module logistics<br>02. Linear Algebra and Probability Primer – Vectors and operations, matrices and operations, axioms of probability, independent events, Bayes rule<br>03. Bayes Filter – Recursive Bayesian updating, state transitions, Markov property, derivation<br>04. Probabilistic Modeling – Odometry- and velocity-based motion models, beam- and scan-based sensor models<br>05. Localisation with Nonparametric Filters – Discrete Bayes filter, importance sampling, particle filter<br>06. Localisation with Gaussian Filters – Kalman filter, Extended Kalman filter<br>07. Mapping with Known Poses – Occupancy maps, reflection probability maps<br>08. Landmark-based SLAM – SLAM problem, EKF SLAM, loop closing, Rao-Blackwellization, FastSLAM<br>09. Grid-based SLAM – Scan matching, FastSLAM, improved proposals, selective resampling<br>10. Motion and Path Planning – Configuration space, combinatorial planning, graph-based search, collision avoidance<br>11. Markov Decision Processes – MDP definition, utility, value iteration, policy iteration<br>12. Reinforcement Learning – Temporal-difference learning, exploration vs exploitation, Q-learning, policy search | | |

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| **Literatur** | • Probabilistic Robotics, Sebastian Thrun and Wolfram Burgard and Dieter Fox, MIT Press, 978-0262201629, 2005<br>• Artificial Intelligence: A Modern Approach, Stuart Russell and Peter Norvig, 4th ed. Prentice Hall, 978-0136042594, 2021 |

# Ausgewählte Kapitel der Embedded Systems (5071038)

*Selected Topics in Embedded Systems*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Deutsch/Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Wintersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>2 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Arndt Balzer | | |
| **Dozierende** | Prof. Dr. Arndt Balzer, Prof. Dr. Andreas Lehrmann | | |
| **Verwendbarkeit** | Master Artificial Intelligence, Master Digital Business Systems | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: Affinität zu technischen Anwendungen | | |
| **Prüfung** | *Art der Prüfung*: Referat, Kolloquium<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Die Studierenden sind in der Lage<br>• Notwendigkeit, Marktrelevanz und das Potential Eingebetteter (mobiler) Systeme zu bewerten,<br>• Herausforderungen bei Bau autonomen fahrender Systeme beurteilen und Lösung entwerfen zu können,<br>• Aufbau und Funktionsweise der Hard- und Software von Regelungssystemen am Beispiel eines Quadrokopters zu beschreiben, einschließlich der Echtzeitanforderungen,<br>• Teile der Systemsoftware zu implementieren,<br>• eingesetzte mathematische Methoden zu beurteilen,<br>• Ansätze zur Verbesserung der Signalverarbeitung zu entwerfen. | | |
| **Modulinhalte** | Die Inhalte der Lehrveranstaltung werden aktuellen Erfordernissen angepasst.<br>Seit 2020 ist der Schwerpunkt die Entwicklung von Software für ein autonom fahrendes Fahrzeug auf Basis von NVIDIA Hardware<br>Grundlagen des maschinellen Lernen, dabei u.a. künstliche neuronale Netze<br>Maschinelles Sehen, \\\\"klassische\\\\" Bildverarbeitung<br>Bis 2019 war der Schwerpunkt: Entwicklung von Software zur Steuerung eines Quadrokopters<br>Programmierung von Embedded Systems<br>Regelungstechnik, insbesondere PID Regler<br>Sensorik, Telemetrie<br>Mathematische Grundlagen: Kartesische und Polar Koordinaten, Euler Winkel, komplexe Zahlen, Quaterionen, Vektoralgebra<br>Signalverarbeitung: Zustandsschätzer, Bayes-, Gauss-, Kalman-Filter<br>Lageregelung, Yaw Regelung, Telekommandos<br>Bei Bedarf: Entwicklung von Software für MCU mit aktuellen IDEs, teil-autonomes Fahren | | |
| **Literatur** | Tom M. Mitchell, Machine Learning, http://www.cs.cmu.edu/~tom/mlbook.html<br>Christopher M. Bishop, Pattern Recognition and Machine Learning, online<br>Trevor Hastie et al., The Elements of Statistical Learning, online<br>Kevin P. Murphy, Machine learning, online<br>S. Thrun, W. Burgard, D. Fox: Probabilistic Robotics, The MIT Press, 2005<br>Unterlagen der Uni Würzburg / Emqopter, 2019<br>A. Gelb, Applied Optimal Estimation, MIT Press, 1974<br>R. Kalman, A New Approach to Linear Filtering and Prediction Problems, Transaction of the ASME—Journal of Basic Engineering, 1960<br>P. Marwedel: Embedded System Design - Foundations of Cyber-Physical Systems, Springer, 2011 | | |

