TECHNISCHE UNIVERSITÄT WIEN

Bachelor

Master

Doktorat

Universitäts-lehrgang

Studienplan (Curriculum)
für das

Masterstudium

Logic and Artificial Intelligence

UE 066 931

Technische Universität Wien
Beschluss des Senats der Technischen Universität Wien
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§ 1 Grundlage und Geltungsbereich

Der vorliegende Studienplan definiert und regelt das ingenieurwissenschaftliche, englischsprachige Masterstudium *Logic and Artificial Intelligence* an der Technischen Universität Wien. Es basiert auf dem Universitätsgesetz 2002 - UG (BGBl. I Nr. 120/2002 idgF. und den „Studienrechtlichen Bestimmungen“ der Satzung der Technischen Universität Wien in der jeweils geltenden Fassung. Die Struktur und Ausgestaltung des Studiums orientieren sich an folgendem Qualifikationsprofil (§2).

§ 2 Qualifikationsprofil

Das Masterstudium *Logic and Artificial Intelligence* vermittelt eine vertiefte, wissenschaftlich und methodisch hochwertige, auf dauerhaftes Wissen ausgerichtete Bildung, welche die Absolvent_innen sowohl für eine Weiterqualifizierung vor allem im Rahmen eines facheinschlägigen Doktoratsstudiums als auch für eine Beschäftigung in beispielsweise folgenden Tätigkeitsbereichen befähigt und international konkurrenzfähig macht:

- in der Grundlagenforschung im universitären und industriellen Bereich;
- in angewandter Forschung und Entwicklung in Industrieunternehmen und universitären Spin-Offs, mit Blickrichtung der Verwendung logikbasierter Ansätze, maschinellen Lernen und von Methoden der künstlichen Intelligenz in Gebieten wie Formal Systems Engineering, Web und Semantic Systems, Logistik, Operations Research, Produktion, Sicherheit, und Telekommunikation; sowie
- für Analyse und Consulting in diesen Gebieten.

Nach entsprechender operationeller Qualifikation sind die Absolventinnen und Absolventen in der Lage leitende Positionen zu übernehmen.

Aufgrund der beruflichen Anforderungen werden im Masterstudium *Logic and Artificial Intelligence* Qualifikationen hinsichtlich folgender Kategorien vermittelt.

Fachkompetenzen Aufbauend auf einem einschlägigen Bachelorstudium werden, neben fortgeschrittenen Kenntnissen im Bereich der Informatik und einem kritischen Verständnis ihrer Theorien und Grundsätze, Kenntnisse in folgenden Teilbereichen der Logik und künstlichen Intelligenz vermittelt:

- Logik;
- Berechenbarkeit, Algorithmen und Komplexität;
- diskrete Mathematik und theoretische Informatik;
- logikbasierte künstliche Intelligenz;
- maschinelles Lernen;
- künstliche Intelligenz und Gesellschaft; sowie
- sichere und vertrauenswürdige Systeme.

Besonderes Augenmerk wird auf die Rolle von logikbasierten Methoden für die Entwicklung von Theorien und Systemen in einer abstrakten, symbolorientierten Sicht gelegt,

aber auch auf die Verbindung dieser Sicht mit einem datengetrieben Ansatz, der im Bereich der subsymbolischen künstlichen Intelligenz wie neuronaler Netzwerke und maschinellem Lernen vorherrscht. Desweiteren werden Aspekte der künstlichen Intelligenz im Kontext von Mensch und Gesellschaft vermittelt, wie Interaktion, Normen und Ethik, Nachhaltigkeit und Umwelt, sowie Kenntnisse über die Entwicklung von Systemen, die sicher und vertrauenswürdig sind, unter Verwendung von formalen Methoden aus diesem Bereich.

Überfachliche Kompetenzen Durch die praktische und theoretische Auseinandersetzung mit aktuellen Technologien und Methoden werden folgende Fertigkeiten vermittelt:

- Analyse komplexer Aufgabenstellungen auf Basis formaler, mathematischer und logikbasierter Methoden, sowie Lösung und praktische Umsetzung derselben;
- Weiterentwicklung formal-mathematischer Methoden;
- wissenschaftlich fundiertes Vorgehen;
- logisch-mathematisches Abstraktionsvermögen und Methodik;
- Lösung und praktische Umsetzung von Aufgabenstellungen mit allfälliger Systementwicklung;
- Entscheidungsverantwortung und Führungskompetenz;
- Kommunikationsfähigkeit;
- Fähigkeit zur kritischen Reflexion des Status Quo und des eigenen Handelns.

§ 3 Dauer und Umfang

Der Arbeitsaufwand für das Masterstudium *Logic and Artificial Intelligence* beträgt 120 ECTS-Punkte. Dies entspricht einer vorgesehenen Studiendauer von 4 Semestern als Vollzeitstudium.

ECTS-Punkte (ECTS) sind ein Maß für den Arbeitsaufwand der Studierenden. Ein Studienjahr umfasst 60 ECTS-Punkte, wobei ein ECTS-Punkt 25 Arbeitsstunden entspricht (gemäß § 54 Abs. 2 UG).

§ 4 Zulassung zum Masterstudium

Die Zulassung zum Masterstudium *Logic and Artificial Intelligence* setzt den Abschluss eines fachlich in Frage kommenden Bachelorstudiums oder eines anderen fachlich in Frage kommenden Studiums mindestens desselben hochschulischen Bildungsniveaus an einer anerkannten inländischen oder ausländischen postsekundären Bildungseinrichtung voraus. Ein Studium kommt fachlich in Frage, wenn mindestens 120 ECTS aus den Fachgebieten Mathematik und Informatk absolviert wurden, davon mindestens

1. 25 ECTS aus Mathematik und Statistik, sowie den theoretischen Grundlagen der Informatik, mit vermittelten Kenntnissen, Fertigkeiten und Kompetenzen entsprechend den Modulen *Algebra und Diskrete Mathematik*, *Analysis*, *Statistik und*

Wahrscheinlichkeitstheorie, sowie *Theoretische Informatik* des Bachelorstudiums *Informatik* an der TU Wien;

2. 20 ECTS aus Algorithmen, Datenstrukturen und Programmierung, mit vermittelten Kenntnissen, Fertigkeiten und Kompetenzen entsprechend den Modulen *Algorithmen und Datenstrukturen*, *Einführung in die Programmierung* sowie *Programmierparadigmen* des Bachelorstudiums *Informatik* an der TU Wien.

Jedenfalls ohne Ergänzungsprüfungen zuzulassen sind Absolvent_innen der Bachelorstudien *Informatik*, *Medieninformatik und Visual Computing*, *Medizinische Informatik*, *Software & Information Engineering*, *Technische Informatik*, *Wirtschaftsinformatik*, *Technische Mathematik*, *Statistik und Wirtschaftsmathematik* und *Finanz- und Versicherungsmathematik* der Technischen Universität Wien.

Zum Ausgleich wesentlicher fachlicher Unterschiede können Ergänzungsprüfungen im Ausmaß von maximal 30 ECTS-Punkten vorgeschrieben werden, die bis zum Ende des zweiten Semesters des Masterstudiums abzulegen sind. Diese können im Ausmaß von maximal 4,5 ECTS im Modul *Freie Wahlfächer und Transferable Skills* als freie Wahlfächer, jedoch nicht als Transferable Skills verwendet werden.

Die Unterrichtssprache ist Englisch. Studienwerber_innen, deren Erstsprache nicht Englisch ist, haben die erforderlichen Sprachkenntnisse nachzuweisen. Die Form des Nachweises ist in einer Verordnung des Rektorats festgelegt.

Manche Wahllehrveranstaltungen können auf Deutsch angeboten werden. Für diese werden Deutschkenntnisse nach Referenzniveau B1 des Gemeinsamen Europäischen Referenzrahmens für Sprachen empfohlen.

§ 5 Aufbau des Studiums

Die Inhalte und Qualifikationen des Studiums werden durch *Module* vermittelt. Ein Modul ist eine Lehr- und Lerneinheit, welche durch Eingangs- und Ausgangsqualifikationen, Inhalt, Lehr- und Lernformen, den Regelarbeitsaufwand sowie die Leistungsbeurteilung gekennzeichnet ist. Die Absolvierung von Modulen erfolgt in Form einzelner oder mehrerer inhaltlich zusammenhängender *Lehrveranstaltungen*. Thematisch ähnliche Module werden zu *Prüfungsfächern* zusammengefasst, deren Bezeichnung samt Umfang und Gesamtnote auf dem Abschlusszeugnis ausgewiesen wird.

Prüfungsfächer und zugehörige Module

Das Masterstudium *Logic and Artificial Intelligence* gliedert sich in nachstehende Prüfungsfächer mit den ihnen zugeordneten Modulen. Die mit (∗) markierten Module sind *Wahl-*, die anderen *Pflichtmodule*. Die Pflichtmodule sind in jedem Fall zu absolvieren. Desweiteren ist mindestens ein Modul aus dem Prüfungsfach *Artificial Intelligence and Society* oder *Safe and Trustworthy Systems* zu wählen, sowie mindestens zwei Seminare aus dem Prüfungsfach *Methods in Logic and Artificial Intelligence*. Insgesamt sind in den Pflicht- und Wahlmodulen mit Ausnahme des Moduls *Freie Wahlfächer und Transferable*

Skills Lehrveranstaltungen im Umfang von mindestens 81 ECTS zu absolvieren. Im Modul *Freie Wahlfächer und Transferable Skills* sind so viele Lehrveranstaltungen zu absolvieren, dass ihr Umfang zusammen mit der Diplomarbeit sowie dem Umfang der in den übrigen Pflicht- und Wahlmodulen gewählten Lehrveranstaltungen 120 ECTS oder mehr ergibt. Werden in den übrigen Pflicht- und Wahlmodulen insgesamt mehr als 81 ECTS absolviert, können im Modul *Freie Wahlfächer und Transferable Skills* im gleichen Ausmaß weniger ECTS absolviert werden, jedoch sind darin mindestens 4,5 ECTS aus dem Bereich der Transferable Skills zu absolvieren.

Logic and Theory

Discrete Mathematics (6,0 ECTS)
Logic and Computability (6,0 ECTS)
∗Automata and Logic (6,0 ECTS)
∗Automated Deduction (6,0 ECTS)
∗Database Theory (6,0 ECTS)
∗Decidable Logics for Knowledge and Data (6,0 ECTS)
∗Deontic Logic for Normative Reasoning (6,0 ECTS)
∗Gödel's Incompleteness Theorems (4,5 ECTS)
∗History of Logic (6,0 ECTS)
∗Logical Foundations of Inductive Theorem Proving (4,5 ECTS)
∗Modal Logics (6,0 ECTS)
∗Nonclassical Logics (6,0 ECTS)
∗Nonstandard Deduction Systems (6,0 ECTS)
∗Proof Theory (6,0 ECTS)
∗Quantum Computing (6,0 ECTS)
∗SAT Algorithms, Applications and Extensions (6,0 ECTS)

Algorithms and Complexity

Algorithmics (6,0 ECTS)
∗Advanced Research in Algorithmics (6,0 ECTS)
∗Algorithmic Encoding Techniques (6,0 ECTS)
∗Algorithmic Geometry (6,0 ECTS)
∗Algorithms in Graph Theory (6,0 ECTS)
∗Beyond Exact Algorithms (6,0 ECTS)
∗Complexity Theory (6,0 ECTS)
∗Fixed-Parameter Algorithms and Complexity (6,0 ECTS)
∗Graph Drawing Algorithms (6,0 ECTS)
∗Heuristic Optimization Techniques (6,0 ECTS)
∗Mathematical Programming and Optimization in Transport Logistics (6,0 ECTS)
∗Structural Decompositions and Meta Theorems (6,0 ECTS)

Symbolic Artificial Intelligence

Logic-based Artificial Intelligence (6,0 ECTS)
∗Abstract Argumentation (6,0 ECTS)
∗Algorithmic Social Choice (6,0 ECTS)
∗Knowledge Graphs (6,0 ECTS)
∗Management of Graph Data (6,0 ECTS)
∗Nonmonotonic Reasoning (6,0 ECTS)
∗Preferences in Artificial Intelligence (6,0 ECTS)
∗Principles of Knowledge Representation (6,0 ECTS)
∗Probabilistic Reasoning (6,0 ECTS)
∗Problem Solving and Search in Artificial Intelligence (6,0 ECTS)
∗Processing of Declarative Knowledge (6,0 ECTS)
∗Theory of Graph Data (6,0 ECTS)

Machine Learning

Machine Learning (6,0 ECTS)
∗Advanced Reinforcement Learning (6,0 ECTS)
∗Algorithms for Data Science (6,0 ECTS)
∗Applied Generative AI and LLM-based Systems (6,0 ECTS)
∗Deep Learning for Natural Language Processing (6,0 ECTS)
∗Generative AI (6,0 ECTS)
∗Machine Learning for Optimization (6,0 ECTS)
∗Neurosymbolic Reasoning (6,0 ECTS)
∗Reinforcement Learning (6,0 ECTS)
∗Stochastic Foundations of Cyber-Physical Systems (6,0 ECTS)
∗Theoretical Foundations and Research Topics in Machine Learning (6,0 ECTS)
∗Theoretical Foundations of Deep Learning (6,0 ECTS)

Artificial Intelligence and Society

∗AI Ethics (6,0 ECTS)
∗Critical Algorithm Studies (6,0 ECTS)
∗Critical Theory of Media and Informatics (6,0 ECTS)
∗Digital Humanism (3,0 ECTS)
∗Explainable AI (6,0 ECTS)
∗Human-Centered AI (6,0 ECTS)
∗Information Visualization (6,0 ECTS)
∗Introduction to Computational Sustainability (6,0 ECTS)
∗Responsible Digital Ethics (6,0 ECTS)
∗Virtual and Augmented Reality (6,0 ECTS)

Safe and Trustworthy Systems

∗Advanced Cryptography (6,0 ECTS)
∗Advanced Privacy Enhancing Technologies (6,0 ECTS)
∗Computer-Aided Verification (6,0 ECTS)
∗Cryptocurrencies (6,0 ECTS)
∗Formal Methods for Security and Privacy (6,0 ECTS)
∗Formal Methods in Systems Engineering (6,0 ECTS)
∗Program Analysis (6,0 ECTS)
∗Smart Contracts (6,0 ECTS)
∗Symmetric Cryptography (6,0 ECTS)

Methods in Logic and Artificial Intelligence

∗Seminar in Logic (3,0 ECTS)
∗Seminar in Artificial Intelligence (3,0 ECTS)
∗Seminar in Theoretical Computer Science (3,0 ECTS)
∗Project in Logic and Artificial Intelligence (6,0–12,0 ECTS)

Extension

∗Extension (up to 12,0 ECTS)

Freie Wahlfächer und Transferable Skills

Freie Wahlfächer und Transferable Skills (9,0 ECTS)

Diplomarbeit

Siehe Abschnitt § 9.

Kurzbeschreibung der Module

Dieser Abschnitt charakterisiert die Module des Masterstudiums *Logic and Artificial Intelligence* in Kürze. Eine ausführliche Beschreibung ist in Anhang A zu finden.

Abstract Argumentation (6,0 ECTS) The module discusses the central properties of Dung's abstract argumentation frameworks, including different semantics for abstract argumentation, properties and complexity of argumentation, and generalizations of Dung's abstract argumentation frameworks.

Advanced Cryptography (6,0 ECTS) Modern cryptography extends far beyond basic concepts like encryption and authentication to meet today's demands for security and privacy and this course presents such advanced topics. We cover the *provable security* paradigm, which yields rigorous security guarantees for practical cryptographic schemes. After introducing *elliptic-curve cryptography*, we discuss advanced forms of encryption. We

intensively study *zero-knowledge proofs*, a general method for showing compliance while preserving privacy. We also touch on *secure multi-party computation* and *lattice-based cryptography*, which provides security against quantum computers.

Advanced Privacy Enhancing Technologies (6,0 ECTS) This module equips students with state-of-the-art techniques, such as differential privacy, secret sharing, and secure multi-party computation, that enable secure data processing without compromising confidentiality. These methods allow sensitive data to be utilized in AI applications and analytics while ensuring strong privacy guarantees, addressing key concerns in sectors like healthcare, finance, and social media. By bridging the gap between privacy protection and data utility, the lecture prepares students to tackle modern challenges in balancing ethical data usage with technological advancement.

Advanced Reinforcement Learning (6,0 ECTS) This module covers advanced topics in reinforcement learning. Regarding algorithms, distributional reinforcement learning and distributional deep reinforcement learning are discussed. Reinforcement learning plays the crucial role in the development of large language models (LLMs) such as ChatGPT and DeepSeek-R1; these algorithms are presented as well. Convergence proofs of important algorithms are given. In the tutorial part, students present the theory of recent algorithms in detail or implement learning algorithms for complex environments.

Advanced Research in Algorithmics (6,0 ECTS) This module introduces students to research-oriented work in algorithmics. Students engage with selected topics from fields such as computational social choice, algorithmic game theory, computational geometry, graph algorithms, and approximation techniques, developing skills in literature analysis, critical thinking, and research formulation.

AI Ethics (6,0 ECTS) With the rapid developments in Artificial Intelligence (AI), we find an inevitable increase in AI's impact on our lives, posing various ethical challenges for developers, policy-makers, and society at large. This has led to a general awareness that AI systems must be aligned with human values, ethics, and laws. This module introduces various ways in which ethics and AI meet. It enables students to develop basic skills for identifying and critically reflecting on AI-specific ethical challenges, and for incorporating critical thinking on these topics in their work and further studies.

Algorithmic Encoding Techniques (6,0 ECTS) This module explores advanced techniques for solving complex computational problems through encoding into established target formalisms. The module focuses on methodological approaches to problem encoding, including satisfiability, maximum satisfiability, and constraint programming. Students learn systematic encoding strategies and techniques for improving solving efficiency, with emphasis on correctness certification and handling dynamic problem instances.

Algorithmic Geometry (6,0 ECTS) Algorithmic geometry deals with efficient computations on basic geometric objects such as points, lines, polygons, and their higher-level analogs. Geometric algorithms play an important role in a variety of applications, e.g., visual computing, geographic information systems, machine learning, robotics, etc. This module studies the design and analysis of geometric algorithms and efficient data struc-

tures. We present fundamental techniques and concepts in algorithmic geometry as well as more advanced results and discuss selected geometric problems arising in applications.

Algorithmic Social Choice (6,0 ECTS) Computational social choice studies algorithmic and computational aspects of collective decision-making processes, including voting, fair division, and matching problems. It provides fundamental tools for addressing fairness, efficiency, and strategic behavior in group decisions. Applications arise in political elections, resource allocation, multi-agent systems, and online platforms. This module introduces key concepts in computational social choice, covering preference aggregation, complexity analysis, and algorithmic techniques. We study fundamental problems as well as selected advanced topics, with emphasis on both theoretical foundations and algorithmic solutions.

Algorithmics (6,0 ECTS) This module thoroughly treats advanced algorithms and data structures, emphasizing theoretical foundations and algorithm analysis. The module focuses on mathematical methods for analyzing computational problems and developing efficient algorithmic solutions. Students learn to understand and prove the correctness and efficiency of algorithms through formal mathematical methods.

Algorithms for Data Science (6,0 ECTS) This module introduces fundamental algorithms for analyzing large amounts of data. It is based on important results of the algorithms community which are widely recognized for their practical applications in data science. The module will cover algorithms for questions, such as: How can one find duplicate pages on the web? How can one detect communities in social networks? How can we embed high-dimensional data into low-dimensional spaces, to analyze data more efficiently? The module's focus will be on the underlying algorithmic principles and the theoretical algorithm analysis, i.e., we will prove that these algorithms work and why. We will also (to a lesser extent) consider use-cases of these algorithms in practice.

Algorithms in Graph Theory (6,0 ECTS) This module provides a thorough theoretical treatment of graph algorithms and their mathematical foundations. The module focuses on fundamental concepts in graph theory and their algorithmic aspects. Students learn to develop and analyze algorithmic solutions through formal mathematical methods.