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| | D. Gajski, F. Vahid: Specification and Design if Embedded Systems, Pearson, 2008<br>J. McClellan. R. Schafer: Signal Processing First, Pearson, 2003 |

# Fundamentals of Mobile Robotics (5172080)

*Fundamentals of Mobile Robotics*

| **Art des Moduls**<br>Pflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Wintersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>2 | **Lehr- und Lernformen**<br>Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr.-Ing. Pascal Meißner | | |
| **Dozierende** | Prof. Dr.-Ing. Pascal Meißner | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Mündliche Prüfung<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | • Apply the Bayes (filter) formula and sample from probability density functions<br>• Determine and apply probabilistic sensor and motion models<br>• Discuss the steps and components of realizations of Bayes filters<br>• Implement realizations of Bayes filters and compute location estimates for robots<br>• Build and analyze grid maps<br>• Differentiate between localization and SLAM systems as well as outline auxiliary techniques for SLAM solutions<br>• Assess and implement components of landmark- and grid-based solutions to the SLAM problem<br>• Differentiate between different path planning techniques and discuss the steps of collision avoidance solutions<br>• Apply and implement graph-search techniques for path planning<br>• Assess the Markov Decision Process definition as well as the concepts of Utility and Policy<br>• Apply dynamic programming on Markov Decision Problems to compute value functions and optimal policies | | |
| **Modulinhalte** | 01. Introduction – Nomenclature, history, state of the art, module logistics<br>02. Linear Algebra and Probability Primer – Vectors and operations, matrices and operations, axioms of probability, independent events, Bayes rule<br>03. Bayes Filter – Recursive Bayesian updating, state transitions, Markov property, derivation<br>04. Probabilistic Modelling – Odometry- and velocity-based motion models, beam- and scan-based sensor models<br>05. Localization with Nonparametric Filters – Discrete Bayes filter, importance sampling, particle filter<br>06. Localization with Gaussian Filters – Kalman filter, Extended Kalman filter<br>07. Mapping with Known Poses – Occupancy maps, reflection probability maps<br>08. Landmark-based SLAM – SLAM problem, EKF SLAM, loop closing, Rao-Blackwellization, FastSLAM<br>09. Grid-based SLAM – Scan matching, FastSLAM, improved proposals, selective resampling<br>10. Motion and Path Planning – Configuration spaces, combinatorial planning, search algorithms, A* with extensions, collision avoidance<br>11. Markov Decision Processes – MDP definition, utility, value iteration, policy iteration | | |
| **Literatur** | • Probabilistic Robotics, Sebastian Thrun and Wolfram Burgard and Dieter Fox, MIT Press, 978-0262201629, 2005<br>• Artificial Intelligence: A Modern Approach, Stuart Russell and Peter Norvig, 4th ed. Prentice Hall, 978-0136042594, 2021 | | |

# Learning of structured data (5171100)

*Learning of structured data*

| **Art des Moduls** | **Sprache** | **SWS** | **ECTS** |
|---|---|---|---|
| Pflichtmodul | Englisch | 4 | 5 |
| **Häufigkeit** | **Dauer** | **Studiensemester** | **Lehr- und Lernformen** |
| Jedes Wintersemester | 1 Semester | 2 | Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr. Dominik Seuß | | |
| **Dozierende** | Prof. Dr. Dominik Seuß, Prof. Dr. Andreas Lehrmann | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt* | *Präsenzzeit* | *Selbststudium* |
| | 150 | 60 | 90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*:<br>Hands-on knowledge from the modules:<br>• Mathematical (and Theoretical) Foundations of AI<br>• Artificial Intelligence and Machine Learning<br>• Artificial Neural Networks and Cognitive Models | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | • being able to evaluate and to apply modelling techniques for non-standard data<br>• being able to analyse non-vectorial data and to derive and improve predictive models<br>• knowing how to evaluate and assess respective representation techniques<br>• being able to implement pipelines for non-vectorial data analysis<br>• learn the how-to of proximity based learning<br>• learn how to assess, use and potentially extend the respective frameworks<br>• Students know how to characterize, choose, evaluate, assess and construct practical tools for structured data analysis and respective application fields<br>• learn how to use scientific literature and to understand, derive, implement and potentially extend the presented methods | | |
| **Modulinhalte** | The module explains the generic analysis and processing of non-vectorial or structured data like graphs, trees, sequential data or alike.<br>We discuss algebraic methods as well as neural network based techniques. The algorithmic part is shown in matlab, numpy/python<br>or by use of other numerical frameworks.<br>Exemplary the following key topics are addressed:<br>• Particularities of non-vectorial, compositional and structured data<br>• General proximity measures and implications on mathematical models<br>• Mathematical concepts like information theoretic measures,non-euclidean spaces, local and global embedding approaches<br>• Representation by proximity measures and simple learning methods<br>• Particular algebraic and neural network based Embedding techniques<br>• Evaluation methods for the representation of non-vectorial data<br>• Exemplary implementations and applications | | |
| **Literatur** | • The Dissimilarity Representation for Structural Pattern Recognition, Pekalska & Duin, World Scientific, 2005<br>• Graph Classification And Clustering Based On Vector Space Embedding, Bunke et al., 2010<br>• Kernels For Structured Data, Gartner, 2008<br>• Graph Representation Learning, Hamilton, 2020 | | |

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| | • Recent publications on learning of structured data are provided / suggested during the lecture |

# Mathematical Finance and Machine Learning (5171517)

*Mathematical Finance and Machine Learning*

| **Art des Moduls** | **Sprache** | **SWS** | **ECTS** |
|---|---|---|---|
| Wahlpflichtmodul | Englisch | 4 | 5 |
| **Häufigkeit** | **Dauer** | **Studiensemester** | **Lehr- und Lernformen** |
| Unregelmäßig | 1 Semester | 2 | Seminar |
| **Modulverantwortung** | Prof. Dr. Ivan Yamshchikov | | |
| **Dozierende** | Prof. Dr. Ivan Yamshchikov | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt* | *Präsenzzeit* | *Selbststudium* |
| | 150 | 60 | 90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: A course on stochastic calculus and/or theory of stochastic processes would be a plus. | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | The educational outcomes are as follows.<br>The student that successfully completed the course:<br>— understands fundamental mathematical properties of financial markets<br>— can conceptualise an approach for pricing a new financial tool<br>— has deep understanding of the underlying mathematical principles that are essential for financial markets<br>— can apply those ground principle in practice<br>— can model an empirically observed financial product using machine learning methods | | |
| **Modulinhalte** | The course is dedicated Financial Markets and tools that one can apply to the analysis of the financial data. The course consists of two components: a component on financial markets and a component on the applications of machine learning to financial markets.<br>We start with an overview of standard methods of Mathematical Finance and develop deep theoretical understanding of the stochastic processes behind them. This include:<br>— Notion of Stochastic Processes<br>— Geometric Brownian Motion<br>— Self-financing strategy<br>— Black-Scholes Formula<br>— Greeks<br>— Factor models on incomplete markets<br>— Pricing with dividends<br>— Bond pricing and yield curve<br>— Time series analysis (ARIMA, SARIMA, ARCH, GARCH etc.)<br>— Hamilton-Jacobi-Bellmann Equaltion<br>The second part of the course covers a set of empirically-driven data analysis approaches to financial modelling and decision making under time pressure. The practical aspects of the course include:<br>— processing real financial time series<br>— creating a game strategy for a Texas hold'em Poker bot tournament, where the bots created by the participants compete with one another<br>— analysis of cryptocurrency price dynamics with methods for time series analysis | | |
| **Literatur** | T. Björk, \\\\\"Arbitrage Theory in Continuous Time\\\\\"<br>M.L. De Prado \\\\\"Advances in Financial Machine Learning\\\\\" | | |

# Project Module II (5172060)

*Project Module II*

| **Art des Moduls**<br>Pflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Wintersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>2 | **Lehr- und Lernformen**<br>Projekt |
| **Modulverantwortung** | Prof. Dr. Magda Gregorová | | |
| **Dozierende** | Prof. Dr. Arndt Balzer, Prof. Dr. Frank Deinzer, Prof. Dr. Frank-Michael Schleif, Prof. Dr. Magda Gregorová, Prof. Dr.-Ing. Pascal Meißner, Prof. Dr. Ivan Yamshchikov | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: Project Module I<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Students can methodically process and solve comprehensive tasks. The students can develop and implement suitable solution strategies in a team. They know how team processes work and can assess how to<br>contribute their own personality. The students can independently set up, implement, accompany and present a small AI project in a team. They can select and use appropriate development technologies and test and document their code. | | |
| **Modulinhalte** | The students will work in groups to solve projects using AI techniques (supervised by at least one professor). The topics are provided by professors of the FIW, other faculties or external partners. In general the project will contain a software development (potentially accompanied by a technical solution) and a respective documentation or other form or presentation. | | |
| **Literatur** | Literature will be distributed based on the respective project tasks. | | |