Applied Generative AI and LLM-based Systems (6,0 ECTS) This module focuses on the practical implementation and integration of generative AI systems. It introduces modern model architectures such as mixture-of-experts, advanced optimization techniques including parameter-efficient tuning, and integration patterns such as tool use, function calling, or agentic systems. Through practical group projects, this module aims to transfer theoretical understanding to practical implementations of generative AI systems.

Automata and Logic (6,0 ECTS) This module provides an introduction to the interplay between automata theory, logic, and algebra, three foundational pillars of theoretical computer science. Students will explore how automata serve as computational models for languages and systems, how logic provides precise tools for specifying and reasoning about them, and how algebraic methods unify and deepen our understanding of both.

Automated Deduction (6,0 ECTS) The reasoning power that computational logic offers brings new perspectives in the field of system verification and certification. This module is about computational logic, with particular focus on algorithmic and automated methods for proving logical properties expressed in first-order logic with equality. Such properties naturally model safety/security assumptions on computer systems; for example memory accesses are naturally modeled using unbounded data structures, and hence quantifiers. The module aims at teaching attendees algorithmic techniques and fundamental results in first-order theorem proving for logic with equality. We will address both the theoretical and practical aspects for using and implementing reasoning engines for such logic.

Beyond Exact Algorithms (6,0 ECTS) Exact algorithms always give the correct answer or provide optimal solutions but they can be complex and computationally intensive. This module explores alternatives to exact algorithms through the study of randomized and approximation algorithms. Such algorithms can be significantly simpler and more efficient by either making controlled random decisions during execution or finding near-optimal solutions. The module covers design principles and analysis methods for both paradigms, including probabilistic performance guarantees, approximation ratios, and running-time bounds.

Complexity Theory (6,0 ECTS) When developing algorithms for different problems, it turns out that some problems admit efficient algorithms while others don't. Complexity theory provides tools that allow us to explain why for a given problem no "better" algorithm can be expected, where "better" typically means faster or with less memory consumption. It may also mean that a problem is better suited for parallel processing than others.

Computer-Aided Verification (6,0 ECTS) This module focuses on the automated verification of hardware and software systems using model checking techniques. It covers specification languages for system properties, system models, and verification algorithms.

Critical Algorithm Studies (6,0 ECTS) This module takes an interdisciplinary approach to examining the ethical, social, and political dynamics of algorithmic systems. It explores how algorithms influence society, focusing on issues like bias, fairness, transparency, accountability, and trust and safety. Through theoretical and practical discussions, students critically assess the harms and safeguards of algorithms in real-world settings, tackling challenges such as misinformation, extremist content, and online harassment. The module also includes a final report where students design technical or policy-based solutions to mitigate algorithmic harms.

Critical Theory of Media and Informatics (6,0 ECTS) This module enables students to develop an understanding of technology and media in society through a critical theory lens. A philosophical foundation is provided, discussing a wide range of thinkers and their central ideas. Students will be able to discuss cutting edge trends in digital technology and media along perspectives such as power, oppression, meaning, culture and the political dimensions of technology. They will further learn how to translate such

critical thinking into a future oriented design practice to develop alternative technological futures.

Cryptocurrencies (6,0 ECTS) The module provides in-depth knowledge on the foundations of blockchain technologies.

Database Theory (6,0 ECTS) This module delves into the theoretical foundations of databases, emphasizing the expressive power, computational complexity, and formal properties of query languages and data models. Students will explore topics such as the semantics of query languages, reasoning with integrity constraints, decidability, and optimization from a mathematical perspective.

Decidable Logics for Knowledge and Data (6,0 ECTS) This module explores decidable fragments of classical first-order logic, focusing on their computational complexity, reasoning techniques, and applications. Students will learn to formulate well-structured logical expressions in different fragments, classify them within specific fragments, and apply appropriate reasoning algorithms. The considered fragments include description logics, guarded fragments, bounded variable fragments, counting quantifiers, quantifier prefix fragments, and restrictions that reduce the complexity, such as Horn-ness.

Deep Learning for Natural Language Processing (6,0 ECTS) This module provides an in-depth introduction to deep learning for natural language processing (NLP). Students will explore fundamental and advanced deep learning techniques for NLP applications, including theoretical concepts and practical implementations using PyTorch.

Deontic Logic for Normative Reasoning (6,0 ECTS) This module deals with normative reasoning and its logic, the focus being on logical semantics. It provides advanced training in using logical formalisms as tools for the specification of norms. It also introduces students to topics in AI and ethics and in AI and law, where norms are used.

Digital Humanism (3,0 ECTS) The module deals with topics that describe, analyze, and, most importantly, influence the complex interplay of technology and humankind, for a better society and life, fully respecting universal human rights.

Discrete Mathematics (6,0 ECTS) The module presents a tour through various topics of advanced discrete mathematics ranging from algebraic graph theory and combinatorics over number theory to algebra as well as some applications of the theory. It consists of a lecture part and an exercise part in small groups. The exercise part serves for deepening the understanding, creating crosslinks between the module topics and developing the ability to design formal mathematical proofs.

Explainable AI (6,0 ECTS) The module discusses the theory of explanation, central challenges, existing methods in various AI subfields (including symbolic and subsymbolic AI), and some applications. Specific topics covered are visualization techniques for explainable AI (XAI), symbolic XAI methods in knowledge representation and reasoning (computational argumentation based approaches), recent XAI work using interactive

dialogue models, as well as challenges for XAI techniques with respect to trustworthiness, bias, and correctness.

Extension (up to 12,0 ECTS) This module allows students to extend their profile either by choosing courses from other Master curricula that fit the qualification profile of *Logic and Artificial Intelligence*.

Fixed-Parameter Algorithms and Complexity (6,0 ECTS) Fixed-parameter algorithms provide a powerful approach for efficiently solving many NP-hard problems by exploiting structural aspects of problem instances in terms of a problem parameter. This module provides an overview of the main techniques for developing fixed-parameter algorithms as well as the fundamentals of parameterized complexity theory.

Formal Methods for Security and Privacy (6,0 ECTS) The module provides in-depth knowledge on the formal methods used in industry and academia to certify the security and privacy of software, cryptographic protocols, blockchains, machine learning, and more.

Formal Methods in Systems Engineering (6,0 ECTS) Ensuring system reliability became mandatory in our digital world. The area of formal methods provide rigorous arguments to prove that systems have no errors and behave as expected. Yet, there are theoretical results showing that there is no "one" formal approach that can be used for every system error, in every technology. This module focuses for software and hardware systems and presents formal methods for ensuring trustworthiness of such systems. We address SAT/SMT solving, deductive program verification, model checking, and static code analysis. Module concepts will be demonstrated using fully automated tools, allowing students to practice and consolidate their knowledge in formal methods for efficient systems engineering.

Freie Wahlfächer und Transferable Skills (9,0 ECTS) Die Lehrveranstaltungen dieses Moduls dienen der Vertiefung des Faches sowie der Aneignung außerfachlicher Kenntnisse, Fähigkeiten und Kompetenzen.

Generative AI (6,0 ECTS) Generative AI has brought fundamental paradigm shifts in AI and beyond. This module provides a comprehensive introduction to both theoretical foundations and practical applications of it. The module explores principles of generative AI around language modeling, image generation, multimodal systems and discusses intersections between generative AI and other research areas such as knowledge-based architectures and recommender systems. Besides theoretical foundations, it covers practical implementation aspects such as prompt engineering, retrieval-augmented generation, and modern tooling/frameworks. Finally, the module also addresses crucial ethical considerations and societal implications of generative AI systems.

Gödel's Incompleteness Theorems (4,5 ECTS) In this lecture, we will prove one of the most important results mathematical logic, Gödel's incompleteness theorems. In doing so, we will not take the most direct route, instead we take the incompleteness theorems as motivation to study topics and proof techniques in their vicinity, like diagonalisation and arithmetisation.

Graph Drawing Algorithms (6,0 ECTS) Graph drawing is concerned with the geometric representation of graphs in the plane and constitutes the algorithmic core of network visualization. The research area of graph drawing combines aspects of algorithmics, graph theory, computational geometry, and visualization. In this module we define common aesthetic quality criteria and layout styles in graph drawing. Subsequently, we study the corresponding optimization problems from a formal, algorithmic perspective. We cover some of the most fundamental graph drawing algorithms, ranging from general-purpose algorithms to specific algorithms for certain graph classes (e.g., trees and planar graphs). The algorithms use known algorithm design principles such as divide-and-conquer, incremental constructions, and network flow models. The module covers both practical and theoretical aspects of graph drawing.

Heuristic Optimization Techniques (6,0 ECTS) This module deals with algorithmic techniques to heuristically solve practicably challenging optimization problems in reasonable time.

History of Logic (6,0 ECTS) This module provides an overview about the historical development of key contributions of logic, ranging from Aristotle to modern logic. Particular emphasis is given on the discussion of how the central concepts of logic have been introduced in their original form, on the respective historical context, as well as on relations between the original formulations and their modern counterpart.

Human-Centered AI (6,0 ECTS) This module provides foundational knowledge of user interfaces, "human in the loop" systems, and artificial intelligence, including supervised and unsupervised learning, as well as reinforcement learning. Students will explore key domains of human-AI interaction, such as recommender systems, chatbots, intelligent text entry, explainable AI, user modeling, and personalized and adaptive user interfaces.

Information Visualization (6,0 ECTS) This module covers theoretical concepts and practical applications of information visualization, which is defined as the use of computer-supported, interactive, visual representations of abstract data to amplify cognition.

Introduction to Computational Sustainability (6,0 ECTS) This lecture addresses the urgent need to align the rapid growth of technology and computing with the pressing challenges of environmental, societal, and economic sustainability.

Knowledge Graphs (6,0 ECTS) Knowledge graphs combine scalable graph data management with both symbolic AI (e.g., logic-based) and subsymbolic AI (i.e., machine learning). Key techniques are logic-based reasoning, knowledge graph embeddings, graph neural networks, and graph transformers. An overarching aim of the module is to understand the connections between knowledge graphs, artificial intelligence, neuro-symbolic AI, Machine Learning, Deep Learning and Data Science.

Logical Foundations of Inductive Theorem Proving (4,5 ECTS) Automated inductive theorem proving is an area of research that is concerned with the development of algorithms which find proofs by induction automatically. In this module, the logical

foundations of this topic are studied. We use proof-theoretic and model-theoretic methods to analyse common approaches and algorithms in terms of mathematical logic. The emphasis is on delineating the strength and capabilities of these methods.

Logic and Computability (6,0 ECTS) The module aims at a consolidation as well as an extension of skills and knowledge in mathematical logic and computability theory acquired at the bachelor level. It provides advanced training in using logical formalisms as tools for specification and problem-solving across diverse applications. Among other things, students will study various logical systems for proof search, explore elements of modal and intuitionistic logic, and gain a deeper understanding of computability, including its connections to logic, program verification, and complexity theory.

Logic-based Artificial Intelligence (6,0 ECTS) This module provides an advanced introduction to logic-based artificial intelligence. The students will learn selected logic formalisms used to represent complex domains of interest and the computational methods for deriving conclusions from these representations. By discussing both theoretical principles and practical techniques, the module aims to prepare students for advanced applications and research in AI. The module begins by introducing predicate logic as a specification language, and then moves on to description logics (DL) for representing ontological knowledge. The students will learn the basics of DL reasoning; special attention will be given to the description logic EL popular in biomedical informatics. The students will learn the principles behind nonmonotonic reasoning, and become acquainted with answer-set programming and its application for declarative problem solving in combinatorial domains. Students will learn the foundations of probabilistic reasoning and, finally, rule learning, bridging the gap between logical inference and data-driven learning. By the end of the module, students will have developed both theoretical expertise and practical skills, enabling them to deploy logic-based AI solutions to solve problems in different domains.

Machine Learning (6,0 ECTS) The module provides a broad introduction to fundamental topics in machine learning. It covers core concepts of machine learning, the basics of machine learning theory, and the main techniques in supervised learning, unsupervised learning, and reinforcement learning.

Machine Learning for Optimization (6,0 ECTS) Combinatorial optimization problems arise in various domains, and solving them is crucial to improve efficiency and resource consumption. Traditionally, such problems have been solved using exact methods and heuristic techniques. In recent years, machine learning approaches have been developed and used to improve traditional solvers and to directly solve such problems. This module provides an introduction to methods for solving combinatorial optimization problems based on machine learning. It includes various learning approaches based on supervised learning, reinforcement learning, and large language models for hard combinatorial optimization problems.

Management of Graph Data (6,0 ECTS) Graph data, such as knowledge graphs, plays a pivotal role in numerous cutting-edge applications, including graph analytics, data integration, and machine learning. However, managing graph data effectively requires

navigating a diverse landscape of technologies and selecting the right methods to meet specific application requirements. This module provides a comprehensive introduction to the principles, technologies, and advanced topics in graph data management. Students will explore popular graph data models, query languages, and management systems, covering topics such as query formulation, query optimization, schema design, provenance, data integration, and dynamic updates. By completing the module, participants will be well-equipped to apply graph data technologies in real-world scenarios and engage with emerging trends in this rapidly evolving field.

Mathematical Programming and Optimization in Transport Logistics (6,0 ECTS) This module covers the theory and practice of solving challenging optimization problems by means of mathematical programming techniques, in particular integer linear programming methods. While highly relevant in many application areas, a particular focus is put on optimization problems in transport logistics.

Modal Logics (6,0 ECTS) The module discusses different families of modal logics, both from a semantical as well as from a proof-theoretical point of view. Besides the standard normal modal logics, also non-normal and multimodal logics will be considered. Concerning the proof theory of modal logics, the module will cover Hilbert-type axiomatisations, sequent-style systems, tableaux, and natural deduction methods. The module will also deal with first-order modal logics as well as different application areas of modal logics like modeling dishonest agents.

Neurosymbolic Reasoning (6,0 ECTS) This module introduces methods and techniques to combine symbolic and subsymbolic AI. While symbolic AI builds on logic and deals with structured data, subsymbolic AI (encompassing modern machine learning methods like neural networks) deals with unstructured data (like images and natural language) and builds on probabilistic and analysis based methods. Neurosymbolic AI combines these two approaches and is targeted at problems that require dealing with reasoning, uncertainty and unstructured data. The module will also consider logical expressivity of AI approaches, models of their combinations, algorithms and methods for evaluation, as well as selected applications.

Nonclassical Logics (6,0 ECTS) The module provides an overview of concepts, methods, and results in different areas of the vast field of nonclassical logics. In particular, the following topics are covered: general theory of modal logics, epistemic logic, elements of intuitionistic logic, and mathematical fuzzy logics.

Nonmonotonic Reasoning (6,0 ECTS) Nonmonotonic reasoning deals with the formalisation of human commonsense reasoning, typically in the form of reasoning under incomplete information. This module discusses the most important nonmonotonic reasoning formalisms, the central properties of nonmonotonic inference relations, as well as the proof theory of different nonmonotonic logics.

Nonstandard Deduction Systems (6,0 ECTS) Traditional proof calculi deal with the axiomatization of the *valid formulas* of a logic. However, one can also have an alternative point of view and devise proof systems which axiomatize the *invalid formulas* of a logic,

or which axiomatize *contingent formulas* (i.e., formulas which are invalid yet satisfiable in a given logic). The former kind of calculi were first studied by Jan Łukasiewicz and are referred to as *rejection systems* or *complementary calculi*. In this module, different such nonstandard deduction systems for a variety of different logics are studied, as well as applications of such systems for logics in artificial intelligence.

Preferences in Artificial Intelligence (6,0 ECTS) Preferences are ubiquitous. They determine our decisions, from simple everyday decisions (such as having tea or coffee, or ordering another glass of beer) to much more fundamental decisions (such as accepting a job offer, getting married, political participation). Preferences also play a tremendous role in many applications, such as logic programming, multi-agent systems, diagnosis etc. Given this, it is far from surprising that various subfields of artificial intelligence (AI) have come up with models for representing preferences and for reasoning and decision making based on these models. Whereas classical decision theory is based on a numerical representation of preferences (utilities), more recently qualitative as well as mixed qualitative/quantitative models of preferences have been a major focus of research.

Principles of Knowledge Representation (6,0 ECTS) The module deals with topics that arise in the context of knowledge representation and reasoning at a foundational level, such as changing knowledge bases, dealing with actions and planning, nonmonotonic and abductive reasoning, and distributed knowledge. In addition to approaches and techniques for dealing semantically with these issues, the module also considers computational and expressiveness aspects that arise with them.

Probabilistic Reasoning (6,0 ECTS) The module gives an overview on the area of probabilistic modeling and reasoning in artificial intelligence.

Problem Solving and Search in Artificial Intelligence (6,0 ECTS) Solving logical problems and complex real-world constraint satisfaction and optimization problems requires strong problem solving skills. While experienced human experts can often find good solutions for small problems, efficiently solving large-scale problems and automating problem-solving are important goals of AI. This module covers core topics in AI problem solving including problem modeling, AI-based exact and heuristic search techniques, learning in search, and hybrid approaches. It also demonstrates the application of these techniques in various practical domains, including planning and scheduling.

Processing of Declarative Knowledge (6,0 ECTS) This module introduces methods and techniques for declarative knowledge processing. In this paradigm, knowledge and problem specifications can be expressed using sentences in symbolic languages, while specialized reasoning engines can be used to process these sentences. Unlike procedural approaches, which require programmers to explicitly define how computations should be performed, declarative methods allow reasoning systems to determine the necessary computations based on the input specification. This distinction makes declarative methods a powerful alternative to procedural approaches. By separating problem specifications and domain knowledge from implementation details, declarative methods offer benefits such as improved solution quality, reusability, transparency, and explicability.

Program Analysis (6,0 ECTS) This module provides an in-depth introduction to program analysis, a set of techniques and tools for automatically reasoning about the behavior and properties of software programs. We will explore foundational concepts, including static analysis, program semantics, abstract interpretation, and type systems, along with their applications in verification, optimization, and software quality.

Project in Logic and Artificial Intelligence (6,0–12,0 ECTS) In this module, practical problems from the field of logic and/or artificial intelligence are solved. This gives insights into scientific practice and current research in these areas. For working on larger problems, the two practical projects can be combined.

Proof Theory (6,0 ECTS) The module deals with the elementary results in proof theory, like cut-elimination in sequent-type calculi, intuitionistic logic, interpolation theorems, and the second consistency proof of Gentzen, natural deduction systems, higher-order logics, and provability logics.

Quantum Computing (6,0 ECTS) This module provides the fundamental concepts of quantum computers and discusses both basic as well as advanced quantum algorithms and quantum complexity classes. Moreover, it covers issues related to quantum information, cryptography, and quantum teleportation. Necessary preliminaries from mathematics and quantum mechanics are provided also.

Reinforcement Learning (6,0 ECTS) Reinforcement learning is the field of machine learning that is concerned with the control of time-dependent systems. It can also be described as stochastic optimal control, or as dynamic programming plus learning. It can be used with or without models. In this module, the basic data structures such as Markov decision processes are defined, and the most important learning algorithms are derived. Furthermore, important theoretic results regarding convergence to optimal solutions are discussed. In the last part of the class, deep reinforcement learning and the algorithms that were developed to solve chess, Go, shogi, the Atari 2600 games, and further computer games are presented. In the tutorial part, algorithms are implemented, sample problems are solved, and theoretic questions are answered.

Responsible Digital Ethics (6,0 ECTS) This module addresses the critical importance of responsible digital ethics in the age of pervasive digital systems and increasing regulatory requirements. Students explore foundational concepts such as trust, fairness, accountability, digital rights, and ethical design principles. Through lectures, interactive seminars, and student-led activities, participants engage with real-world challenges and diverse literature to develop a nuanced, experiential understanding of digital ethics and their role in fostering ethical digital practices.

SAT Algorithms, Applications and Extensions (6,0 ECTS) Formal verification techniques for software and hardware systems often rely on Boolean satisfiability (SAT) solvers, which have already become powerful practical tools for solving a wide range of problems in formal methods, artificial intelligence, and beyond. This module provides a deep dive into the algorithms and advanced data structures behind SAT solvers, some of their practical applications, and their extensions to reasoning beyond propositional logic,

such as solvers for SMT (satisfiability modulo theories), MaxSAT (maximum satisfiability), and QBF (quantified Boolean formulas). Through a combination of lectures, exercises, and small programming projects, students will gain both theoretical insights and hands-on experience with state-of-the-art tools. Topics include core SAT solving techniques (such as the CDCL algorithm combined with formula simplification techniques and incremental reasoning), advanced heuristics, and practical applications. By the end of the module, students will not only understand how SAT and SAT-based solvers work but also how to apply and extend them to solve new challenging problems.

Seminar in Artificial Intelligence (3,0 ECTS) In the seminar, students work on literature of a chosen topic in artificial intelligence and present their results in written and oral form.

Seminar in Logic (3,0 ECTS) In the seminar, students work on literature of a chosen topic in logic and present their results in written and oral form.

Seminar in Theoretical Computer Science (3,0 ECTS) In the seminar, students work on literature of a chosen topic in theoretical computer science and present their results in written and oral form.

Smart Contracts (6,0 ECTS) Smart contracts are cryptocurrency-based, event-driven computer programs that run on a peer-to-peer network, the blockchain, with the purpose to automate the exchange of digital assets without the need for an external trusted authority. This module focuses on blockchains as a distributed programming platform. It presents the peculiarities of smart contracts, common patterns and pitfalls, security aspects, as well as the methods and technologies for developing secure smart contracts.

Stochastic Foundations of Cyber-Physical Systems (6,0 ECTS) Modern systems possessing both computational and physical abilities are called *cyber-physical systems* (CPS). They range from the internet of things to the human brain. Automatically learning a partially-observable CPS-model from input-output data, as well as an optimal CPS-policy from received rewards, are topics of paramount importance for CPS. This class provides an in depth coverage of these topics, by navigating trough Bayesian interpretation of uncertainty, exact and approximate inference in Bayesian networks, optimality of rational agents, interpretable deep neural networks, supervised learning of CPS models, and both imitation and reinforcement learning of CPS policies. We review the latest advances in all these areas, and rehearse them through captivating homeworks and projects. Finally, we discuss artificial general intelligence as an emerging, self explaining form of model-based policies, applicable to all types of CPS.

Structural Decompositions and Meta Theorems (6,0 ECTS) This module explores the relationship between structural decompositions and logical frameworks in algorithmic problem-solving. The module develops two complementary perspectives: structural parameters that measure the complexity of input instances and logical frameworks that can express families of algorithmic problems. These come together in meta-theorems that establish general conditions for efficient solvability.

Symmetric Cryptography (6,0 ECTS) Symmetric cryptography studies the cryptographic algorithms that secure the bulk of digital data. That includes the AES blockciphers

(used in D/TLS, smart cards, on-chip security, bank payments, etc.), authenticated/encryption mechanisms like CTR, CBC, GCM, and CCM (used in the D/TLS protocol for secure Internet, pseudorandom number generation, storage encryption, etc.), hash functions like SHA-2 and SHA-3 (used for digital signing, D/TLS, authentication tokens, password protection, etc.), and novel building blocks (MiMC hash, Poseidon hash, Merkle trees) that are used in privacy-friendly blockchain and cloud computation protocols. In this module, we examine the security rationale for all those designs both from a theory and a practical perspective. Furthermore, we demonstrate attack vulnerabilities and reason security in the provable security theoretical framework.

Theoretical Foundations and Research Topics in Machine Learning (6,0 ECTS) Machine learning enables computers to learn from data and make intelligent decisions. Through a combination of theoretical analysis and practical applications, this module provides a rigorous introduction to the theoretical aspects of machine learning. Students will develop the ability to prove key results in learning theory, analyze and compare machine learning algorithms, and apply them effectively. Additionally, the module will enhance the students' ability to critically engage with the machine learning literature and present some of the latest developments in the field.

Theoretical Foundations of Deep Learning (6,0 ECTS) Deep learning surpasses human accuracy in classification tasks and outperforms champions in games like Go. As its applications grow, practitioners have identified key properties behind its effectiveness, such as early layers resembling dictionary learning, and deeper layers encoding invariance to transformations. This module explores emerging mathematical theories that explain these observations.

Theory of Graph Data (6,0 ECTS) Graph-structured data is becoming an increasingly prominent method for storing and then providing sophisticated access methods for information with complex structure, especially in scenarios where it is difficult to come up with a strict database schema required in traditional relational databases. This data model is at the core of recent technologies likes knowledge graphs, property graphs, RDF graphs, and graph databases. Modeling and design, integrity maintenance, as well as querying answering in graph-structured data are quite different from the analogous tasks for standard relational database, which is due to the different use-cases and requirements in the context of graph-structured data. The goal of this module is to provide a solid understanding of the foundations of various methods and techniques for graph-structured data, which will enable the students to compare their uses, limits and possibilities. Studying these foundations through the lens of database theory, computational logic, and computational complexity, the students will achieve an understanding that abstracts from the concrete existing implementations and official standards, enabling them to effectively leverage the potential of existing technologies.

Virtual and Augmented Reality (6,0 ECTS) This module introduces virtual and augmented reality (VR/AR). Students gain basic knowledge via VR/AR hardware and software, 3D input, output methods, and user-specific aspects. In addition, psychological and basic neuroscience aspects are presented to help students understand the importance

of human factors in the design of VR/AR systems. The module includes an overview of current research areas and applications in order to provide students with the technical and scientific skills to design and develop VR/AR applications. The module also aims to provide a deeper understanding of design methods, production methods, reception, and use of concrete forms of VR/AR systems.

§ 6 Lehrveranstaltungen

Die Stoffgebiete der Module werden durch Lehrveranstaltungen vermittelt. Die Lehrveranstaltungen der einzelnen Module sind in Anhang A in den jeweiligen Modulbeschreibungen spezifiziert. Lehrveranstaltungen werden durch Prüfungen im Sinne des UG beurteilt. Die Arten der Lehrveranstaltungsbeurteilungen sind in der Prüfungsordnung (§ 7) festgelegt.

Betreffend die Möglichkeiten der Studienkommission, Module um Lehrveranstaltungen für ein Semester zu erweitern, und des Studienrechtlichen Organs, Lehrveranstaltungen individuell für einzelne Studierende Wahlmodulen zuzuordnen, wird auf § 27 des studienrechtlichen Teils der Satzung der TU Wien verwiesen.

Vorgaben zu Lehrveranstaltungen und Prüfungen aus dem Universitätsgesetz 2002

Vor Beginn jedes Semesters ist ein elektronisches Verzeichnis der Lehrveranstaltungen zu veröffentlichen (Titel, Name der Leiterin oder des Leiters, Art, Form inklusive Angabe des Ortes und Termine der Lehrveranstaltung). Dieses ist laufend zu aktualisieren.

Die Leiterinnen und Leiter einer Lehrveranstaltung haben, zusätzlich zum veröffentlichten Verzeichnis, vor Beginn jedes Semesters die Studierenden in geeigneter Weise über die Ziele, die Form, die Inhalte, die Termine und die Methoden ihrer Lehrveranstaltungen sowie über die Inhalte, die Form, die Methoden, die Termine, die Beurteilungskriterien und die Beurteilungsmaßstäbe der Prüfungen zu informieren.

Für Prüfungen, die in Form eines einzigen Prüfungsvorganges durchgeführt werden, sind Prüfungstermine jedenfalls drei Mal in jedem Semester (laut Satzung am Anfang, zu Mitte und am Ende) anzusetzen, wobei die Studierenden vor Beginn jedes Semesters über die Inhalte, die Form, die Methoden, die Termine, die Beurteilungskriterien und die Beurteilungsmaßstäbe der Prüfungen zu informieren sind.

Bei Prüfungen mit Mitteln der elektronischen Kommunikation ist eine ordnungsgemäße Durchführung der Prüfung zu gewährleisten, wobei zusätzlich zu den allgemeinen Regelungen zu Prüfungen folgende Mindesterfordernisse einzuhalten sind:

- Vor Semesterbeginn Bekanntgabe der Standards, die die technischen Geräte der Studierenden erfüllen müssen, damit Studierende an diesen Prüfungen teilnehmen können.
- Zur Gewährleistung der eigenständigen Erbringung der Prüfungsleistung durch die Studierende oder den Studierenden sind technische oder organisatorische Maßnahmen vorzusehen.

- Bei technischen Problemen, die ohne Verschulden der oder des Studierenden auftreten, ist die Prüfung abzubrechen und nicht auf die zulässige Zahl der Prüfungsantritte anzurechnen.

Vorgaben zu Lehrveranstaltungen aus der Satzung der TU Wien

Im Folgenden steht SSB für *Satzung der TU Wien, Studienrechtliche Bestimmungen.*

- Der Umfang der Lehrveranstaltung ist in ECTS-Anrechnungspunkten und in Semesterstunden anzugeben. vgl.§ 9 (2) SSB (Module und Lehrveranstaltungen)
- Die Abhaltung einer Lehrveranstaltung als „Blocklehrveranstaltung“ ist nach Genehmigung durch das Studienrechtliche Organ möglich. vgl. § 9 (3) SSB (Module und Lehrveranstaltungen)
- Zur Abhaltung und Prüfung einer Lehrveranstaltung in einer Fremdsprache ist die Zustimmung des Studienrechtlichen Organs nötig. vgl. § 11 (1) SSB (Fremdsprachen)
- Lehrveranstaltungsprüfungen dienen dem Nachweis der Lernergebnisse, die durch eine einzelne Lehrveranstaltung vermittelt wurden. vgl. § 12 (1) SSB (Lehrveranstaltungsprüfung)
- Die Lehrveranstaltungsprüfungen sind von dem_der Leiter_in der Lehrveranstaltung abzuhalten. Bei Bedarf hat das Studienrechtliche Organ eine_n andere_n fachlich geeignete_n Prüfer_in zu bestellen. vgl. § 12 (2) SSB (Lehrveranstaltungsprüfung)
- Jedenfalls sind für Prüfungen in Pflicht- und Wahlpflichtlehrveranstaltungen, die in einem einzigen Prüfungsakt enden, drei Prüfungstermine für den Anfang, für die Mitte und für das Ende jedes Semester anzusetzen. Diese sind mit Datum vor Beginn des Semesters bekannt zu geben. vgl. § 15 (1) SSB (Prüfungstermine)
- Prüfungen dürfen auch am Beginn und am Ende lehrveranstaltungsfreier Zeiten abgehalten werden. vgl. § 15 (1) SSB (Prüfungstermine)
- Die Prüfungstermine sind in geeigneter Weise bekannt zu machen. vgl. § 15 (1) SSB (Prüfungstermine)

Beschreibung der Lehrveranstaltungstypen

VO: Vorlesungen sind Lehrveranstaltungen, in denen die Inhalte und Methoden eines Faches unter besonderer Berücksichtigung seiner spezifischen Fragestellungen, Begriffsbildungen und Lösungsansätze vorgetragen werden. Die Prüfung wird mit einem einzigen Prüfungsvorgang durchgeführt. In der Modulbeschreibung ist der Prüfungsvorgang je Lehrveranstaltung (schriftlich oder mündlich, oder schriftlich und mündlich) festzulegen. Bei Vorlesungen herrscht keine Anwesenheitspflicht, das Erreichen der Lernergebnisse muss dennoch gesichert sein.

EX: Exkursionen sind Lehrveranstaltungen, die außerhalb der Räumlichkeiten der TU Wien stattfinden. Sie dienen der Vertiefung von Lehrinhalten im jeweiligen lokalen Kontext.

LU: Laborübungen sind Lehrveranstaltungen, in denen Studierende einzeln oder in Gruppen unter Anleitung von Betreuer_innen experimentelle Aufgaben lösen, um den Umgang mit Geräten und Materialien sowie die experimentelle Methodik des Faches zu lernen. Die experimentellen Einrichtungen und Arbeitsplätze werden zur Verfügung gestellt.

PR: Projekte sind Lehrveranstaltungen, in denen das Verständnis von Teilgebieten eines Faches durch die Lösung von konkreten experimentellen, numerischen, theoretischen oder künstlerischen Aufgaben vertieft und ergänzt wird. Projekte orientieren sich am Qualifikationsprofil des Studiums und ergänzen die Berufsvorbildung bzw. wissenschaftliche Ausbildung.

SE: Seminare sind Lehrveranstaltungen, bei denen sich Studierende mit einem gestellten Thema oder Projekt auseinandersetzen und dieses mit wissenschaftlichen Methoden bearbeiten, wobei eine Reflexion über die Problemlösung sowie ein wissenschaftlicher Diskurs gefordert werden.

UE: Übungen sind Lehrveranstaltungen, in denen konkrete Aufgabenstellungen – beispielsweise rechnerisch, konstruktiv, künstlerisch oder experimentell – zu bearbeiten sind. Dabei werden unter fachlicher Anleitung oder Betreuung die Fähigkeiten und Fertigkeiten der Studierenden zur Anwendung auf konkrete Aufgabenstellungen entwickelt.

VU: Vorlesungen mit integrierter Übung sind Lehrveranstaltungen, in denen die beiden Lehrveranstaltungstypen VO und UE in einer einzigen Lehrveranstaltung kombiniert werden. Der jeweilige Übungs- und Vorlesungsanteil darf ein Viertel des Umfanges der gesamten Lehrveranstaltungen nicht unterschreiten. Beim Lehrveranstaltungstyp VU ist der Übungsteil jedenfalls prüfungsimmanent, der Vorlesungsteil kann in einem Prüfungsakt oder prüfungsimmanent geprüft werden. Unzulässig ist es daher, den Übungsteil und den Vorlesungsteil gemeinsam in einem einzigen Prüfungsvorgang zu prüfen.

Beschreibung der Lehrveranstaltungen und Prüfungen im Informationssystem zu Studien und Lehre

- Typ der Lehrveranstaltung (VO, EX, LU, PR, SE, UE, VU)
- Form (Präsenz, Online, Hybrid, Blended)
- Termine (gegebenenfalls auch die für die positive Absolvierung erforderliche Anwesenheit)
- Inhalte (Beschreibung der Inhalte, Vorkenntnisse)
- Literaturangaben
- Lernergebnisse (Umfassende Beschreibung der Lernergebnisse)
- Methoden (Beschreibung der Methoden in Abstimmung mit Lernergebnissen und Leistungsnachweis)
- Leistungsnachweis (in Abstimmung mit Lernergebnissen und Methoden)

  - Ausweis der Teilleistungen, inklusive Kennzeichnung, welche Teilleistungen wiederholbar sind. Bei Typ VO entfällt dieser Punkt.
- Prüfungen:
  - Inhalte (Beschreibung der Inhalte, Literaturangaben)
  - Form (Präsenz, Online)
  - Prüfungsart bzw. Modus
    * Typ VO: schriftlich, mündlich oder schriftlich und mündlich;
    * bei allen anderen Typen: Ausweis der Teilleistungen inklusive Art und Modus bezugnehmend auf die in der Lehrveranstaltung angestrebten Lernergebnisse.
  - Termine
  - Beurteilungskriterien und Beurteilungsmaßstäbe

§ 7 Prüfungsordnung

Der positive Abschluss des Masterstudiums erfordert:

1. die positive Absolvierung der im Studienplan vorgeschriebenen Module, wobei ein Modul als positiv absolviert gilt, wenn die ihm gemäß Modulbeschreibung zuzurechnenden Lehrveranstaltungen positiv absolviert wurden.

2. die Abfassung einer positiv beurteilten Diplomarbeit und

3. die positive Absolvierung des Seminars für Diplomand_innen, sowie der kommissionellen Abschlussprüfung. Diese erfolgt mündlich vor einer Prüfungskommission gemäß § 13 und § 19 der *Studienrechtlichen Bestimmungen der Satzung der Technischen Universität Wien* und dient der Präsentation und Verteidigung der Diplomarbeit und dem Nachweis der Beherrschung des wissenschaftlichen Umfeldes. Dabei ist vor allem auf Verständnis und Überblickswissen Bedacht zu nehmen. Die Anmeldevoraussetzungen zur kommissionellen Abschlussprüfung gemäß § 17 (1) der *Studienrechtlichen Bestimmungen der Satzung der Technischen Universität Wien* sind erfüllt, wenn die Punkte 1 und 2 erbracht sind.

Das Abschlusszeugnis beinhaltet

(a) die Prüfungsfächer mit ihrem jeweiligen Umfang in ECTS-Punkten und ihren Noten,

(b) das Thema und die Note der Diplomarbeit,

(c) die Note der kommissionellen Abschlussprüfung,

(d) die Gesamtbeurteilung sowie

(e) auf Antrag des_der Studierenden die Gesamtnote des absolvierten Studiums gemäß §72a UG.

Die Note des Prüfungsfaches „Diplomarbeit“ ergibt sich aus der Note der Diplomarbeit. Die Note jedes anderen Prüfungsfaches ergibt sich durch Mittelung der Noten jener Lehrveranstaltungen, die dem Prüfungsfach über die darin enthaltenen Module zuzuordnen sind, wobei die Noten mit dem ECTS-Umfang der Lehrveranstaltungen gewichtet werden. Bei einem Nachkommateil kleiner gleich 0,5 wird abgerundet, andernfalls wird aufgerundet. Wenn keines der Prüfungsfächer schlechter als mit „gut““ und mindestens die Hälfte mit „sehr gut“ benotet wurde, so lautet die *Gesamtbeurteilung* „mit Auszeichnung bestanden“ und ansonsten „bestanden“.

Lehrveranstaltungen des Typs VO (Vorlesung) werden aufgrund einer abschließenden mündlichen und/oder schriftlichen Prüfung beurteilt. Alle anderen Lehrveranstaltungen besitzen immanenten Prüfungscharakter, d.h., die Beurteilung erfolgt laufend durch eine begleitende Erfolgskontrolle sowie optional durch eine zusätzliche abschließende Teilprüfung.

Der positive Erfolg von Prüfungen und wissenschaftlichen sowie künstlerischen Arbeiten ist mit „sehr gut“ (1), „gut“ (2), „befriedigend“ (3) oder „genügend“ (4), der negative Erfolg ist mit „nicht genügend“ (5) zu beurteilen. Bei Lehrveranstaltungen, bei denen eine Beurteilung in der oben genannten Form nicht möglich ist, werden diese durch „mit Erfolg teilgenommen“ (E) bzw. „ohne Erfolg teilgenommen“ (O) beurteilt.

§ 8 Studierbarkeit und Mobilität

Studierende des Masterstudiums *Logic and Artificial Intelligence* sollen ihr Studium mit angemessenem Aufwand in der dafür vorgesehenen Zeit abschließen können.

Den Studierenden wird empfohlen, ihr Studium nach dem Semestervorschlag in Anhang C zu absolvieren.

Die Beurteilungs- und Anwesenheitsmodalitäten von Lehrveranstaltungen der Typen UE, LU, PR, VU, SE und EX sind im Rahmen der Lehrvereinbarungen mit dem Studienrechtlichen Organ festzulegen und im Informationssystem für Studien und Lehre bekanntzugeben. Weiters sind die Bestimmungen der Satzung (Studienrechtliche Bestimmungen zur Wiederholbarkeit von Teilleistungen) zu beachten.

Jede Lehrveranstaltung mit Teilnehmer_innenbeschränkung, wo eine nicht ermöglichte von einem_r Studierenden beabsichtigte Teilnahme das Potential einer Studienzeitverzögerung hat, muss entsprechend dem UG mit den verfügbaren Plätzen und dem Vergabeprozedere im Studienplan vermerkt werden. Die betroffenen Lehrveranstaltungen sowie die Anzahl der Plätze und das Verfahren zur Vergabe sind von der Studienkommission festzulegen und für die Studierenden klar und verständlich in den Modulbeschreibungen darzulegen.