# Semantic data processing and representation (5171090)

*Semantic data processing and representation*

| **Art des Moduls** | **Sprache** | **SWS** | **ECTS** |
|---|---|---|---|
| Pflichtmodul | Englisch | 4 | 5 |
| **Häufigkeit** | **Dauer** | **Studiensemester** | **Lehr- und Lernformen** |
| Jedes Wintersemester | 1 Semester | 2 | Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr. Ivan Yamshchikov | | |
| **Dozierende** | Prof. Dr. Ivan Yamshchikov | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt* | *Präsenzzeit* | *Selbststudium* |
| | 150 | 30 | 120 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*:<br>Mathematical Foundations of AI<br>Artificial Intelligence and Machine Learning<br>Artificial Neural Networks and Cognitive Models | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | After successfully completing the module:<br>• students are able to apply the basic methods of Natural Language Processing and related applications. The students are able to develop result-oriented applications that integrate Natural Language Processing methods. These methods can be based in whole or in part on various forms of artificial neural networks (deep neural networks).<br>• students are able to analyse concrete tasks in the field of natural language processing from applied science or industrial practice and evaluate and select suitable methods and software components from the field of natural language processing. In particular, students are also able to describe and develop suitable Deep Learning architectures.<br>• students are also able to describe, implement and present a corresponding overall software architecture. In doing so, they draw on common frameworks from the field of deep learning (e.g. KERAS, TensorFlow, PyTorch, etc.). They organise themselves and their team independently in the application of learned methods of Natural Language Processing. | | |
| **Modulinhalte** | — Introduction and Natural Language Processing Applications<br>— Text and Speech Basics<br>— Reading scientific papers<br>— Tokenization<br>— Embeddings<br>— Verbal Intelligence<br>— Semantic Representations<br>— Distributed Representations / Word Embeddings<br>— Language Models<br>— Transformers<br>— Large Language Models<br>— Frontiers of modern NLP<br>The model is implementing a learning-by-doing approach. The students read a variety of scientific publications that are fundamental for the topic, present and discuss these contributions as the course unfolds. | | |
| **Literatur** | • Kamath, Uday, John Liu, and James Whitaker. Deep learning for NLP and speech recognition. Vol. 84. Cham: Springer, 2019. | | |

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| | • Chris Manning and Hinrich Schütze, Foundations of Statistical Natural Language Processing, MIT Press. Cambridge, MA: May 1999. |

# Trustworthy AI and AI regulations (5171070)

*Trustworthy AI and AI regulations*

| **Art des Moduls**<br>Pflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Wintersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>2 | **Lehr- und Lernformen**<br>Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr. Markus Oermann | | |
| **Dozierende** | Prof. Dr. Markus Oermann | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Schriftliche Prüfung<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | After the module participants will<br>• have profound insights regarding central clusters of ethical challenges of AI<br>• know how to integrate an ethical assessment in professional workstreams/AI development processes<br>• have gained insights on data protection law requirements for AI and the shortcommings of the EU's General Data Protection Regulation<br>• know the basic requirements on AI by established international ethical guidelines<br>• know the basics of the new legal framework for AI in the EU that will be established by the AI Act<br>• have insights on current legal discussions on the use of copyright protected material as training data and on the protection of AI's output in terms of intellectual property<br>• know the basic structures of civil liabilty and have insights on the next phase of the EU's regulation of AI which will address the liability regime<br>• are thereby well prepared to communicate and cooperate with ethical and legal professionals in their future work environment | | |
| **Modulinhalte** | • \\\"Trustworthy AI\\\", a dazzling concept - basic definitions of AI by OECD and EU<br>• Ethics 101 and the traditional schools of Ethics<br>• Clusters of ethical challenges related to AI:<br>- agency and human/machine relation<br>- power and responsibility<br>- biases and discrimination<br>- data ownership/data protection (including basics structures of data protection law)<br>- democracy, election integrity, free discourse and the problem of AI driven malinformation, disinformation and deep fakes<br>- AI vs. sustainability (?)<br>- AI as catalyst of radical transformation?: job displacement/transformation of work<br>• Approaches and standards on how to integrate ethical assessment in professional workstreams/development of AI and AI applications<br>• Selected established international ethical guidelines and their take on these challenges: EU, OECD, UNESCO, Council of Europe, G7<br>• Self-regulation vs. state regulation (?)<br>• Overview on the new legal framework for AI by the EU's AI Act<br>• Further current legal and regulatory discussions on AI:<br>- How to deal with the use of copyright protected material as training data?<br>- How to deal with AI's output in terms of copyright law?<br>- What's ahead: the planed reform of the liability regime for AI in the EU | | |

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| **Literatur** | Coeckelbergh, Mark (2021): AI ethics, Cambridge, MA: MIT Press.<br>Dignum, Virginia (2019): Responsible Artificial Intelligence: How to Develop and Use AI in a Responsible Way, Cham: Springer Int. Publ.<br>Further basic texts will be announced or made available in the first session |

# Semester 2,3

# Competitive Programming (5171521)

*Competitive Programming*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>2,3 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Ivan Yamshchikov | | |
| **Dozierende** | Pavel Chizhov | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*:<br>Understanding of algorithms and data structures, full command of Python, knowledge of other languages such as C/C++ is a plus.<br>Rust programming for safety-critical systems or Sicher Programmieren in Rust.<br>Algorithmen und Datenstrukturen 1/2. | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | After the completion of the course the participants will obtain:<br>— Ability to rapidly prototype in a stressful and challenging environment;<br>— Deeper understanding of algorithms and computational complexity;<br>— Ability to critically assess the proposed solutions, choose the optimal one, and efficiently implement it in code;<br>— Efficient skills of interaction within a team of software developers. | | |
| **Modulinhalte** | The module mostly consists of Hands-on prototyping and code-reviewing. However, certain topics will be covered in flash-lectures.<br>– Basics of algorithms, i.e. sorting, binary search, dynamic programming, greedy algorithms, graph algorithms, etc.<br>— Data structures, i.e. stacks, sets, hashmaps, heaps, graphs, binary search trees, priority queues, etc.<br>— Complexity theory, in particular, big-O notation.<br>The focus of the course is programming practice in solving programming problems, specifically the ones offered at ICPC. The methodology implies follow-up discussions after every set of problems that allow to extend the variety of possible solutions and outlines the optimal ones. The best team will take part in the North European ICPC. | | |
| **Literatur** | Thomas H. Cormen, Charles E. Leiserson, Introduction to Algorithms. 2022. Fourth Edition. | | |

# Computational Creativity (5171522)

*Computational Creativity*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>2,3 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Ivan Yamshchikov | | |
| **Dozierende** | Prof. Dr. Ivan Yamshchikov | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: Full command of Python and “Artificial Neural Networks and Cognitive Models” are prerequisites for the course. | | |
| **Prüfung** | *Art der Prüfung*: Schriftliche Prüfung<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | This course explores the intersection of artificial intelligence and creative processes. It introduces students to the fundamentals of computational creativity, discussing how AI can be used to simulate or replicate human-like creative abilities in various domains such as art, music, engineering, and problem-solving.<br>Course Objectives:<br>— Understand the theoretical foundations of computational creativity.<br>— Explore various AI techniques used in creative processes.<br>— Analyze case studies where AI has been applied in creative industries.<br>Upon completion of the course, the students develop and implement AI models that demonstrate creative behaviour or have certain artistic merit. | | |
| **Modulinhalte** | Module Structure:<br>Introduction to Computational Creativity<br>— Definition and history<br>— Key concepts and challenges<br>— Overview of the field and its importance in AI<br>Theoretical Foundations<br>— Models of creativity in psychology and cognitive science<br>— Computational models of creative thinking<br>— Philosophical aspects of creativity and AI<br>Technologies and Algorithms<br>— Machine learning techniques in creativity<br>— Natural language processing for creative writing<br>— Evolutionary algorithms and their creative applications<br>— Neural networks (e.g., GANs, RNNs) in art and music generation<br>Creative Domains and Applications<br>— Visual arts: automated image and video generation<br>— Music: composition and performance enhancements<br>— Literature: poetry and prose generation<br>Practical Workshops and Projects<br>— Group projects to design a creative AI model<br>— Weekly iteration of the project and a final showcase gallery<br>The selected projects might be presented at the Deutsche Technische Museum Bonn. | | |

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| **Literatur** | Machado, Romero and Greenfield. Artificial Intelligence and the Arts: Computational Creativity, Artistic Behavior, and Tools for Creatives (Computational Synthesis and Creative Systems).<br>Levin and Brain. Code as Creative Medium: A Handbook for Computational Art and Design |