Lehrveranstaltungen, für die ressourcenbedingte Teilnahmebeschränkungen gelten, sind im Informationssystem für Studien und Lehre entsprechend gekennzeichnet. Außerdem sind die Anzahl der verfügbaren Plätze und das Verfahren zur Vergabe dieser Plätze anzugeben.

Die Anerkennung von im Ausland absolvierten Studienleistungen erfolgt durch das zuständige Studienrechtliche Organ. Um die Mobilität zu erleichtern, stehen die in

§ 27 Abs. 1 bis 3 der *Studienrechtlichen Bestimmungen* der Satzung der Technischen Universität Wien angeführten Möglichkeiten zur Verfügung. Diese Bestimmungen können in Einzelfällen auch zur Verbesserung der Studierbarkeit eingesetzt werden.

Die im Zuge einer Mobilität erreichten ECTS-Punkte können verwendet werden, um die im Modul „Freie Wahlfächer und Transferable Skills“ geforderten Transferable Skills im entsprechenden Ausmaß abzudecken. Insbesondere können sie auch dem Themenpool Technikfolgenabschätzung, Technikgenese, Wissenschaftsethik, Gender Mainstreaming und Diversity Management zugerechnet werden.

Kommt es in einer Lehrveranstaltung ohne explizit geregelte Platzvergabe zu einem unvorhergesehenen Andrang, kann die Lehrveranstaltungsleitung in Absprache mit dem studienrechtlichen Organ Teilnahmebeschränkungen vornehmen. Studierende, die zum Masterstudium *Logic and Artificial Intelligence* zugelassen sind und für die eine Nichtteilnahme zu einer Studienzeitverzögerung führen könnte, werden in jedem Fall aufgenommen. Die Vergabe der allenfalls übrigen Plätze ist nach folgenden Kriterien (mit absteigender Priorität) zu regeln.

- Es werden jene Studierenden bevorzugt aufgenommen, die die formalen und inhaltlichen Voraussetzungen erfüllen. Die inhaltlichen Voraussetzungen können etwa an Hand von bereits abgelegten Prüfungen oder durch einen Eingangstest überprüft werden.
- Unter diesen hat die Verwendung der Lehrveranstaltung als Pflichtfach Vorrang vor der Verwendung als Wahlfach und diese vor der Verwendung als Freifach.
- Innerhalb dieser drei Gruppen sind jeweils jene Studierenden zu bevorzugen, die trotz Vorliegens aller Voraussetzungen bereits in einem früheren Abhaltesemester abgewiesen wurden.

Die Studierenden sind darüber ehebaldigst zu informieren.

§ 9 Diplomarbeit

Die Diplomarbeit ist eine künstlerisch-wissenschaftliche Arbeit, die dem Nachweis der Befähigung dient, ein wissenschaftliches Thema selbstständig inhaltlich und methodisch vertretbar zu bearbeiten. Das Thema der Diplomarbeit ist von der oder dem Studierenden frei wählbar und muss im Einklang mit dem Qualifikationsprofil stehen.

Das Prüfungsfach *Diplomarbeit* umfasst 30 ECTS-Punkte und besteht aus der wissenschaftlichen Arbeit (Diplomarbeit), die mit 27 ECTS-Punkten bewertet wird, einem „Seminar für Diplomand_innen“ im Ausmaß von 1,5 ECTS-Punkten, sowie der kommissionellen Abschlussprüfung im Ausmaß von 1,5 ECTS-Punkten.

§ 10 Akademischer Grad

Den Absolvent_innen des Masterstudiums *Logic and Artificial Intelligence* wird der akademische Grad „Diplom-Ingenieur“/„Diplom-Ingenieurin“ – abgekürzt „Dipl.-Ing.“ oder „DI“ (international vergleichbar mit „Master of Science“) – verliehen.

§ 11 Qualitätsmanagement

Das Qualitätsmanagement des Masterstudiums *Logic and Artificial Intelligence* gewährleistet, dass das Studium in Bezug auf die studienbezogenen Qualitätsziele der TU Wien konsistent konzipiert ist und effizient und effektiv abgewickelt sowie regelmäßig überprüft wird. Das Qualitätsmanagement des Studiums erfolgt entsprechend dem Plan-Do-Check-Act Modell nach standardisierten Prozessen und ist zielgruppenorientiert gestaltet. Die Zielgruppen des Qualitätsmanagements sind universitätsintern die Studierenden und die Lehrenden sowie extern die Gesellschaft, die Wirtschaft und die Verwaltung, einschließlich des Arbeitsmarktes für die Studienabgänger_innen.

In Anbetracht der definierten Zielgruppen werden sechs Ziele für die Qualität der Studien an der Technischen Universität Wien festgelegt: (1) In Hinblick auf die Qualität und Aktualität des Studienplans ist die Relevanz des Qualifikationsprofils für die Gesellschaft und den Arbeitsmarkt gewährleistet. In Hinblick auf die Qualität der inhaltlichen Umsetzung des Studienplans sind (2) die Lernergebnisse in den Modulen des Studienplans geeignet gestaltet, um das Qualifikationsprofil umzusetzen, (3) die Lernaktivitäten und -methoden geeignet gewählt, um die Lernergebnisse zu erreichen, und (4) die Leistungsnachweise geeignet, um die Erreichung der Lernergebnisse zu überprüfen. (5) In Hinblick auf die Studierbarkeit der Studienpläne sind die Rahmenbedingungen gegeben, um diese zu gewährleisten. (6) In Hinblick auf die Lehrbarkeit verfügt das Lehrpersonal über fachliche und zeitliche Ressourcen um qualitätsvolle Lehre zu gewährleisten.

Um die Qualität der Studien zu gewährleisten, werden der Fortschritt bei Planung, Entwicklung und Sicherung aller sechs Qualitätsziele getrennt erhoben und publiziert. Die Qualitätssicherung überprüft die Erreichung der sechs Qualitätsziele. Zur Messung des ersten und zweiten Qualitätszieles wird von der Studienkommission zumindest einmal pro Funktionsperiode eine Überprüfung des Qualifikationsprofils und der Modulbeschreibungen vorgenommen. Zur Überprüfung der Qualitätsziele zwei bis fünf liefert die laufende Bewertung durch Studierende, ebenso wie individuelle Rückmeldungen zum Studienbetrieb an das Studienrechtliche Organ, laufend ein Gesamtbild über die Abwicklung des Studienplans. Die laufende Überprüfung dient auch der Identifikation kritischer Lehrveranstaltungen, für welche in Abstimmung zwischen Studienrechtlichem Organ, Studienkommission und Lehrveranstaltungsleiter_innen geeignete Anpassungsmaßnahmen abgeleitet und umgesetzt werden. Das sechste Qualitätsziel wird durch qualitätssichernde Instrumente im Personalbereich abgedeckt. Zusätzlich zur internen Qualitätssicherung wird alle sieben Jahre eine externe Evaluierung der Studien vorgenommen.

Jedes Modul besitzt eine_n Modulverantwortliche_n. Diese Person ist für die inhaltliche Kohärenz und die Qualität der dem Modul zugeordneten Lehrveranstaltungen verantwortlich. Diese wird insbesondere durch zyklische Kontrollen, inhaltliche Feinabstimmung mit vorausgehenden und nachfolgenden Modulen sowie durch Vergleich mit analogen Lehrveranstaltungen bzw. Modulen anderer Universitäten im In- und Ausland sichergestellt.

Lehrveranstaltungskapazitäten

Um die Qualität der Umsetzung der Lehrveranstaltungen zu sichern, dienen für die verschiedenen Typen von Lehrveranstaltungen (siehe Seite 22) die folgenden Gruppengrößen als Richtwert:

	Gruppengröße	
Lehrveranstaltungstyp	je Leiter(in)	je Tutor(in)
VO	100	
UE mit Tutor(inn)en	30	15
UE	15	
LU mit Tutor(inn)en	20	8
LU	8	
EX, PR, SE	10	

Für Lehrveranstaltungen des Typs VU werden für den Vorlesungs- bzw. Übungsteil die Gruppengrößen für VO bzw. UE herangezogen. Die Beauftragung der Lehrenden erfolgt entsprechend der tatsächlichen Abhaltung.

Gender, Ethik und Diversität

Kontext: Um Lehr- und Lernumgebungen zu schaffen, in denen alle Studierenden – unabhängig von Geschlecht, Herkunft, Fähigkeiten oder sozialem Hintergrund – gleichermaßen geschätzt, gefördert und gefordert werden, ist eine inklusive Lehre basierend auf diversitätssensibler Didaktik erforderlich. Dies kann nicht in eigenen separaten Lehrveranstaltungen abgehandelt werden, sondern muss auf allen Ebenen des Studiums umgesetzt werden – als „Embedded Gender, Ethics and Diversity".

Dazu gehört die Einbettung ethischer und gesellschaftlicher Themen in den Studienplan, sowie die Auseinandersetzung mit diesen Themen in jeder Lehrveranstaltung. So lassen sich Rahmenbedingungen schaffen, die ein diskriminierungsfreies Lernumfeld ermöglichen. Dies umfasst auch Maßnahmen gegen Diskriminierung und Belästigung, etwa durch explizite Verhaltenscodizes.

Lehrinhalt: Inklusivität und Vielfalt werden gefördert, indem in allen Lehrveranstaltungen unterschiedliche Perspektiven einbezogen werden, die sich auf ein breites Spektrum von Autor_innen und Rollenvorbildern stützen. Die ethische Reflexion von Kernbereichen wird in allen Lehrveranstaltungen eingebettet, indem sie in Vorlesungen und Übungsbeispielen angesprochen und berücksichtigt wird, etwa durch Diskussion ethischer Aspekte und sozialer Auswirkungen. Zusätzlich wird auf das Angebot der Abteilung für Genderkompetenz der TU Wien hingewiesen, die für das Absolvieren eines Zusatzkatalogs das Zertifikat *Gender- und Diversitätskompetenz* ausstellt.

Lehrmethoden: Die Lehrmethoden fördern Gender-Inklusivität und Diversität und schaffen ein Lernumfeld, in dem sich alle Studierenden gleichermaßen willkommen fühlen. Dazu gehören unter anderem die Verwendung einer inklusiven, vorurteilsfreien Sprache,

um die Verstärkung von Stereotypen zu vermeiden; Lehrmaterial mit Beispielen, Fallstudien oder Anschauungsmaterial, die unsere vielfältige Gesellschaft widerspiegeln; die Abhaltung der Lehre in einer Form, die für Menschen mit unterschiedlichen Fähigkeiten geeignet ist und eine gleichberechtigte Teilnahme gewährleistet; sowie die Einbindung von Gastredner_innen mit unterschiedlichen Hintergründen.

§ 12 Inkrafttreten

Dieser Studienplan tritt mit 1. Oktober 2026 in Kraft.

§ 13 Übergangsbestimmungen

Die Übergangsbestimmungen sind in Anhang B zu finden.

A Modulbeschreibungen

Die den Modulen zugeordneten Lehrveranstaltungen werden in folgender Form angeführt:
9,9/9,9 XX Titel der Lehrveranstaltung
Dabei bezeichnet die erste Zahl den Umfang der Lehrveranstaltung in ECTS-Punkten und die zweite ihren Umfang in Semesterstunden. ECTS-Punkte sind ein Maß für den Arbeitsaufwand der Studierenden, wobei ein Studienjahr 60 ECTS-Punkte umfasst und ein ECTS-Punkt 25 Stunden zu je 60 Minuten entspricht. Eine Semesterstunde entspricht so vielen Unterrichtseinheiten wie das Semester Unterrichtswochen umfasst. Eine Unterrichtseinheit dauert 45 Minuten. Der Typ der Lehrveranstaltung (XX) ist in § 6 unter *Lehrveranstaltungstypen* auf Seite 22 im Detail erläutert.

Abstract Argumentation

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to:

- explain the fundamental concepts of formal argumentation;
- apply the methodology of formal argumentation to selected research topics; and
- apply established methods from the field of knowledge representation to a new formalism.

Überfachliche Kompetenzen: Students learn how to contribute to scientific research within a team of experts.

Inhalt:

- Dung's abstract argumentation frameworks;
- semantics for abstract argumentation;
- properties and complexity of argumentation;
- algorithms and ASP and (Q)SAT encodings; as well as
- generalizations of Dung's abstract argumentation frameworks.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Abstract Argumentation

Advanced Cryptography

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module expands the students' basic knowledge and skills in the area of cryptography.

Fachkompetenzen: Upon successful completion of this module, students are able to describe topics and concepts (see below) in cryptography, which form the basis for interacting in a privacy-preserving way in the digital world; they are capable of evaluating systems and analyzing their security by applying the provable-security framework and its extensions.

Überfachliche Kompetenzen: Students learn to argue in a rigorous way, by first modeling desired notions and then giving formal guarantees (e.g. by using the complexity-theoretic notion of "proofs by reduction") against adversaries whose attack strategies are unknown to the system designer. Furthermore, students are able to identify and discuss ethical questions in the context of cryptography.

Inhalt:

- Provable security, the random-oracle model;
- elliptic-curve-based cryptography;
- zero-knowledge and succinct proof systems;
- secure multi-party computation;
- post-quantum (lattice-based) cryptography.

Erwartete Vorkenntnisse: Knowledge of the basic concepts of cryptography in symmetric and public-key encryption and authentication as well as familiarity with the concept of provable security.

These prerequisites are taught in the module *Einführung in Kryptographie*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Advanced Cryptography

Advanced Privacy Enhancing Technologies

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: Upon successful completion of this module, students are able to critically analyze privacy risks in data processing systems and apply cryptographic and information-theoretic methods to enhance privacy. They are able to design solutions using techniques such as secret sharing, differential privacy, and secure multiparty computation,

and evaluate their effectiveness in practical scenarios. Additionally, they can compare different approaches to privacy-preserving data analysis and, time permitting, implement basic mechanisms for privacy protection in machine learning applications. This knowledge equips students to develop privacy-enhancing technologies that balance data utility with strong privacy guarantees in AI-driven and data-intensive domains.

Fachkompetenzen: Students are able to analyze, design, and evaluate advanced privacy-enhancing technologies such as secret sharing, differential privacy, and secure multiparty computation, and apply them in modern application contexts.

Überfachliche Kompetenzen: Students are able to transfer and adapt methods of privacy-enhancing technologies to new domains, critically assess their applicability, and communicate technical concepts effectively across interdisciplinary teams.

Inhalt:

- Definitions of confidentiality and introduction of the concepts;
- secret sharing;
- differential privacy;
- secure multi-party computation;
- machine learning and privacy.

Erwartete Vorkenntnisse: Students are expected to know the fundamentals of IT security, cryptography, provable security, and privacy-enhancing technologies.

These prerequisites are taught in the bachelor modules

- *Einführung in Kryptographie*;
- *Einführung in Security*; and
- *Privacy-Enhancing Technologies*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Advanced Privacy Enhancing Technologies

Advanced Reinforcement Learning

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module provides more advanced insights into reinforcement learning, one of the main fields of machine learning.

Fachkompetenzen: After successful completion of the module, students are able to:

- explain the advanced theory of reinforcement learning;

- implement advanced reinforcement algorithms; and
- apply advanced reinforcment algorithms to realistic problems.

Überfachliche Kompetenzen: Students acquire the ability to understand advanced methods for machine learning and artificial intelligence and to solve complex problems in (stochastic) optimal control. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Distributional reinforcement learning;
- distributional deep reinforcement learning;
- convergence proofs in non-distributional reinforcement learning;
- convergence proofs in distributional reinforcement learning.

Erwartete Vorkenntnisse: Students should already have familiarity with basics of reinforcement learning.

These prerequisites are taught in module *Reinforcement Learning*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Advanced Reinforcement Learning

Advanced Research in Algorithmics

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: Through a combination of theoretical analysis and practical exploration, the course delves into advanced techniques for designing algorithms and analyzing their complexity.

Fachkompetenzen: Students will learn how to

- identify and tackle new and familiar research situations,
- explain and model new computational problems,
- read and understand scientific publications,
- identify relevant research questions for concrete problems in algorithms and complexity,
- carry out independent scientific research on concrete problems in algorithms and complexity,
- cooperate with other team members and with advisors on research,
- present their results in a clear and concise manner, both orally and in writing, and

- classify and assess recent research results as well as their own results.

Überfachliche Kompetenzen: Students will be able to perform

- formal reasoning and critical analysis of algorithmic approaches,
- structured problem-solving in complex, research-oriented contexts,
- abstract modeling of computational and optimization problems,
- evaluation of trade-offs between solution quality, efficiency, and resource usage, and
- have awareness of ethical, fairness, and societal issues in algorithmic decision-making.

Inhalt: The module introduces students to research-oriented work in algorithmics. Students engage with the topics through literature review, critical analysis, the development of preliminary research ideas. Additional technical results and methods useful for tackling the individual topics may be supplied by the advisors and lecturers.

The research topics come from a range of areas such as computational social choice, algorithmic game theory, computational geometry, graph algorithms, and approximation techniques.

Representative topics include:

- voting rules and algorithmic aspects of elections;
- cooperative games and coalition formation in multi-agent systems;
- resource allocation and fair division algorithms;
- complexity and approximation of computationally hard problems such as clustering;
- geometric problems such as convex hulls, proximity graphs, and low-dimensional embeddings; and
- graph drawing problems such as planarization and crossing minimization.

Erwartete Vorkenntnisse: Good knowledge from algorithmics and complexity analysis. These prerequisites are taught in the following modules:

- *Algorithmen und Datenstrukturen*;
- *Effiziente Algorithmen* (recommended);
- *Algorithmics*; and
- *Complexity Theory*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Advanced Research in Algorithmics

AI Ethics

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with the various ethical challenges and topics arising in the context of AI. Besides an in-depth introduction to ethical frameworks and AI ethics themes, the module focuses on the development of critical reflection and argumentation/discussion skills.

Fachkompetenzen: After successful completion of the course, students are able to:

- explain and summarize central concepts and problems in AI ethics (e.g., AI alignment, algorithmic bias);
- describe fundamental ethical theories (e.g., utilitarianism, care ethics) and illustrate their application to AI ethics topics through examples;
- analyze and construct a critical ethical reflection on central technical and philosophical challenges in AI ethics (e.g., fairness, sustainability, AI alignment);
- formulate and defend clearly structured, state of the art informed arguments on key AI ethics questions (e.g., the right to explanation, data privacy), engaging with counterarguments; and
- justify the importance of ethical reflection in AI development, using ethical reflection and/or case studies to support claims.

Überfachliche Kompetenzen: Students will acquire critical thinking skills that are strongly rooted in humanity studies. They will also learn how to study text on policy, law, and regulations concerning AI.

This course will address ethics, gender, and diversity in the following ways: The main purpose of the course is for students to develop critical reflection skills on ethical aspects of AI, this includes obtaining a broad an diverse overview of various perspectives on ethical challenges. It reflects explicitly on questions of gender and diversity in terms of fairness and bias both in ethics and in AI. Furthermore, the literature for the course is aimed at reflecting diverse backgrounds too.

Inhalt:

- Novel ethical challenges in AI such as disinformation, explainability, sustainability, data-privacy, autonomy;
- methods such as embedded ethics, multi-scale ethics, AI ethics audits, AI alignment, human-in-the-loop AI;
- ethical theories including consequentialism, utilitarianism, virtue ethics, deontology, care ethics, and critical methods such as feminist ethics.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU AI Ethics

Algorithmic Encoding Techniques

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with systematic approaches to encode hard computational problems into well-studied target formalisms.

Fachkompetenzen: Students gain comprehensive knowledge of encoding techniques and solving strategies. They learn to develop correct and efficient encodings for complex problems and verify their solutions through formal methods.

Überfachliche Kompetenzen: Students acquire the ability to abstract computational problems into formal representations and analyze solution approaches through mathematical reasoning. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender and diversity in the context of algorithmic encoding techniques and their applications.

Inhalt:

- Encoding strategies for target formalisms, including eager and lazy approaches;
- local consistency and propagation;
- static and dynamic symmetry-breaking techniques for improving solving efficiency;
- correctness certification methods for encodings and solutions;
- incremental solving techniques for dynamic problem instances;
- encodings for parallel solving and portfolio-based approaches.

Erwartete Vorkenntnisse: A solid understanding of algorithms and logic is required. These prerequisites are taught in the following modules:

- *Algorithmen und Datenstrukturen*;
- *Discrete Mathematics*; and
- *Algorithmics* (strongly recommended).

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Algorithmic Encoding Techniques

Algorithmic Geometry

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module introduces fundamental efficient algorithms and data structures for combinatorial geometric problems.

Fachkompetenzen: Students will learn to

- explain fundamental concepts, structures, and problems in algorithmic geometry,
- design and analyze geometric algorithms and data structures,
- model geometric problems and adapt known algorithms and data structures to new problems, and
- investigate unknown geometric problems and develop new algorithmic solutions.

Überfachliche Kompetenzen: Students will be able to

- perform formal reasoning, correctness proofs, and proofs of asymptotic time complexity of algorithms,
- structured analysis of computational problems,
- abstract problem modelling,
- judge trade-offs between time and space complexity, and
- being aware of possible ethical, gender, and diversity issues in the context of geometric data processing.

Inhalt: The module content covers fundamental techniques and algorithms for geometric problems including

- basic geometric algorithms for computing convex hulls, polygon triangulations, and segment intersections,
- data structures for orthogonal range searching, windowing queries, and point location queries,
- Voronoi diagrams and Delaunay triangulations,
- point-line duality,
- distance approximation,
- geometric shortest paths and robot motion planning, and
- sweep-line algorithms and randomized incremental constructions.

Erwartete Vorkenntnisse: Extended knowledge of algorithms and data structures.
These prerequisites are taught in the following recommended modules:

- *Effiziente Algorithmen*
- *Algorithmics*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Algorithmic Geometry

Algorithmic Social Choice

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: The module provides a comprehensive overview of algorithmic and computational approaches to collective decision-making and social choice problems.

Fachkompetenzen: Students will learn to:

- explain fundamental concepts in voting theory, fair division, and matching problems
- analyze computational properties and complexity results in social choice settings
- design and evaluate algorithms for collective decision-making processes
- model social choice problems formally and propose algorithmic solutions

Überfachliche Kompetenzen: Students develop interdisciplinary skills by tackling problems at the intersection of economics, social choice theory, and computer science. They explore diversity-related dimensions of algorithmic decision-making, analyzing how different voting rules, matching algorithms, and fair division procedures can advantage or disadvantage various social groups. Issues of gender representation and fairness are considered as specific aspects of diversity in algorithmic decision-making. The module emphasizes the design of algorithms that are not only efficient, but also equitable and sensitive to diverse needs.

Inhalt:

- Aggregating preferences (rank aggregation) and voting
- Preference domain restrictions
- Matching under preferences
- Algorithmic mechanism design
- Cake cutting protocols
- Fair allocation of resources
- Judgment aggregation

Erwartete Vorkenntnisse: Knowledge from algorithmics and complexity analysis.

These prerequisites are taught in the following modules:

- *Algorithmen und Datenstrukturen*
- *Effiziente Algorithmen*
- *Algorithmics*
- *Complexity Theory*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Algorithmic Social Choice

Algorithmics

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with advanced algorithmic methods and their theoretical analysis for solving complex computational problems.

Fachkompetenzen: Students gain comprehensive knowledge of algorithm design principles and analysis techniques. They learn to develop theoretical solutions for computational problems and prove their correctness using mathematical methods.

Überfachliche Kompetenzen: Students acquire the ability to align theoretical and practical aspects of algorithms. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Advanced algorithmic methods and complexity analysis, including asymptotic analysis and computational complexity theory;
- graph theory and algorithms, structural decompositions, and planarity theory;
- mathematical optimization techniques, including linear programming theory and modelling; and
- advanced algorithm design paradigms and theoretical frameworks, including geometric algorithms, approximation theory, and randomization.

Erwartete Vorkenntnisse: A good understanding of basic algorithms and data structures and methods to analyze them.

These prerequisites are taught in the following modules:

- *Algorithmen und Datenstrukturen*;
- *Effiziente Algorithmen*; and
- *Discrete Mathematics*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Algorithmics

Algorithms for Data Science

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module introduces fundamental algorithms and their analysis for analyzing large amounts of data.

Fachkompetenzen: After successful completion of the module, students are able to

- design and theoretically analyze algorithms for processing large amounts of data,
- implement and use data science algorithms on real-world datasets,
- select an appropriate algorithm for a given data science problem,
- explain how randomization can be exploited to obtain more efficient algorithms

in order to build and analyze highly efficient data processing pipelines for analyzing large amounts of data.

Überfachliche Kompetenzen: Students acquire the ability to understand methods for algorithmically identifying and exploiting properties of data in various domains. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Graph analysis and graph mining (e.g., densest subgraph, arboricity, triangle counting, sublinear-time estimation of Personalized PageRank);
- similarity and nearest neighbor search (e.g., min-hash, locality sensitive hashing);
- streaming algorithms (e.g., heavy hitters, reservoir sampling);
- clustering (e.g., k-Means++, coresets);
- dimensionality reduction (e.g., Johnson–Lindenstrauss lemma, feature hashing, subspace embeddings);
- matrix factorizations and their applications (e.g., singular value decomposition for community detection in random graphs, non-negative matrix factorization, DeepWalk, node2vec).

Erwartete Vorkenntnisse: Knowledge of theoretical algorithm analysis and basics of data science. A good understanding of probability theory and linear algebra is an advantage.

These prerequisites are taught in the following modules:

- *Algorithmen und Datenstrukturen* and
- *Algorithmics*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Algorithms for Data Science

Algorithms in Graph Theory

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with algorithmic aspects of graph theory from a theoretical perspective.

Fachkompetenzen: Students gain the ability to explain basic and advanced concepts and structures in graph theory. They learn to describe and design algorithms for fundamental graph problems while developing theoretical foundations for their analysis.

Überfachliche Kompetenzen: Students acquire the ability to combine structural properties of graphs with algorithm design and analysis. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Matching algorithms and theory;
- planarity testing, embeddings, and algorithms for planar graphs;
- graph width measures and their relationship;
- algorithms for sparse graph classes.

Erwartete Vorkenntnisse: A solid understanding of algorithms, data structures, and graph theory is required.

These prerequisites are taught in the following modules:

- *Algorithmen und Datenstrukturen*;
- *Effiziente Algorithmen*;
- *Discrete Mathematics*; and
- *Algorithmics* (strongly recommended).

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Algorithms in Graph Theory

Applied Generative AI and LLM-based Systems

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module builds on foundational knowledge of generative AI to explore advanced architectural concepts, emerging research directions, and sophisticated integration patterns, with an emphasis on practical implementation and project-based learning.

Fachkompetenzen: After successful completion of the module, students are able to:

- explain internal dynamics, trade-offs, and efficient adaptation (e.g., quantization-aware training, parameter-efficient fine-tuning) of modern transformer and diffusion models;

- apply embedding-based strategies for enhancing generative AI, including conditioning, context augmentation, and retrieval-based improvements; and
- implement, deploy, evaluate, and monitor advanced generative AI systems beyond chatbots for business integration.

Überfachliche Kompetenzen: After the module, students are able to explain the trade-offs between cloud-based and on-premises generative AI solutions, particularly in terms of performance, compliance, and ethical dimensions. They will also be able to assess and communicate the ethical implications of generative AI systems, including transparency, privacy, and bias. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Modern Generative AI Architectures and Paradigms: Foundations of modern generative AI, such as Transformer and Diffusion Architectures. Advanced paradigms including mixture of expert models and diffusion transformers.
- Generative AI in Practice: Advanced model optimization techniques including distillation and pruning strategies, parameter-efficient fine-tuning techniques. Integration/interface patterns of generative AI like augmentation strategies, function calling and tool use, or agentic behavior. Introduction to transparency, explainability, and corrigibility requirements and responsible development practices including output monitoring, content filtering, and safety measures.
- Implementation of Applied Generative AI: Applications of applied generative AI across a range of domains, such as modular text assessment in latent space using LLMs, embedding strategies for retrieving chunked legal documents, privacy-aware document re-purposing, and others.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Applied Generative AI and LLM-based Systems

Automata and Logic

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module explores the deep connections between automata, logic, and algebra, providing a unified framework for analyzing and reasoning about languages, systems, and their properties.

Fachkompetenzen: The focus is on general principles, emphasizing conceptual connections and providing tools for analyzing languages, systems, and their properties through the

lenses of automata, logic, and algebra. Students will learn both theoretical foundations and practical methods that have broad applications across computer science and mathematics.

By the end of this module, students will

- understand how automata, logic, and algebra are interrelated and reinforce one another,
- use logic to specify and reason about formal languages and systems,
- apply algebraic structures to analyze and classify automata and languages,
- explore the extension of automata and logic to infinite behaviors and temporal properties, and
- gain insight into how these theoretical tools can be applied in various fields, including verification, synthesis, and computational mathematics.

Überfachliche Kompetenzen: This module fosters interdisciplinary competencies by combining mathematical rigor, logical reasoning, and algebraic techniques to analyze and model computational systems. Students will learn to bridge theoretical and applied perspectives, enabling them to apply automata, logic, and algebraic methods across diverse domains like verification, synthesis, and formal reasoning. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: The module covers core topics, including:

- finite automata and their relationship to regular languages;
- logical formalisms, such as propositional and monadic second-order (MSO) logic, and their connection to automata;
- algebraic structures (e.g., monoids, semirings) and their role in automata theory and formal languages;
- extensions of automata for infinite behaviors and their connections to temporal logics; and
- applications of automata, logic, and algebra in verification, synthesis, and formal reasoning.

Erwartete Vorkenntnisse: A background in discrete mathematics and a basic understanding of formal languages is recommended.

These prerequisites are taught in the following modules:

- Algebra und Diskrete Mathematik
- Theoretische Informatik

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:

6,0/4,0 VU Automata and Logic

Automated Deduction

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with algorithmic techniques and fundamental results in first-order theorem proving for logic with equality.

Fachkompetenzen: After successful completion of the module, students are able to address the theoretical and practical aspects for devising algorithmic procedures for automated reasoning in first-order logic with equality.

Überfachliche Kompetenzen: Students acquire the ability to understand, apply and use automated deduction methods, in particular within first-order theorem proving tools.

Inhalt:

- Resolution and superposition calculi for first-order logic with equality;
- unification algorithms;
- redundancy checking methods for efficient reasoning;
- saturation-based proof search ;
- inference processes;
- experiments and projects with theorem provers;
- recent advancements in research in theorem proving.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Automated Deduction

Beyond Exact Algorithms

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module introduces randomized and approximation algorithms as efficient alternatives to exact algorithms, focusing on their design, analysis, and applications.

Fachkompetenzen: After successful completion of the module, students are able to

- explain the principles and design goals of randomized and approximation algorithms,
- understand the basic strategies for designing such algorithms,
- design and analyze randomized algorithms with probabilistic performance guarantees,
- design and analyze approximation algorithms with provable solution quality bounds,
- understand the mathematical foundations and formal analysis techniques for the above,

- model computational problems to apply randomized or approximation techniques, and
- investigate new problems and develop novel randomized or approximate solutions.

Überfachliche Kompetenzen: Students are able to perform

- probabilistic reasoning and structured analysis of algorithmic approaches,
- formal reasoning and basic proofs regarding correctness and efficiency,
- abstract modelling of computational problems,
- critical evaluation of trade-offs between accuracy, running time, and resource consumption, and
- being aware of ethical, fairness, and societal issues related to approximate and randomized algorithms.

Inhalt:

- Fundamentals of randomized algorithms: probability theory, expected values, concentration bounds, and others;
- key techniques in randomization such as Monte Carlo methods, random walks, and Markov chains;
- applications of randomization such as sorting, hashing, Bloom filters, linear programming;
- approximation algorithm design techniques such as greedy algorithms, linear programming relaxation, random rounding;
- analysis of approximation ratios and probabilistic guarantees;
- hardness of approximation;
- case studies and practical applications in various domains.

Erwartete Vorkenntnisse: Knowledge of algorithms and data structures, discrete mathematics, basic probability theory, and complexity theory

These prerequisites are taught in the following modules:

- *Algorithmen und Datenstrukturen*;
- *Statistik und Wahrscheinlichkeitstheorie*;
- *Effiziente Algorithmen*; and
- *Algorithmics*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Beyond Exact Algorithms

Complexity Theory

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: Complexity theory provides tools to characterize the inherent complexity of problems and, for instance, to formally show that, for a given problem, no significantly more efficient algorithm can be expected.

Fachkompetenzen: After successful completion of the module, students are able to

- explain fundamental complexity classes and their intuition and
- carry out complexity analyses of problems (in particular in the polynomial hierarchy).

Überfachliche Kompetenzen: Students acquire the ability to analyse problems from different domains and to identify the main source(s) of the complexity of a given problem. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: The module covers basic notions of complexity theory, deterministic und nondeterministic complextiy classes, in particular: the classes L, NL, P, NP, the polynomal hierarchy, PSPACE, and EXPTIME. We also look inside the class P to study parallelizable problems. Students get practice with these complexity classes by analysing the complexity of problems from various applications on various levels of complexity.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Complexity Theory

Computer-Aided Verification

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to

- formally describe systems and specify their correctness using transition relations, automata, and temporal logic,
- understand state-of-the-art model checking algorithms for verification of systems, and
- use contemporary model checking tools and implement a proof-of-concept verification tool.

Überfachliche Kompetenzen: After successful completion of the module, students are able to

- analyze employed techniques and methods,
- select relevant techniques and methods for a given problem, and
- critically assess relevant solutions and formalisms.

Inhalt:

- Modeling of hardware and software;
- specification using temporal logic;
- assertions, and automata;
- explicit-state model checking;
- symbolic model checking with BDDs;
- bounded model checking with SAT;
- abstraction-based algorithms such as interpolation and IC3.

Erwartete Vorkenntnisse: Basic knowledge of theoretical computer science (propositional logic, finite automata); Programming skills.

These prerequisites are taught in modules

- *Theoretische Informatik*
- *Einführung in die Programmierung*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Computer-Aided Verification

Critical Algorithm Studies

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module explores the ethical, social, and political dynamics of algorithmic systems, critically examining their impact on society and the associated challenges.

Fachkompetenzen: After successful completion of the module, students are able to understand fundamental concepts of algorithmic systems, including bias, fairness, transparency, and accountability, as well as strategies to mitigate harms such as misinformation, extremist content, and online harassment.

Überfachliche Kompetenzen: Students gain the ability to critically analyze the societal impact of algorithms, evaluate ethical dilemmas in algorithmic systems, and propose technical or policy-oriented solutions to address trust and safety challenges. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Introduction to critical algorithm studies and trustand safety in algorithmic systems;
- algorithmic imaginaries and future scenarios;
- bias, fairness, and accountability in algorithmic decisions and design;
- technical solutions to harmful online behavior, such as detection and intervention methods;
- ethical and legal frameworks guiding algorithmic systems; and
- applications of trust and safety practices to real-world challenges, including combating misinformation and extremist/terrorist content.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Critical Algorithm Studies

Critical Theory of Media and Informatics

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:
Fachkompetenzen: After successful completion of the module students obtained the following skills:

- Technical and methodological skills:
  - name and explain historical and current day approaches to critical theories as presented in class;
  - assess technologies using critical lenses regarding different axes of power such as gender, class, race, disability, and colonialism.
- Cognitive and practical skills:
  - analyse and discuss the potential societal effects and impacts of technologies;
  - identify and argue for design changes to technological development in front of a technical audience;
  - assess and position academic and general media publications critiquing technologies.
- Social skills and self-competencies:
  - present their assessment in a written manner that is grounded in the literature presented in class;
  - articulate valid critical questions concerning the future of technology in society.

Überfachliche Kompetenzen: Students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Introduction to epistemologies in computer science;
- discussion of different critical theories along different schools of thoughts;
- focussed discussion and analysis of changing topics along current topics relevant to computer science (e.g., emerging technologies and their assessment);
- practical exercises to develop a critical reflexive practice.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Critical Theory of Media and Informatics

Cryptocurrencies

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to describe and analyze the foundations of blockchain technologies, including the basic concepts (mining, consensus protocols, etc.) as well as with the techninques underlying modern cryptocurrencies (layer-2 technologies).

Überfachliche Kompetenzen: Students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Introduction to blockchains and cryptocurrencies;
- consensus in synchrony and partial synchrony;
- longest chain consensus and PoW
- Bitcoin specifics;
- economics of blockchains;
- proof of stake;
- payment channels: the Bitcoin Lightning Network and the state-of-the-art;
- other scaling techniques (e.g., sharding);
- privacy.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Cryptocurrencies

Database Theory

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:
Fachkompetenzen: After successful completion of the course, students are able to:

- explain the formal concepts of data models and their associated query languages;
- analyze and compare query languages in terms of expressive power and computational complexity;
- apply theoretical results to optimize and evaluate queries systematically; and
- formulate open research questions and critically evaluate new approaches in database theory.

Überfachliche Kompetenzen: Students can formulate open research questions and critically evaluate new approaches in database theory. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: The module covers key concepts related to the foundations of data management. In particular, the following topics are covered:

- fundamental aspects of database query languages;
- relational query languages (introduction);
- Datalog;
- Codd's Theorem: relational calculus, relational algebra, and Datalog;
- Trakhtenbrot's Theorem;
- complexity of query evaluation;
- conjunctive queries;
- worst-case optimal joins;
- expressive power and Ehrenfeucht-Fraïssé games.

Erwartete Vorkenntnisse: Basic knowledge of database systems, algorithms and data structures, and programming.

These prerequisites are taught in the following module:

- *Formal Methods in Systems Engineering*)

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Database Theory

Decidable Logics for Knowledge and Data

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After the successful completion of the module, students are able to:

- describe selected decidable fragments of classical first-order logic and categorize them by their computational complexity of reasoning;
- write well-formed formulas and solve reasoning tasks in these fragments;
- name typical use-cases and application domains for different fragments;
- compare the fragments and formulate examples of formulas that (do not) belong to the fragments and their combinations;
- explain the model- and proof-theoretic reasons that make these fragments decidable;
- apply reasoning algorithms tailored for the corresponding fragments and argue their correctness and termination;
- judge whether a given specification can be expressed in a decidable fragment and identify restrictions on the formulas that may help tame their expressiveness.

Überfachliche Kompetenzen: Students are able to

- identify features of real-life problem descriptions that impact their suitability for formal computational approaches,
- formulate lean and accurate descriptions of problem domains, and
- critically assess the suitability of diverse computational techniques for different real-life problems of interest.

The material taught in this module does not carry ethical implications in itself nor does it have inherent gender aspects; the module focuses on foundational skills based on formal logic and mathematics. Teaching resources and methods will be developed with an awareness of diversity and ensuring a welcoming environment for students from underrepresented groups. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Description logics and ontological reasoning;
- guarded fragments and locality;
- two-variable logics and related fragments;
- counting and other generalized quantifiers;
- quantifier prefix fragments;
- Horn fragments and effectively propositional fragments.

Erwartete Vorkenntnisse: Basic knowledge of classical predicate logic.

These prerequisites are thought in the module *Logic and Computability*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung:
Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Decidable Logics for Knowledge and Data

Deep Learning for Natural Language Processing

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module introduces students to deep learning approaches for NLP, including hands-on experience with PyTorch.

Fachkompetenzen: After successful completion of the module, students are able to design, implement, and explain neural network models for natural language processing via deep learning, using the PyTorch framework.