# Unsupervised Deep Learning (5171523)

*Unsupervised Deep Learning*

| **Art des Moduls** | **Sprache** | **SWS** | **ECTS** |
|---|---|---|---|
| Wahlpflichtmodul | Englisch | 4 | 5 |
| **Häufigkeit** | **Dauer** | **Studiensemester** | **Lehr- und Lernformen** |
| Jedes Wintersemester | 1 Semester | 2,3 | Seminar |
| **Modulverantwortung** | Prof. Dr. Magda Gregorová | | |
| **Dozierende** | Prof. Dr. Magda Gregorová | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt* | *Präsenzzeit* | *Selbststudium* |
| | 150 | 60 | 90 |
| **Voraussetzungen** | *nach SPO*:<br>Finished the following courses with grade better than 2.5:<br>• Artificial Neural Networks and Cognitive Models<br>• Mathematical Foundations of AI<br>*empfohlen*:<br>excellent knowledge of probability theory basics<br>fluency in implementing and training neural networks in PyTorch | | |
| **Prüfung** | *Art der Prüfung*: Portfolio<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Upon taking up the course students shall understand the differences between supervised, unsupervised and self-supervised learning and be able to name their primary usage and pros/cons.<br>Students shall be aware of the variety of possible approaches and shall be able to explain the main ideas underlying the five main deep unsupervised learning paradigms.<br>Students shall understand the mathematical formulations underlying the models and shall be able to build on this understanding when exploring independently more complex versions of the models.<br>Students shall be able to implement and train the basic versions of the main deep unsupervised models and shall be able to appreciate the intricacies of implementing and training more complex versions of the models.<br>Students shall be aware of classical as well as recent use-cases for the models, their challenges and strategies to tackle them, as well as of current limitations for the models. | | |
| **Modulinhalte** | In this course we shall cover the fundamental ideas of deep unsupervised learning, generative modelling and self-supervised learning.<br>We will explore the main types of models for deep unsupervised learning: autoregressive models, flow models, latent variable models, generative adversarial networks and diffusion models.<br>We will discuss their motivation, mathematical description as well as their practical implementation.<br>We will investigate the the strengths and weaknesses of the models for various tasks and data modalities.<br>We will put the models into the context of modern AI and establish the links to foundational models, unsupervised distribution alignment, compression and AI for science.<br>The course will be organized as a seminar with strong focus on independent work of the students.<br>Students will be expected to follow pre-recorded videos and read recommended papers which will be further discussed in the class.<br>An important part of the course will be coding homeworks, where students shall implement and train the main unsupervised deep learning architectures. | | |

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| | Throughout the whole course students will be supported by common discussion and question&answer sessions, online discussion forum as well as the possibility for one-on-one consultation sessions. |
| **Literatur** | Videos and slides of the Berkeley course on deep unsupervised learning - https://sites.google.com/view/berkeley-cs294-158-sp24/home<br>Papers referred to in the Berkeley course<br>Material (slides, papers and other artifacts) distributed in the class |

# Semester 3

# Advanced Topics in Deep Learning ()

*Advanced Topics in Deep Learning*

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|---|---|---|---|
| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>3 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Magda Gregorová | | |
| **Dozierende** | Prof. Dr. Magda Gregorová | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: This course assumes that students are comfortable with the topics discussed in the course Artificial Neural Networks and Cognitive Models. | | |
| **Prüfung** | *Art der Prüfung*: Präsentation<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Upon completion of this course students:<br>• can analyse scientific articles in the area of machine learning and deep learning and identify the most important points and pieces of information therein<br>• can research the relevant literature, assessing its plausibility and importance<br>• can summarize the main theoretical findings as well as their practical applicability<br>• can explain complex topics covered in the scientific papers to their peers and less informed audience<br>• can actively contribute to discussions on a wide variety of topics in deep learning | | |
| **Modulinhalte** | The course shall be structured around discussions of selected papers covering advanced topics in deep learning and machine learning.<br>Students are expected to independently explore a selected area of interest, present it to their peers and take a leading role in the follow-up discussion establishing a position of the \\\\\\ \"local guru\\\\\\\".<br>The topics shall be agreed upon in the beginning of the course. They can be suggested by the students themselves or selected from a recommended list (will be available in the beginning of the course) covering areas such as: transformers and attention models, autoencoders, batchnorm/layer norm and friends, object detection - what makes yolo so special, image segmentation - U-Net, simCLR - how to win ImageNet competition, deep generative models - zoo (shall I trust chat GPT), etc.<br>The course will be enriched by contributions of PhD students discussing their areas of interest. | | |
| **Literatur** | Will be provided in the course | | |

# Bayesian Statistics and Learning (5171518)

*Bayesian Statistics and Learning*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Sommersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>3 | **Lehr- und Lernformen**<br>Seminaristischer Unterricht |
| **Modulverantwortung** | Prof. Dr. Martin Storath | | |
| **Dozierende** | Prof. Dr. Martin Storath | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: Mathematical Foundations of AI must be completed | | |
| **Prüfung** | *Art der Prüfung*: Schriftliche Prüfung<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | • Develop a comprehensive understanding of statistical methods including Bayes's Theorem, various probability distributions, hypothesis testing, and regression analysis.<br>• Gain expertise in Bayesian statistics, covering concepts like conjugate priors, Markov Chain Monte Carlo (MCMC) techniques, and approximate Bayesian computation.<br>• Acquire skills to apply statistical methods to real-world scenarios using Python. | | |
| **Modulinhalte** | • Distributions and conjugate priors<br>• Estimation techniques<br>• Decision analysis<br>• Testing<br>• Classification techniques<br>• Inference<br>• Computational methods | | |
| **Literatur** | Allen B. Downey, Think Bayes 2, online publication<br>B. Lambert, A student's guide to Bayesian Statistics, SAGE Publications, 2018<br>G. James, D. Witten, T. Hastie, R. Tibshirani: An Introduction to Statistical Learning, Second Edition, Springer, 2021 | | |

# Computational Mechanization of Reasoning (5171520)

*Computational Mechanization of Reasoning*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Sommersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>3 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr.-Ing. Pascal Meißner | | |
| **Dozierende** | Dr. Alex Goeßmann | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Mündliche Prüfung<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Students will be enabled to<br>• understand the principles of logical and probabilistic reasoning<br>• apply tensor networks to design efficient reasoning algorithms<br>• learn and infer graphical models such as Markov Logic Networks<br>• design Knowledge Graphs respecting Semantic Web Standards<br>• work on research topics of the ENEXA project | | |
| **Modulinhalte** | The module is an introduction to the research topics of the ENEXA project (https://enexa.eu). Starting with the principles of logical and probabilistic reasoning we will apply the formalism of tensor networks to mechanize reasoning in an efficient way.<br>In particular the following topics will be treated:<br>• Principles of Logical Reasoning: Syntax, Semantics, Inference algorithms<br>• Tensor Networks for Logical Reasoning: Representation of Semantics, Sparsity of Sentences<br>• Graphical Models: Tensor Network representation, Bayesian Networks, Markov Logic Networks<br>• Principles of Probabilistic Reasoning: Variable Elimination, Gibbs Sampling<br>• Knowledge Graphs: Semantic Web Standards, Description Logic Reasoners<br>• Inductive Reasoning: Inductive Logic Programming, Maximum Likelihood Estimation<br>All topics will be accompanied by demonstrations and exercises based on the python library tnreason (developed within ENEXA). | | |
| **Literatur** | • Russel, Norvig: Artificial Intelligence - A Modern Approach (Fourth Edition), Pearson Education 2021<br>• Kolda, Bader: Tensor Decompositions and Applications, SIAM 2009<br>• Koller, Friedman: Probabilistic Graphical Models - Principles and Techniques, MIT Press 2009<br>• Murphy: Machine Learning - A Probabilistic Perspective, MIT 2012<br>• Brachman, Levesque: Knowledge Representation and Reasoning, Morgan Kaufman 2004 | | |

# Design and Analysis of Learning Problems (5171515)

*Design and Analysis of Learning Problems*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Jedes Sommersemester | **Dauer**<br>1 Semester | **Studiensemester**<br>3 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Frank-Michael Schleif | | |
| **Dozierende** | Dr. Alex Goeßmann | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: keine<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Kolloquium<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | 1. Students develop a solid intuition about the statistical and numerical principles driving machine learning. Equipped with this intuition they will be able to independently design machine learning approaches and analyse them by classical methods.<br>2. Students understand the necessity and advantages of regularizing learning methods, based on simple but well understood examples in compressed sensing and sparse regression.<br>3. Students acquire a numerical understanding of the curse of dimensions, represented by tensors of large orders. They further get familiar with available methods to mitigate the curse of dimensions with carefully designed learning methods such as tensor network based regression.<br>4. Students get familiar with current approaches towards understanding the success of neural networks. | | |
| **Modulinhalte** | Advanced linear regression:<br>1. Function spaces, scaler-products and norms<br>2. Squares risks and their geometrical interpretation<br>3. Kernel ridge regression and the representer theorem<br>Sparse regression and compressed sensing:<br>1. l_0 and l_1-regularized learning problems and their algorithmic solutions<br>2. Compressed sensing and applications<br>3. Data properties enabling the success of sparse regression<br>Success guarantees and complexities of regression problems:<br>1. Statistical foundation of learning by risk minimization<br>2. Complexities of learning architectures and success guarantees<br>3. Concentration inequalities and uniform concentration bounds<br>Tensor regression:<br>1. Applications of tensors in machine learning<br>2. Dimensionality reduction with tensor networks<br>3. Fitting tensor networks to data<br>Neural network regression:<br>1. Expressivity and concentration of neural networks<br>2. Advantages of deep against shallow networks<br>3. Uniform concentration bounds and Rademacher complexities<br>Accompanying use cases:<br>1. Prediction of the stability of materials to be used in solar cells<br>2. Identification of sparse dynamical laws<br>3. Embedding of knowledge graphs for link predictions | | |