Überfachliche Kompetenzen: Students develop the ability to critically assess deep learning applications in NLP, considering ethical challenges and implications. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Word vectors, word window classification, language models;
- backpropagation and neural networks;
- PyTorch framework;
- recurrent neural networks and language models;
- sequence-to-sequence models, machine translation, subword models;
- self-attention and transformers;
- pretraining, natural language generation;
- hugging face transformers;
- prompting, reinforcement learning from human feedback;
- question answering;
- convolutional neural networks, tree recursive neural networks, constituency parsing;
- intersections between NLP and linguistics;
- code generation;
- training large language models;
- multimodal deep learning;
- co-reference resolution;
- interpretability and explainability.

Erwartete Vorkenntnisse: Basic knowledge of programming and machine learning.
These prerequisites are covered in the module *Machine Learning*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Deep Learning for Natural Language Processing

Deontic Logic for Normative Reasoning

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: Deontic logic studies how we reason about moral and legal obligations, permissions, and prohibitions through formal mathematical structures. As artificial intelligence and automated systems play a larger role in decision-making, deontic logic has become crucial for distinguishing between actual states of affairs and ideal or required ones. This module draws from computer science, artificial intelligence, economics, philosophy, linguistics, and law, to explore how formal logical systems can model and analyze normative reasoning.

Fachkompetenzen: After successful completion of the module, students are able to:

- understand the normative concepts in ethical theories and legal reasoning;
- understand the mainstream formalisms in deontic logic for normative reasoning;
- understand and discuss some of the main problems encountered in deontic logic;
- apply deontic logic to formalise normative concepts (e.g., duties, responsibilities, best strategies and legal rights);
- communicate the basic concepts of deontic logic and their relevance for computer science and AI ethics and law;
- get a better insight on how formal and logical tools in symbolic logic can be relevant for their own work; and
- implement norms in a state of the art prover.

They will also be well-prepared for future developments in the area.

Überfachliche Kompetenzen: The module will cover the fundamentals of normative reasoning, which are based on the emphasis of logical semantics. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: Two research traditions have dominated the landscape of deontic logic, one drawing on methods from mathematical logic, and the other drawing on methods from AI and rule-based systems. This module will introduce four frameworks representative of these two research traditions: monadic deontic logic (MDL), dyadic deontic logic (DDL), deontic STIT logic, and input/output (I/O) logic. We will describe their language, semantics, axiom systems, and automation. We will also introduce students to some of the main topics discussed in deontic logic, including reasoning about norm violation and conflicts, as well as responsibility and rationality. The applications of various deontic

logics in modelling legal rights is another important topic in this module as well as the automation of (normative) reasoning tasks in Isabelle/HOL.

Erwartete Vorkenntnisse: The prerequisite of this module is a basic knowledge of symbolic logic, which is taught in the module *Logic and Computability*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Deontic Logic for Normative Reasoning

Digital Humanism

Regelarbeitsaufwand: 3,0 ECTS

Lernergebnisse:
Fachkompetenzen: After successful completion of the module, students are able to analyse and reflect on the current developments in informatics, and, hopefully, have both commitment and ideas to influence the future development. Thus, students gain a better understanding of digital humanism, which we define as a concept that describes, analyzes, and, most importantly, influences the complex interplay of technology and humankind, for a better society and life, fully respecting universal human rights.
Überfachliche Kompetenzen: Students are able to identify and discuss ethical questions in the context of digital humanism.

Inhalt: The module consists of two parts:

(a) lectures on selected topics of digital humanism;
(b) students in groups (size 3 – 5) will work on specific subconcepts and/or dimensions of digital humanism. In interactive session they will present their intermediate and final results.

The module starts with "classical" lectures, then students work on their projects. There will be intermediate presentations of the group works.
In parallel, there will be public presentations of internationally renowned academics.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung:
Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
3,0/2,0 VU Digital Humanism

Discrete Mathematics

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with proof techniques, advanced concepts and theorems of several topics of discrete mathematics.

Fachkompetenzen: After successful completion of the module, students

- are able to state formally the definitions belonging to the module topics,
- to present important results and ideas of mathematical proofs in discrete mathematics,
- find and formulate formal proofs for problems from discrete mathematics,
- explain concepts of discrete mathematics and their interrelations, and
- state and explain some applications.

Überfachliche Kompetenzen: Students acquire the ability to present problem solutions in front of a group.

Inhalt: The module covers the following topics:

- Graph theory:
  - matroids and general greedy algorithm;
  - special classes like planar graphs, bipartite graphs and matchings; and
  - graph colorings and Ramsey theory.
- Advanced combinatorics:
  - counting principles;
  - generating functions and recurrences; and
  - combinatorial constructions.
- Number theory:
  - divisibility and factorization;
  - congruences and systems of congruences;
  - structural properties of elements in abelian groups; and
  - application to the RSA algorithm.
- Finite fields:
  - rings;
  - special classes: Euclidean and factorial rings;
  - ideals in rings; and
  - finite fields and algebraic extensions.
- Applications:
  - linear and polynomial codes;
  - BCH-codes; and
  - linear shift register sequences.

Erwartete Vorkenntnisse: Basic knowledge of functions, sets, relations, graph theory, combinatorics, group theory and linear algebra as well as elementary mathematical proof techniques involving mathematical induction, elementary combinatorial arguments, algebraic manipulations in groups, linear mappings, and matrix calculus.

These prerequisites are taught in the following modules:

- *Algebra und Diskrete Mathematik.*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Discrete Mathematics

Explainable AI

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with the various methods of explainability that are currently developed for artificial intelligence systems. The module aims at providing students with a broad overview of what explainable AI is.

Fachkompetenzen: After successful completion of the course, students are able to:

- explain key components of what explanations are from the view point of the humanities;
- present the state of the art in subfields of explainable AI;
- argue for why explainability is essential for trustworthy and ethical AI;
- apply various techniques from symbolic and subsymbolic explainable AI.

Überfachliche Kompetenzen: Students acquire the ability to reflect on a broader level on questions concerning explainability and artificial intelligence; this includes the EU policy on transparent AI and ethical and societal impact of AI that warrants the development of explainability methods.

This course will address ethics, gender, and diversity in the following ways: it embeds the challenge of explainability in the broader context of ethical challenges of AI, these challenges include gender bias in AI. Furthermore, the literature for the course is aimed at reflecting diverse backgrounds too.

Inhalt: The module covers

- philosophy of explanation and social sciences studies on explanation;
- symbolic XAI methods in knowledge representation and reasoning (computational argumentation based approaches);
- visualization techniques for explainable AI;

- XAI work using interactive dialogue models;
- trustworthiness, bias, and correctness challenges in (explainable) AI.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Explainable AI

Extension

Regelarbeitsaufwand: up to 12,0 ECTS

Lernergebnisse: This module allows students to extend their profile by choosing courses from other Master curricula that fit the qualification profile of *Logic and Artificial Intelligence* .

Fachkompetenzen: Depends on the chosen courses.

Überfachliche Kompetenzen: Depends on the chosen courses.

Inhalt: Depends on the chosen courses.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls: The courses in this module can be chosen freely from other Master curricula, provided they fit the qualification profile. Courses from other Informatics Master Curricula at TU Wien can always be chosen.

Furthermore, courses from Master Curricula of Mathematics at TU Wien can be chosen.

Fixed-Parameter Algorithms and Complexity

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to understand the theory of parameterized complexity and fixed-parameter tractability in sufficient depth to read and follow latest developments in the area and, crucially, to analyze problems they encounter from the parameterized viewpoint. First and foremost, this includes the ability to obtain asymptotically efficient algorithms and strong lower bounds for problems of interest.

Überfachliche Kompetenzen: Students will learn about the methodology in today's state-of-the-art research on algorithms and complexity, and will be able to better comprehend and produce formal proofs. Students will also be confronted with tasks such as literature research and comparison of known results.

Inhalt: Fixed-parameter algorithms provide a powerful approach for efficiently solving many NP-hard problems by exploiting structural aspects of problem instances in terms of a problem parameter. This module provides an overview of the main techniques for developing fixed-parameter algorithms (including bounded search trees, kernelization, color coding, modulators) as well as the fundamentals of parameterized complexity theory (such as the Weft-hierarchy, XP and para-NP-hardness, kernelization lower bounds) which allows to provide strong evidence that certain problems cannot be solved by a fixed-parameter algorithm.

Erwartete Vorkenntnisse: Students should be aware of the foundations of algorithms and complexity.

These prerequisites are taught in the following modules:

- *Algorithmen und Datenstrukturen*
- *Effiziente Algorithmen*
- *Algorithmics*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Fixed-Parameter Algorithms and Complexity

Formal Methods for Security and Privacy

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to develop a static analysis technique to enforce security and privacy properties in a variety of domains, such as cryptographic protocols, programming languages, bytecode, and deep neural networks. In particular, this module explains the foundations of the static analysis of security and privacy properties, with a particular focus on SMT solving and type systems. Students will learn to formalize a static analysis, prove its soundness, and implement it in an efficient way using state-of-the-art verification tools.

Überfachliche Kompetenzen: Students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Foundations of theorem proving;
- type theory and static analysis for security and privacy;
- formal modelling and verification of security and privacy in software;
- cryptographic protocols, Blockchains, and machine learning.

Erwartete Vorkenntnisse: Foundations of security and logic taught in typical bachelor's programs in computer science.

These prerequisites are taught in the following bachelor modules:

- *Einführung in Security*;
- *Logic and Reasoning in Computer Science*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Formal Methods for Security and Privacy

Formal Methods in Systems Engineering

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with foundations and applications of automated reasoning and verification techniques for computer systems.

Fachkompetenzen: After successful completion of the module, students are able to understand the theory and practice of automated reasoning and verification techniques for computer systems.

Überfachliche Kompetenzen: Students acquire the ability to understand, use, and apply formal methods for ensuring system correctness.

Inhalt:

- Methods for checking correctness of system requirements, in particular using SAT and satisfiability modulo theory (SMT) solving;
- model checking approaches, in particular using temporal logics and bounded model checking;
- deductive verification techniques, such as Hoare logic and weakest precondition reasoning;
- program-analysis methods, in particular interval analysis and pointer semantics.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Formal Methods in Systems Engineering

Freie Wahlfächer und Transferable Skills

Regelarbeitsaufwand: 9,0 ECTS

Lernergebnisse: Die Lehrveranstaltungen dieses Moduls dienen der Vertiefung des Faches sowie der Aneignung außerfachlicher Kenntnisse, Fähigkeiten und Kompetenzen.

Inhalt: Abhängig von den gewählten Lehrveranstaltungen.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls: Die Lehrveranstaltungen dieses Moduls können frei aus dem Angebot an wissenschaftlichen und künstlerischen Lehrveranstaltungen, die der Vertiefung des Faches oder der Aneignung außerfachlicher Kenntnisse, Fähigkeiten und Kompetenzen dienen, aller anerkannten in- und ausländischen postsekundären Bildungseinrichtungen ausgewählt werden, mit der Einschränkung, dass zumindest 4,5 ECTS aus den Themenbereichen der Transferable Skills zu wählen sind. Für die Themenbereiche der Transferable Skills werden insbesondere Lehrveranstaltungen aus dem Wahlfachkatalog „Transferable Skills“ der Fakultät für Informatik (Anhang E) und aus dem zentralen Wahlfachkatalog der TU Wien für „Transferable Skills“ empfohlen.

Generative AI

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module provides a comprehensive introduction to modern generative AI fundamentals and applications, from large language models (LLMs) to multimodal systems, including practical implementation aspects, intersections with related research areas, and ethical considerations.

Fachkompetenzen: After successful completion of the module, students are able to:

- explain the fundamentals of generative AI, including language models, multimodal approaches (vision transformers, diffusion models), and the transformer architecture;
- apply training techniques such as pre-training, fine-tuning, and reinforcement learning;
- integrate LLMs using advanced prompting, retrieval-augmented generation, and tools like LangChain;
- assess the role, potential, and limitations of generative AI in applications like recommender systems;
- use knowledge graphs to address generative AI challenges such as hallucinations and lack of domain knowledge; and
- explain the intersection between symbolic AI and subsymbolic architectures in generative models.

Überfachliche Kompetenzen: Students learn to critically evaluate the ethical implications of generative AI systems, their potential biases and societal impact. Moreover, they learn the intersections between generative AI and other research areas like recommender systems or symbolic AI systems. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Theory of LLMs and generative AI:
  - AI paradigms and generative AI within the broader taxonomy, covering autoregressive language modeling, probabilistic approaches, tokenization, and embedding spaces;
  - Transformers, encoder-decoder structures, self-attention mechanisms, and LLM training, including reinforcement learning and proximal policy optimization.
- Practice of LLMs and generative AI:
  - advanced prompt engineering to address LLM limitations;
  - retrieval-augmented generation (RAG), including architecture, integration, and enhancement techniques;
  - tooling for LLM deployment, interaction, and integration.
- Generative AI beyond language modelling:
  - multimodal AI, including vision transformers, text-to-speech models, and diffusion models;
  - knowledge graphs (KGs) for addressing LLM limitations (hallucinations, domain knowledge, trust) using KG embeddings, graph neural networks, and GraphRAG;
  - symbolic and subsymbolic AI intersections, knowledge-enhanced generation, and LLM-enhanced knowledge representations;
  - generative AI in recommender systems, including architecture, evaluation, and limitations;
  - ethical considerations, covering bias, fairness, privacy, and embedded ethical frameworks.

Erwartete Vorkenntnisse: Basic knowledge of programming and machine learning.
These prerequisites are taught in the module *Machine Learning*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Generative AI

Gödel's Incompleteness Theorems

Regelarbeitsaufwand: 4,5 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to explain Gödel's incompleteness theorems and their proofs as well as the central proof techniques obtaining them.

Überfachliche Kompetenzen: Students deepen their ability to use and critically assess central proof-theoretical techniques and concepts.

Inhalt:

The module starts with a short introduction to computability theory which allows to get to know the central proof techniques of diagonalisation and arithmetisation in a comparatively simple setting. The consideration of the notion of truth in the standard model will lead us to the logical level. Afterwards we will study arithmetical theories and their non-standard models. Thus prepared, various forms and proofs of the incompleteness theorems will be proven and discussed.

Erwartete Vorkenntnisse: Basic knowledge in mathematical logic: first-order logic, models, proofs, soundness, completeness, compactness.

These prerequisites are taught in the following modules:

- *Logic and Computability*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung:

Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:

3,0/2,0 VO AKLOG Gödel's Incompleteness Theorems
1,5/1,0 UE AKLOG Gödel's Incompleteness Theorems

Graph Drawing Algorithms

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module introduces efficient algorithms and complexity results for drawing and representing graphs in different visual layout styles.

Fachkompetenzen: Students are able to

- explain fundamental concepts, structures, and problems in graph drawing,
- explain and compare different aesthetic optimization goals in graph drawing,
- design and analyze graph drawing algorithms,

- model graph drawing problems and adapt known algorithms and graph layout styles to related problems,
- implement and evaluate graph drawing algorithms, and
- investigate new graph drawing problems and develop new layout algorithms.

Überfachliche Kompetenzen: Student are able to perform

- formal reasoning, correctness proofs, and proofs of computational complexity,
- structured analysis of computational geometric graph representation problems,
- modeling and solving interdisciplinary problems at the interface of application domains, information visualization, design, and graph algorithms,
- to judge trade-offs between different conflicting optimization goals, and
- being aware of possible ethical, gender, and diversity issues in the context of network visualization

Inhalt: The module content covers fundamental and advanced topics in graph drawing including

- graph layout for restricted graph classes such as trees, planar graphs, directed graphs,
- optimization problems for different quality metrics and drawing styles in graph drawing,
- general purpose algorithms using physical analogies,
- graph drawing frameworks, and
- heuristics/approximation algorithms for NP-hard problems.

Erwartete Vorkenntnisse: Extended knowledge of algorithms and basics of graph theory.

These prerequisites are taught in the following modules:

- *Effiziente Algorithmen*;
- *Discrete Mathematics*; and
- *Algorithmics*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Graph Drawing Algorithms

Heuristic Optimization Techniques

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:
Fachkompetenzen: After successful completion of the module, students are able to, students understand concepts and techniques from heuristic optimization and problem solving, and are able to apply them in efficient implementations as well as to systematically evaluate and compare approaches experimentally.
Überfachliche Kompetenzen: Students acquire the ability to understand, develop, apply, and experimentally evaluate algorithms for heuristically solving challenging computational optimization problems in practice. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Construction heuristics;
- local search techniques;
- metaheuristics, including simulated annealing, GRASP, tabu search, variable neighborhood search, evolutionary algorithms, and ant colony optimization;
- hybrid optimization techniques, including large neighborhood search techniques;
- Mmchine learning based approaches;
- parallelization;
- analysis and tuning.

Erwartete Vorkenntnisse: Solid programming skills and knowledge in algorithms and data structures
These prerequisites are taught in the following modules:

- *Algorithmen und Datenstrukturen*;
- *Einführung in die Programmierung*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Heuristic Optimization Techniques

History of Logic

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:
Fachkompetenzen: After successful completion of the module, students are able to name and explain the most important milestones in the development of formal logic, as well as

to correctly argue theoretical relations of the considered formalisms and their relevance for modern logic.

Überfachliche Kompetenzen: After successful completion of the module, students are able to critically reflect the relevance of historical context for the forming of scientific ideas and development. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Aristotle's system of syllogisms;
- the logic of the Megarians and Stoics,
- medieval forms of logic,
- Leibniz's work on logic (algebraic calculi, the idea of a complete and automated language of reasoning - "calculus ratiocinator", work on modal logic),
- developments in algebra and geometry,
- Boole's algebra of logic,
- the contributions of C.S. Peirce,
- Frege's logic,
- Cantor's theory of sets,
- the intuitionism of Brouwer and Heyting,
- Whitehead and Russell's Principia Mathematica,
- Hilbert, Gödel, and the Vienna Circle,
- the Polish school of logic,
- Post, Church, and Kleene.

Erwartete Vorkenntnisse: Basic knowledge of logic.

All prerequisites are covered in the module *Logic and Computability*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU History of Logic

Human-Centered AI

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to:

- explain user interface basics and AI system design principles;
- describe fundamentals of supervised, unsupervised, and reinforcement learning;

- explain and apply gesture recognition (sequence classification, Markov property, gesture and pose detection from video);
- implement adaptive user interfaces (automated optimization based on human factor parameters); and
- work with tools and frameworks (TensorFlow, Unity ML-Agents).

Überfachliche Kompetenzen: After successful completion of the module, students are able to:

- analyze parameter estimation and model selection to suit specific scenarios;
- evaluate human-AI interaction from a human-centered perspective;
- demonstrate critical thinking in balancing user requirements, technical feasibility, and societal impact;
- collaborate effectively in interdisciplinary teams to address complex design problems;
- design AI systems that effectively support or cooperate with human users;
- communicate design concepts and processes clearly and persuasively to diverse audiences; and
- adapt to feedback and iterative processes with resilience and a growth mindset.

Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Basics of AI systems: supervised, unsupervised, and reinforcement learning.
- Recommender systems: definitions, collaborative filtering, similarity measures.
- Natural language processing: syntax, semantics, tokenization, normalization, stemming, chatbot interaction.
- Gesture recognition: sequence classification, Markov property, gesture and pose recognition from video.
- Adaptive user interfaces: automated optimization based on human factor parameters.
- Explainable AI: local and global interpretability, LIME, SHAP, automated rationale generation.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Human-Centered AI

Information Visualization

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to

- describe the theoretical concepts of information visualization, human perception and cognition, as well as the qualitative and quantitative evaluation methods thereof,
- apply information visualization concepts in practical exercises, in combination with data science methods,
- critically evaluate information visualization algorithms, the quality of visual representations, interaction techniques, analytical methods and their interplay,
- apply perceptual and cognitive foundations and state-of-the-art visualization algorithms to information visualization design,
- select information visualization methods suitable for different data types, tasks, and users,
- apply quantitative and qualitative evaluation methods to assess the quality of information visualizations.

Überfachliche Kompetenzen: In this module, students

- learn to analyze complex real-world problems by applying information visualization theory and concepts,
- learn about and analyze the application of information visualization in different domains, such as biology and engineering,
- learn to use information visualization to explain AI methods,
- work and communicate effectively in teams,
- present their analysis results.

Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content. In particular, students learn to design and critically reflect visualizations so that they are accessible and usable by people with different backgrounds, abilities, and perspectives. This includes being mindful of biases in data collection and representation, avoiding stereotypes and cultural insensitivities, and using inclusive visual elements. The course also discusses the potential of visualization to facilitate discovery and mitigation of bias in data science applications. Furthermore, ethical aspects of visualization evaluation are discussed.

Inhalt:

- Fundamentals of data, visualization design, and interaction design
- fundamentals of human visual perception and cognition
- Design methodology, taxonomies, and models
- Qualitative and quantitative evaluation methods
- Explainable AI
- Various application areas, like biology, and other disciplines of natural, social, and economic sciences
- Applying different methods for data preprocessing and visual inspection
- Implementation of a simple interactive information visualization tool
- Presenting visual data analysis results.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Information Visualization

Introduction to Computational Sustainability

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: Modern ICT systems, such as data centers, AI models, and high-performance computing (HPC), consume significant amounts of energy and resources, contributing to growing environmental concerns. As global sustainability goals, including the UN's Sustainable Development Goals (SDGs), become increasingly urgent, computing emerges as a powerful tool to address challenges in areas such as climate modeling, renewable energy optimization, and resource management. Computational sustainability extends beyond traditional computing by equipping students with the knowledge and skills to design algorithms that balance efficiency, cost, and environmental impact, enabling them to develop innovative, sustainable solutions for complex problems.

Fachkompetenzen: Fundamental concepts and techniques on computational sustainability.

Überfachliche Kompetenzen: Students acquire the ability to describe and explain methods for computational sustainability and assess and evaluate existing systems regarding their sustainability. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Sustainable AI: Impact on sustainability by AI models
- Hardware advancements, data explosion, and its energy impacts
- Energy Challenge of AI models: Cost of Training and Inference
- Large Language Models and their energy consumption
- Methods to address energy consumption of AI models
- AI for sustainability: Using AI to combat the climate change issues
- Specific Use cases on AI for sustainability

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Introduction to Computational Sustainability

Knowledge Graphs

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: Learning outcomes are divided into three main blocks: (i) *representations of knowledge graphs* (logic- and ML-based), (ii) *systems for knowledge graphs* (scalablility and reasoning), and (iii) *applications of knowledge graphs* (real-world enterprise AI). An overarching aim of the module is to understand the connections between knowledge graphs (KGs), artificial intelligence (AI), machine learning (ML), deep learning, and data science.

Überfachliche Kompetenzen: Students are able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content. This relates particularly to the role of knowledge graphs as a way to validate information and knowledge in AI systems as well as the ability of many of the knowledge graph techniques discussed in the module to provide explainable AI solutions – hence a key part of providing ethical and explainable AI.

Inhalt: The module includes the following topics:

- knowledge graph embeddings;
- logical knowledge in knowledge graphs;
- graph neural networks;
- graph transformers;
- knowledge graph architectures;
- scalable reasoning in knowledge graphs;
- the knowledge graph lifecycle (creation, evolution, services);
- real-world applications of knowledge graphs (including financial applications).

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Knowledge Graphs

Logical Foundations of Inductive Theorem Proving

Regelarbeitsaufwand: 4,5 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students understand the contents of the module. Among other effects, this understanding forms the basis for the capability to correctly reproduce the statements and notions covered in the module as well as for the ability to explain and apply the proof techniques used in the module.

Überfachliche Kompetenzen: Students deepen their ability to use and critically assess rigorous mathematical techniques and concepts.

Inhalt: This module covers the following topics: analyse

- straighforward induction proofs;
- equational theory exploration;
- superposition with explicit induction axioms; and
- clause set cycles.

The employed mathematical methods concern mostly weak arithmetical theories such as open induction or existential induction.

Erwartete Vorkenntnisse: Basic knowledge in mathematical logic: first-order logic, models, proofs, soundness, completeness, compactness.

These prerequisites are taught in the following modules:

- *Logic and Computability*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung:
Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
4,5/3,0 VO AKLOG Logical Foundations of Inductive Theorem Proving
1,5/1,0 UE AKLOG Logical Foundations of Inductive Theorem Proving

Logic and Computability

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: The module is concerned with a broad range of logical formalisms as modelling and specification tools as well as with techniques for automated proof search. The aim is to provide a solid understanding of the role of mathematical logic and of computability theory in computer science.

Fachkompetenzen: After successful completion of the module, students are able to apply logical formalisms in various application scenarios and to employ concepts of formal logic and computability theory as tools for effective, precise, and innovative problem solving in IT.

Überfachliche Kompetenzen: The students gain logical, mathematical, and computational knowledge and abilities. Moreover, they also understand philosophical aspects relating to the incompleteness of proof systems and to the interpretation of logical connectives.

Inhalt: The topics in logic comprise the following:

- advanced aspects of classical first-order logic as a specification tool;

- expressibility (elements of model theory);
- proof systems for classical first-order logic (including soundness and completeness proofs);
- a comparison of different types of inference systems,
- methods for handling identity;
- elements of modal logic (including temporal and epistemic logics);
- elements of intuitionistic logic and constructivism; and
- principles of automated theorem proving.

As for topics about computability, these include:

- different models of computations;
- the Church-Turing thesis;
- decidable and undecidable problems alongside formal tools to distinguish them;
- various concepts of problem reductions;
- the incompleteness of arithmetic and its consequences for the verification of programs, and
- connections between computability and logic.

Erwartete Vorkenntnisse: Students should have a basic knowledge of classical propositional and first-order logic, of different programming paradigms (imperative, functional, logical), of concepts of formal languages (grammars, Chomsky hierarchy), and of complexity theory. Moreover, students should be able to express problems and requirements in a precise mathematical language.

These prerequisites are taught in the following modules

- *Formal Methods in Systems Engineering*;
- *Theoretische Informatik*; and
- *Algebra und Diskrete Mathematik*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Logic and Computability

Logic-based Artificial Intelligence

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: At the end of this module, the students will be familiar with a range of logic-based formalisms for describing problem domains. They will be able to select an adequate formalism for a problem of interest, and correctly model the problem in the

selected formalisms. The student should also be able to select an adequate reasoning engine for solving the problem at hand, informed by an understanding of the problems it implements.

Fachkompetenzen: The students who complete the module are able to

- read and write correctly domain specifications in classical predicate logic,
- decide whether a given statement is consistent with or entailed by a logic specification,
- describe a given domain using a description logics of adequate expressiveness,
- understand and solve instances of classical DL reasoning services: consistency, instance checking, and concept subsumption,
- understand the principles of nonmonotonic reasoning and recognise different nonmonotonic entailment relations,
- correctly write logic programs witdh default negation and compute their answer set semantics,
- model probabilistic domains and draw inferences from them,
- recognise different types of decision rules, and
- apply algorithms to learn rules from tabular data.

Überfachliche Kompetenzen: Students are able to model problem domains accurately, and to assess and criticize the adequacy of different technqiues for specific situations. The students can identify and verbalise ethical challenges that arise when applying AI techniques in the real world.

The material taught in this module does not involve gender aspects. Teaching resources and methods will be developed with an awareness of diversity and ensuring a welcoming environment for students from underrepresented groups.

Inhalt: The module discusses the following topics:

- propositional and predicate logic as knowledge representation languages;
- description logics and ontological reasoning;
- tractable ontological reasoning;
- foundations of nonmonotonic reasoning;
- answer-set programming and declarative problem solving;
- logics with uncertainty;
- rule learning; and
- applications.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Logic-based Artificial Intelligence

Machine Learning

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: Students will learn fundamental machine learning concepts and techniques and apply them in different domains.

Fachkompetenzen: After successful completion of the module, students are able to:

- explain fundamental concepts of machine learning;
- explain the basics of machine learning theory;
- formulate problems as specific machine learning tasks;
- explain and implement the main supervised machine learning algorithms;
- explain and implement basic clustering algorithms;
- explain and implement basic reinforcement learning algorithms;
- apply learning techniques to various datasets and application domains;
- explain and apply automated machine learning methods;
- evaluate and compare machine learning methods; and
- explain and apply data preprocessing techniques.

Überfachliche Kompetenzen: Students acquire the ability to assess and use machine learning in different application domains. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content. This includes the problem of bias that arises in datasets and learning algorithms, the fairness of learning algorithms with respect to gender, race, age, and other factors, the transparency of machine learning systems, and the societal impact of automated decision-making based on machine learning.

Inhalt: The module includes the following topics:

- fundamental concepts of machine learning;
- basics of machine learning theory;
- fundamental supervised machine learning techniques, including basic techniques and advanced methods such as deep learning;
- basic clustering algorithms;
- basics of reinforcement learning and main tabular methods;
- evaluation and comparison of machine learning techniques;
- data preprocessing techniques and feature selection methods; and
- basic concepts of automated machine learning.

Erwartete Vorkenntnisse: Knowledge of programming, mathematics, and basic algorithms.

These prerequisites are covered in the following modules:

- *Einführung in die Programmierung*;
- *Algebra und Diskrete Mathematik*; and
- *Statistik und Wahrscheinlichkeitstheorie.*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Machine Learning

Machine Learning for Optimization

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: Students will learn fundamental concepts of solving techniques based on machine learning and apply them to various combinatorial optimization problems.

Fachkompetenzen: After successful completion of the module, students are able to:

- explain fundamental concepts of combinatorial optimization problems;
- explain concepts of end-to-end learning;
- explain and implement approaches based on deep learning and graph neural networks to solve combinatorial optimization problems;
- explain and implement reinforcement learning-based approaches for combinatorial optimization;
- apply large language models to combinatorial optimization;
- explain how machine learning can be used to improve general-purpose solvers.

Überfachliche Kompetenzen: Students develop the ability to critically assess the benefits of machine learning methods when solving optimization problems. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content. This includes the problem of bias that arises in datasets and learning algorithms, the fairness of learning algorithms with respect to gender, race, age, and other factors, the transparency of machine learning systems, and the societal impact of automated decision-making based on machine learning.

Inhalt: The module includes the following topics:

- combinatorial optimization problems;
- end-to-end learning for combinatorial optimization;
- deep learning and graph neural networks for combinatorial optimization;
- reinforcement learning for combinatorial optimization;
- large language models for combinatorial optimization; and
- machine learning for general-purpose solvers.

Erwartete Vorkenntnisse: Knowledge of programming and machine learning techniques.

These prerequisites are covered in the following modules:

- *Machine Learning*; and
- *Einführung in die Programmierung.*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Machine Learning for Optimization

Management of Graph Data

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module provides a comprehensive introduction to the principles, technologies, and advanced topics in graph data management, essential for working with knowledge graphs and different graph data models.

Fachkompetenzen: After successful completion of this module, students will be able to:

- Explain key graph data models and query languages,
- Formulate complex queries using graph query languages,
- Explain principles of query optimization,
- Apply schema languages tailored for graph data,
- Ensure data quality through shape constraints,
- Apply and model provenance techniques,
- Manage dynamic updates,
- Use state-of-the-art graph data technologies in popular applications and use cases.

Überfachliche Kompetenzen: Students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: The module covers essential concepts and techniques for effective graph data management, including:

- Key concepts of graph data models and schema languages
- Query formulation, execution, and optimization
- Ensuring graph data quality through validation and shape constraints
- Methods for tracking provenance and ensuring traceability of graph data
- Strategies for managing dynamic updates and versioning of knowledge graphs
- Recent advances and trends in graph data technologies

Erwartete Vorkenntnisse: Students are expected to have basic knowledge in relational database systems and algorithms and data structures.

These prerequisites are taught in the following modules:

- *Datenbanksysteme*
- *Algorithmen und Datenstrukturen*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Management of Graph Data

Mathematical Programming and Optimization in Transport Logistics

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with solving optimization problems arising in transport logistics and related areas with exact and heuristic methods. A main focus is on mathematical programming techniques, in particular integer linear programming as well as the theoretical and technical background for doing so successfully.

Fachkompetenzen: After successful completion of the module, students are able to

- understand theoretical foundations of linear and integer linear programming (ILP),
- model optimization problems as ILP formulations,
- compare different ILP formulations for optimization problems theoretically and in practice,
- apply methods and algorithms for solving ILP models in general, and
- use specific ILP formulations and algorithms (exact and heuristic) for solving various optimization problems in transport logistics and related areas.

Überfachliche Kompetenzen: Students learn to

- apply the aforementioned techniques to problem settings from various fields,
- work together in groups on these problems, and
- present their work as a technical report.

Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: This module covers

- fundamentals of linear and integer linear programming (ILP) and its place within mathematical optimization,
- ILP modelling and solving techniques, both basic (compact formulations) and advanced (branch-and-cut, branch-and-price, Lagrangian relaxation, decomposition methods),
- ILP theory (analysis of different formulations, valid inequalities),

- optimization problems from transport logistics, such as the travelling salesperson problem, the vehicle routing problem and the pickup and delivery problem, and other related areas
- exact and heuristic methods for solving these, and
- real-world optimization problems and their complexities.

Erwartete Vorkenntnisse: Students are expected to be familiar with

- programming,
- linear algebra,
- graph theory,
- fundamentals of (integer) linear programming, and
- fundamentals of heuristic optimization.

These prerequisites are taught in the following modules:

- *Einführung in die Programmierung*
- *Algebra und Diskrete Mathematik*
- *Algorithmics*
- *Heuristic Optimization Techniques*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Mathematical Programming and Optimization in Transport Logistics

Modal Logics

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to name and explain the most important families of modal logics, their central properties and semantical and proof-theoretical characterisations, as well as basic relations among the logics.

Überfachliche Kompetenzen: After successful completion of the module, students are able to

- analyze employed techniques and methods,
- select relevant techniques and methods for a given problem, and
- critically assess relevant solutions and formalisms.

Inhalt:

- Historical overview;
- classes of propositional normal modal logics;
- analytic tableaux, sequent-style systems, and consistency properties;
- logical consequence, compactness, interpolation and definability theorems;
- Hilbert-type systems and natural deduction;
- non-analytic and non-normal logics;
- multi-modal logics;
- first-order modal logics; and
- applications for modelling dishonest agents.

Erwartete Vorkenntnisse: Basic knowledge of classical logic.

All prerequisites are covered in the module *Logic and Computability*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung:

Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Modal Logics

Neurosymbolic Reasoning

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: An introduction to neurosymbolic approaches and modern applications of logic in AI.

Fachkompetenzen: After successful completion of the module, students will be able to:

- identify the differences between sub-symbolic and symbolic AI approaches, and apply them to different tasks;
- describe the landscape of approaches in neurosymbolic AI;
- analyze the logical expressivity of methods in symbolic and sub-symbolic AI;
- develop, assess, and empirically evaluate neurosymbolic models;
- identify practical tools for solving problems using neurosymbolic approaches; and
- model and solve learning and reasoning problems using neurosymbolic AI.

Überfachliche Kompetenzen: Students gain a structured understanding of symbolic, sub-symbolic, and neurosymbolic AI approaches, and learn to critically analyze their expressivity. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Limits of symbolic and subsymbolic AI,

- models that integrate logic; probability and learning e.g., Markov logic, Problog, etc.;
- selected neurosymbolic formalisms, including rule-based approaches for neurosymbolic AI;
- methods for reasoning under uncertainty, such as weighted first-order model counting/sampling;
- role of logic in machine learning theory; and
- expressivity of ML models like graph neural networks and transformers.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Neurosymbolic Reasoning

Nonclassical Logics

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: A broad range of concepts, methods, and results in different areas of nonclassical logics are covered. A selection of specific results and techniques, in particular, in modal and in many-valued logics, are explained and practised extensively. Moreover, a structured overview of the vast field of nonclassical logic is provided that will enable students to assess and choose from a large number of possible models and corresponding formal reasoning tools for a wide range of applications in computer science and beyond.

Fachkompetenzen: Students learn to apply a considerable range of logical and mathematical concepts and tools in nonclassical logics, including: possible world semantics, axiomatic characterisation of relational properties, modelling of epistemic situations, logical aspects of constructive mathematics, principles of graded reasoning, and algebraic tools in fuzzy logic.

Überfachliche Kompetenzen: Students learn logical, mathematical, as well as computational concepts and techniques. Moreover, they gain knowledge about aspects of modeling that concern many potential application areas, ranging from the specification of and formal reasoning about multi-agent systems to solving logical, computational, and philosophical puzzles about knowledge and graded inference. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: The module discusses the following topics:

- general theory of modal logics;
- epistemic logic;
- elements of intuitionistic logic; and

- mathematical fuzzy logics.

Moreover, a structured overview of further topics in nonclassical logics and of logics combining features from different areas of nonclassical logics is provided.

Erwartete Vorkenntnisse: The prerequisites for this module comprise a firm knowledge of basic techniques and results of classical propositional and first-order logic.

These prerequisites are covered in the module *Logic and Computability*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Nonclassical Logics

Nonmonotonic Reasoning

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to name and explain the most important nonmonotonic reasoning formalisms, their central properties, and basic relations among them.

Überfachliche Kompetenzen: After successful completion of the module, students are able to

- analyze employed techniques and methods,
- select relevant techniques and methods for a given problem, and
- critically assess relevant solutions and formalisms.

Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Phenomenology and typology of nonmonotonic reasoning;
- properties of nonmonotonic inference relations;
- central formalisms for nonmonotonic reasoning (like default logic, circumscription, and modal nonmotonic logics);
- relations to the theory of logic programming; and
- proof calculi of different nonmonotonic logics.

Erwartete Vorkenntnisse: Basic knowledge of classical logic.

All prerequisites are covered in the module *Logic and Computability*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Nonmonotonic Reasoning

Nonstandard Deduction Systems

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to name and explain the most important logical calculi for axiomatising classes of formulas different from the valid ones. Moreover, students are able to correctly argue the central properties of such systems and apply them for different tasks.

Überfachliche Kompetenzen: After successful completion of the module, students are able to

- analyze employed techniques and methods,
- select relevant techniques and methods for a given problem, and
- critically assess relevant solutions and formalisms.

Inhalt:

- Introduction and historical overview;
- the biaspectual formalization of deductive systems and the theory of the anti-consequence operator;
- proof systems for the axiomatic rejection of formulas for classical logic, intuitionistic logic, finite-valued logics, and different modal logics;
- deduction methods for axiomatizing satisfiability and contingency; and
- applications for logics in artificial intelligence.

Erwartete Vorkenntnisse: Basic knowledge of classical logic.

All prerequisites are covered in the module *Logic and Computability*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Nonstandard Deduction Systems

Preferences in Artificial Intelligence

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students are able to

- describe the role of preferences in artificial intelligence;
- represent preference data in computer systems;
- integrate preferences in selected knowledge representation formalisms;
- apply and analyze various aggregation methods.

Überfachliche Kompetenzen: After successful completion of the module, students are able to analyze, select, and critically assess methods and solutions involving preferences. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: The module is based on two main parts. The first part will consist of lectures which provide the necessary background and foundational material as well as an introduction to current research topics. In the second part, students have to apply the concepts and techniques presented in the lecture within a small project, which can either be concerned with a theoretical question or about implementation. Hereby, students will thus actively work with up-to-date literature and participate in current research conducted at our group.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung:

Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:

6,0/4,0 VU Preferences in Artificial Intelligence

Principles of Knowledge Representation

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module considers important issues in knowledge representation and reasoning, along with methods and techniques to address them, with attention to semantic and computational aspects.