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|---|---|
| **Literatur** | Mehryar Mohri, Afshin Rostamizadeh and Ameet Talwalkar: Foundations of Machine Learning, Second Edition. Cambridge, MA: MIT Press 2018<br>Roman Vershynin: High-Dimensional Probability, An Introduction with Applications in Data Science. Cambridge University Press 2018<br>Simon Foucart, Holger Rauhut: A Mathematical Introduction to Compressive Sensing. Springer Science & Business Media 2013 |

# Master Thesis (5171130)

*Master Thesis*

| **Art des Moduls** | **Sprache** | **SWS** | **ECTS** |
|---|---|---|---|
| Pflichtmodul | Deutsch/Englisch | 0 | 25 |
| **Häufigkeit** | **Dauer** | **Studiensemester** | **Lehr- und Lernformen** |
| Jedes Semester | 1 Semester | 3 | Seminar |
| **Modulverantwortung** | Prof. Dr.-Ing. Pascal Meißner | | |
| **Dozierende** | Prof. Dr. Arndt Balzer, Prof. Dr. Frank Deinzer, Prof. Dr. Frank-Michael Schleif, Prof. Dr. Magda Gregorová, Prof. Dr.-Ing. Pascal Meißner, Prof. Dr. Ivan Yamshchikov, Prof. Dr. Dominik Seuß, Prof. Dr. Andreas Lehrmann | | |
| **Verwendbarkeit** | Master Artificial Intelligence | | |
| **Aufwand** | *Gesamt* | *Präsenzzeit* | *Selbststudium* |
| | 750 | 0 | 750 |
| **Voraussetzungen** | *nach SPO*:<br>50 ECTS points<br>*empfohlen*: Regarding the actual writing of the thesis it is strongly recommended that the Scientific Seminar is already completed. | | |
| **Prüfung** | *Art der Prüfung*: Thesis<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | With the submission of a Master's thesis and the successful assessment, students document that they<br>have understood the teaching content of the previous semesters and are able to apply it to tasks independently and successfully.<br>They are able to derive an innovative research question on a selected research area, which includes a sufficiently<br>significant and as yet unresearched research field.<br>They can work on this research question largely independently with an appropriate and meaningful<br>research design and lead to an objectively comprehensible, reliable and valid result.<br>The written result is at the level of international standards of scientific publications and, upon successful completion, demonstrates the competences in terms of connectivity in the direction of doctoral projects. | | |
| **Modulinhalte** | Independent preparation of a thesis and processing of a theoretical or practical task according to scientific methods. | | |
| **Literatur** | Is provided based on the topic, but needs also to be<br>identified by the student as part of the master thesis. | | |

# Strong Artificial Intelligence (5171525)

*Strong Artificial Intelligence*

| **Art des Moduls**<br>Wahlpflichtmodul | **Sprache**<br>Englisch | **SWS**<br>4 | **ECTS**<br>5 |
|---|---|---|---|
| **Häufigkeit**<br>Unregelmäßig | **Dauer**<br>1 Semester | **Studiensemester**<br>3 | **Lehr- und Lernformen**<br>Seminar |
| **Modulverantwortung** | Prof. Dr. Dr. h. c. Robert Grebner | | |
| **Dozierende** | Prof. Dr. Dr. h. c. Robert Grebner | | |
| **Verwendbarkeit** | | | |
| **Aufwand** | *Gesamt*<br>150 | *Präsenzzeit*<br>60 | *Selbststudium*<br>90 |
| **Voraussetzungen** | *nach SPO*: Basic knowledge in the architecture of digital machines, formal languages, modeling notations and tools.<br>*empfohlen*: keine | | |
| **Prüfung** | *Art der Prüfung*: Mündliche Prüfung<br>*Art der Note*: Differenzierte Note | | |
| **Lernergebnisse** | Understand concepts, theories and architectures of thinking machines. Understand what these theories must deliver. | | |
| **Modulinhalte** | Strong artificial intelligence deals about the question how to design and build human like thinking machines. In the course we elaborate, what is needed to build a digital machine that is able to think and act like an individual and is able to interact with other individuals. A large number of interconnected and adopted concepts and theories are necessary to implement human like skills and behaviour. A selection of these, like theory of information, action, time and space as well as a theory of thinking is discussed and developed in the course. | | |
| **Literatur** | none | | |

# Modulverzeichnis