Fachkompetenzen: After successfully completing the module, students are able to use results from some of the central core topics of knowledge representation and reasoning in this context both in theory and practice. They are able to theoretically work on technical problems related to the task areas and also to model and solve problems practically using software tools for knowledge representation. This includes the ability to analyze and assess the intrinsic difficulty of computation and reasoning tasks, which are prerequisites for designing efficient algorithms, using tools from the computational complexity.

Überfachliche Kompetenzen: The course will be sensitive to ethics, gender and diversity issues, especially with respect to examples and notions from the literature, as well as to special needs and circumstances of the students. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender and diversity in the context of the module's content.

Inhalt: In this module, we consider different aspects of knowledge representation and reasoning, including

- approaches to change knowledge bases;
- nonmonotonic reasoning and logic programming;
- reasoning about actions and planning;
- abductive reasoning and explanations;
- multi-context systems and distributed knowledge;
- computational complexity tools;
- expressiveness of knowledge representation formalisms; and
- complexity analysis of selected problems (case studies).

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Principles of Knowledge Representation

Probabilistic Reasoning

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After the successful completion of the module, students are able to delineate the main application areas, formalisms, and methodologies for probabilistic modeling and reasoning in artificial intelligence.

Überfachliche Kompetenzen: Students deepen their ability to use and critically assess central concepts related to probabilistic reasoning.

Inhalt:

- Basics of probability theory;
- Bayesian networks;
- probabilistic logic;
- nonmonotonic probabilistic inference;
- probabilistic logic programming;
- decision theory;

- planning under uncertainty in Markov decision processes (MDPs) and partially observable Markov decision processes (POMDPs); and
- game theory.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Probabilistic Reasoning

Problem Solving and Search in Artificial Intelligence

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: Students will learn about core AI problem solving techniques and their applications in various domains.

Fachkompetenzen: After successful completion of the module, students are able to:

- explain fundamental concepts of search methods in AI;
- model problems using solver-independent constraint modeling languages such as MiniZinc;
- explain and implement constraint programming techniques;
- use solvers based on constraint programming and SAT to solve various problems;
- explain structural decomposition techniques;
- explain and apply methods for automated algorithm selection and configuration;
- apply instance space analysis to evaluate the difficulty of problem instances and the impact of problem features;
- explain and implement local search and hyper-heuristic approaches; and
- apply learned techniques to solve complex practical problems, including those in planning and scheduling domains

Überfachliche Kompetenzen: Students acquire the ability to assess and use AI problem solving techniques in different application domains. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content. This includes the transparency and explainability of AI algorithms, and the societal impact of automated problem solving.

Inhalt: The module includes the following topics:

- solving problems by searching;
- constraint satisfaction/optimization problems;
- constraint programming techniques;
- solver-independent constraint modelling language MiniZinc;
- the structure of problems;

- local search techniques;
- application of machine learning in search;
- automated algorithm selection and configuration;
- hyper-heuristics; and
- instance space analysis
- AI-based scheduling and planning.

Erwartete Vorkenntnisse: Knowledge of programming and the basics of algorithms. These prerequisites are covered in the following modules:

- *Einführung in die Programmierung* and
- *Algorithmen und Datenstrukturen.*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Problem Solving and Search in Artificial Intelligence

Processing of Declarative Knowledge

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:
Fachkompetenzen: After a successful completion of the module, students are be able to

- design and declaratively specify (possibly recursive) Datalog queries,
- develop ASP programs and queries, and classify such programs by their language features and computational properties,
- understand the principles of query optimization via magic set transformation,
- describe the structure and concepts of description logics (DLs), as well as distinguish and compare different DLs,
- identify the difference between (logic programming) rules and ontologies, and
- use formalisms for combining rules with other paradigms (e.g., ontologies) and languages.

Überfachliche Kompetenzen: Furthermore, students are able to

- differentiate between *declarative* and *procedural* problem solving approaches,
- extract accurate and complete problem specifications from natural language descriptions,
- develop and optimize solutions for different types of declarative specifications, and
- critically assess the suitability of different declarative solving techniques for different real-world problems of interest.

Moreover, the students are capable of identifying, verbalizing, and discussing the ethical considerations that arise when applying declarative knowledge processing techniques in real-world scenarios.

The material taught in this module does not have inherent gender aspects; the module focuses on foundational skills based on formal logic and mathematics. Teaching resources and methods will be developed with an awareness of diversity and ensuring a welcoming environment for students from underrepresented groups.

Inhalt: In this module, we consider different formalisms for representing and processing declarative knowledge, with particular emphasis on

- Datalog and extensions;
- optimization of Datalog queries;
- answer-set programming;
- description logics as languages for ontologies;
- computational aspects of reasoning;
- combining rules with other formalisms and languages (e.g., hybrid knowledge with rules and ontologies); and
- contextual Reasoning.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Processing of Declarative Knowledge

Program Analysis

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module explores foundational techniques in static program analysis, program semantics, and abstract interpretation, equipping students to reason about program behavior and apply these methods in areas such as verification, optimization, and software quality.

Fachkompetenzen: Students learn techniques and tools designed to analyze and understand the behavior of software programs. The module focuses on methods that allow for the inspection of software code without the need for execution, enabling the identification of potential bugs, security vulnerabilities, and performance bottlenecks.

Überfachliche Kompetenzen: This module equips students with the ability to apply formal methods and mathematical reasoning to analyze and improve software systems.

Inhalt:

- Static analyses for control flow, data flow, and dependence analysis;

- abstract interpretation and lattice-based reasoning for program properties;
- program semantics and its role in understanding program behavior;
- type systems and their role in ensuring program correctness;
- explore the practical applications of program analysis in optimization, verification, and software quality.

Erwartete Vorkenntnisse: Students should have a solid foundation in programming, algorithms, and data structures, as these are essential for understanding and applying the analysis techniques covered in the module. Familiarity with formal methods, logic, or discrete mathematics is beneficial.

These prerequisites are taught in the following modules:

- *Einführung in die Programmierung*;
- *Algorithmen und Datenstrukturen*;
- *Theoretische Informatik*; and
- *Algebra und Diskrete Mathematik*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Program Analysis

Project in Logic and Artificial Intelligence

Regelarbeitsaufwand: 6,0–12,0 ECTS

Lernergebnisse:

Fachkompetenzen: Students can

- identify the background knowledge from logic and/or artificial intelligence that is required for a task,
- apply the knowledge to solve the given task, and
- justify the solution scientifically.

More specifically, the students will

- apply scientific analysis, design and implementation strategies (taking into account the state of the art, critical reflection of the solution),
- select suitable formal and mathematical methods for model building, abstraction, solution finding and evaluation,
- use suitable technologies, software tools and standards to solve the given task,
- thoroughly analyze the results and compare to other solutions proposed in the state of the art,

- document the results in a comprehensive and precise way, and
- convincingly present the results in an interdisciplinary environment.

Überfachliche Kompetenzen: Students learn to

- formulate and solve problems independently,
- present problems and solutions,
- take critical comments on their work into account, and
- judge their own limits and abilities.

The module also fosters individual creativity and innovation potential (curiosity). Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: In this module, practical problems from the field of logic and/or artificial intelligence are solved. This gives insights into scientific practice and current research in these areas. For working on larger problems, the two practical projects can be combined. The work involves

- the specification of a task from logic and/or artificial intelligence,
- the development of a scientifically sound solution of the given task, and
- the scientific documentation and discussion of the results.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls: The second project (∗) is optional. Depending on the magnitude of the task, both certificates can also be awarded for completing a single, larger project.

6,0/4,0 PR Project in Logic and Artificial Intelligence 1
∗ 6,0/4,0 PR Project in Logic and Artificial Intelligence 2

Proof Theory

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After successful completion of the module, students understand the contents of the module. Among other effects, this understanding forms the basis for the capability to correctly reproduce the statements and notions covered in the module as well as for the ability to explain and apply the proof techniques used in the module.

Überfachliche Kompetenzen: After successful completion of the module, students are able to analyze, select, and critically assess relevant methods and solutions.

Inhalt: The module consists of two courses, containing the following topics:

- Proof Theory 1:
  - sequent-type calculi;
  - cut-elimination;
  - intuitionistic logic;
  - interpolation theorems; and
  - Gentzen's second consistency proof.
- Proof Theory 2: This lecture serves for deepening the results of the first part. Topics depend on the interest of the students and include:
  - infinitary systems after Tait and ordinal analysis;
  - systems of higher order, in particular the system ACA_0 of mathematics and computer science;
  - natural deduction systems;
  - incompleteness results; and
  - logics of provability.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
3,0/2,0 VO Proof Theory 1
3,0/2,0 VO Proof Theory 2

Quantum Computing

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:

Fachkompetenzen: After the successful completion of the module, students are able to name and explain the most important methods in quantum computing, their central properties, and applications in different areas.

Überfachliche Kompetenzen: After successfully completing of the module, students are able to

- analyse employed techniques and methods,
- select relevant techniques and methods for a given problem, and
- critically assess relevant solutions and formalisms.

Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Overview;

- mathematical background and principles of quantum mechanics;
- quantum gates and quantum circuits;
- basic and advanced quantum algorithms;
- quantum complexity classes;
- elements of quantum information theory;
- quantum teleportation.

Erwartete Vorkenntnisse: Basic mathematical skills and knowledge of algorithmics. All prerequisites are covered in *Discrete Mathematics* and *Algorithmics*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Quantum Computing

Reinforcement Learning

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module provides an introduction into reinforcement learning, one of the main fields of machine learning.

Fachkompetenzen: After successful completion of the module, students are able to explain and to apply the theory and the methods of reinforcement learning, and also to implement the most fundamental algorithms.

Überfachliche Kompetenzen: Students acquire the ability to understand methods for machine learning and artificial intelligence and to solve problems in (stochastic) optimal control. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Data structures such as Markov decision processes;
- dynamic programming;
- Monte-Carlo algorithms;
- temporal-difference learning such as Q-learning;
- tabular methods vs. approximate solutions;
- on-policy vs. off-policy learning;
- eligibility traces;
- policy-gradient methods;
- convergence;
- deep reinforcement learning;
- applications such as solving chess, Go, shogi, Atari 2600 games, and other computer games.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Reinforcement Learning

Responsible Digital Ethics

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:
Fachkompetenzen: After successful completion of the module, students are able to:

- understand key concepts of digital ethics, including trust, fairness, accountability, and digital rights
- recognize and apply regulatory frameworks and their implications for ethical digital practices
- evaluate ethical design principles in the development and deployment of digital systems

Überfachliche Kompetenzen:

- analyze real-world digital ethics challenges using case studies and scholarly literature
- critically evaluate ethical trade-offs in complex technological environments
- create actionable strategies to incorporate ethical principles into the design, audit, and deployment of digital systems
- understand and reflect on personal and professional responsibilities as practitioners shaping the digital landscape
- apply effective communication strategies about ethical challenges and solutions to diverse audiences
- Design and implement frameworks for ethical practices in interdisciplinary and organizational contexts

Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content. Ethics, Gender, and Diversity in Responsible Digital Ethics are addressed through the exploration of fairness, accountability, and digital rights in technological systems. The module equips students with the ability to evaluate ethical trade-offs, regulatory frameworks, and biases, ensuring inclusive and responsible digital practices. Case studies and ethical design principles help students develop strategies for embedding ethical considerations into real-world digital systems.

Inhalt:

- Introduction to Digital Ethics: The rise of digital systems and the imperative for ethical practices.
- Core Principles: Trust, fairness, accountability, transparency, and digital rights.
- Ethical Design: Principles and methodologies for designing ethical systems.
- Regulatory Landscapes: Overview of regulatory efforts and their impact on system performance and ethical audits.
- Practical Challenges: Case studies on ethical dilemmas in digital technology (e.g., AI bias, privacy concerns, algorithmic accountability).
- Roles and Responsibilities: The critical role of practitioners in fostering responsible digital ethics.

Erwartete Vorkenntnisse:

- Basic knowledge of ethical theories and frameworks
- Basic knowledge of regulatory frameworks and policies

These prerequisites are taught in the module *Denkweisen der Informatik* of the *Informatics* bachelor program.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Responsible Digital Ethics

SAT Algorithms, Applications and Extensions

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with the algorithms, and practical applications of SAT and SAT-based automated reasoning tools.

Fachkompetenzen: After successful completion of the module, students are able to understand fundamental concepts and techniques of modern SAT-based automated reasoning tools and their practical applications.

Überfachliche Kompetenzen: Students acquire the ability to understand the underlying methods of several automated decision procedures and learn how to adapt them to solve new problems.

Inhalt:

- Algorithms and advanced data structures of SAT solvers;
- formula simplification techniques in SAT solvers;
- techniques for certifying and checking SAT solver results;
- incremental SAT reasoning;

- introduction to the algorithm and underlying structure of CDCL(T) SMT solvers;
- different MaxSAT solving techniques, such as core-guided, model-improving, and hitting set based approaches;
- algorithm of search-based QBF solvers;
- modern applications of SAT-based reasoning tools.

Erwartete Vorkenntnisse: Attending students are assumed to be familiar with propositional and predicate logic, and have already some background in algorithms, formal methods, and practical software development.

These prerequisites are taught in the following modules:

- *Logic and Reasoning in Computer Science*;
- *Formal Methods in Systems Engineering*;
- *Algorithmen und Datenstrukturen*; and
- *Programmierparadigmen*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU SAT Algorithms, Applications and Extensions

Seminar in Artificial Intelligence

Regelarbeitsaufwand: 3,0 ECTS

Lernergebnisse:

Fachkompetenzen: Students are able to

- find literature in a selected topic,
- determine and apply an appropriate categorization for the found literature, and
- describe the covered research.

Überfachliche Kompetenzen: Students can present their results to a group in a structured and concise way. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: In the seminar, students work on literature of a chosen topic in artificial intelligence and present their results in written and oral form.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
3,0/2,0 SE Seminar in Artificial Intelligence

Seminar in Logic

Regelarbeitsaufwand: 3,0 ECTS

Lernergebnisse:
Fachkompetenzen: Students are able to

- find literature in a selected topic,
- determine and apply an appropriate categorization for the found literature, and
- describe the covered research.

Überfachliche Kompetenzen: Students can present their results to a group in a structured and concise way.

Inhalt: In the seminar, students work on literature of a chosen topic in logic and present their results in written and oral form.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
3,0/2,0 SE Seminar in Logic

Seminar in Theoretical Computer Science

Regelarbeitsaufwand: 3,0 ECTS

Lernergebnisse:
Fachkompetenzen: Students are able to

- find literature in a selected topic,
- determine and apply an appropriate categorization for the found literature, and
- describe the covered research.

Überfachliche Kompetenzen: Students can present their results to a group in a structured and concise way.

Inhalt: In the seminar, students work on literature of a chosen topic in theoretical computer science and present their results in written and oral form.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
3,0/2,0 SE Seminar in Theoretical Computer Science

Smart Contracts

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:
Fachkompetenzen: Students acquire advanced programming skills specific to the blockchain paradigm. They develop a thorough understanding of the protocols, interfaces, and software infrastructure for developing decentralized systems. The course provides students with the analytical skills necessary to assess smart contracts for potential vulnerabilities and to apply secure development practices that mitigate the risk of exploitation. Furthermore, students are introduced to foundational concepts in program analysis, gaining insight into formal methods and automated techniques for the detection of software weaknesses. They are also trained in the effective use of contemporary analysis tools to support the development of robust and secure blockchain applications.
Überfachliche Kompetenzen: Students understand the interactions of decentralized applications with systems outside the blockchain. They develop awareness of the critical importance of software reliability and security in the blockchain context, where the remediation of errors is often impossible. The course further fosters students' capacity to design and implement secure applications through both theoretical grounding and practical training. Ethical considerations are integral to the curriculum, including a dedicated focus on responsible disclosure practices and the principles of ethical hacking as a means to strengthen the security and resilience of blockchain-based systems.

Inhalt: The module covers the following topics.

- programming languages and programming techniques for smart contracts;
- protocols, interfaces and technologies for blockchain applications;
- weaknesses and mitigation strategies in smart contracts; and
- methods and tools for analyzing smart contracts automatically.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Smart Contracts

Stochastic Foundations of Cyber-Physical Systems

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: Stochastic foundation of cyber-physical systems, artificial intelligence, and robotics.

Fachkompetenzen: After successful completion of the module, students will be able to:

- automatically synthesize stochastic models and policies of CPS;
- explain methods for automated software synthesis; and
- apply methods for automated software synthesis in new application domains.

Überfachliche Kompetenzen: Students acquire the ability to apply automated software and policy synthesis for CPS to new domains and to critically assess their suitability and limitations. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Probabilistic interpretation of uncertainty;
- rational agents as smart cyber-physical systems (CPS);
- static and dynamic Bayesian networks (BN);
- uncertain environments as BN;
- exact and approximate inference in BN;
- machine learning (supervised) of BN;
- decision making and optimal control for Markov decision processes (MDP);
- supervised and reinforcement learning;
- machine learning with deep and recurrent neural networks;
- large language models (LLM) and artificial general intelligence (AGI); and
- application of LLM and AGI to all types of CPS.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Stochastic Foundations of Cyber-Physical Systems

Structural Decompositions and Meta Theorems

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with structural graph decompositions and their algorithmic applications through meta-theorems.

Fachkompetenzen: Students learn how such meta-theorems arise from the interaction between logic and structure, and how to apply them to problems in AI and database theory.

Überfachliche Kompetenzen: Students acquire the ability to combine logic theory, on the one hand, with algorithm design and analysis, on the other. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender and diversity in the context of structural decompositions and algorithmic meta-theorems.

Inhalt:

- Graph width parameters including tree-width and its generalizations;
- algorithmic meta-theorems and their applications;
- applications to AI and database theory, including propositional model counting, conjunctive query evaluation, and Bayesian Networks;
- well-behaved graph classes and their algorithmic implications.

Erwartete Vorkenntnisse: A solid understanding of algorithms, graph theory as well as fist-order logic is required.

These prerequisites are taught in the following modules:

- *Algorithmen und Datenstrukturen*;
- *Effiziente Algorithmen*;
- *Discrete Mathematics*; and
- *Algorithmics* (strongly recommended).

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Structural Decompositions and Meta Theorems

Symmetric Cryptography

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with attack and proof techniques for building symmetric cryptographic algorithms for secure data communication, storage, and computation.

Fachkompetenzen: Upon successful completion of the module, the students are able to:

- explain, argue the security of, and identify generic attacks on (tweakable) block ciphers, forkciphers, and compression functions in encryption, message authentication, hashing, authenticated encryption, and key derivation modes, among others;
- identify and reason about suitable use cases and applications of symmetric cryptographic schemes in higher level protocols and systems like TLS, IoT, end-to-end encryption, blockchains, messaging protocols, storage encryption, etc.;
- pin down lightweight symmetric cryptographic security requirements and design criteria;
- prove security of basic symmetric designs in the provable framework;
- design and attack implementation of small-scale toy symmetric designs;
- assess and compare existing symmetric designs with respect to security levels, efficiency, and applicability features; and

- present proofs and implementations, explain in detail contemporary use cases, and attacks and/or security proofs on symmetric algorithms.

Überfachliche Kompetenzen: Students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: The module contains the following topics:

- provable security and notions in symmetric cryptography: pseudorandom functions and permutations, indistinguishability, unforgeability, collision resistance, etc.;
- designs and implementation strategies of building blocks: (tweakable) block ciphers, forkciphers, permutations, compression functions, etc.;
- secure modes of operation: encryption, message authentication, hashing, authenticated encryption, key derivation modes, etc.;
- symmetric lightweight cryptographic designs and the ongoing NIST competition;
- attacks and crypto failures;
- applications of symmetric cryptography: communication protocols like TLS, end-to-end encryption protocols, etc.

Erwartete Vorkenntnisse: Basic knowledge in security/cryptography and probability theory, basic programming skills.

These prerequisites are taught in the following modules:

- *Einführung in Kryptographie*;
- *Einführung in Security*;
- *Statistik und Wahrscheinlichkeitstheorie*; and
- *Einführung in die Programmierung.*

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Symmetric Cryptography

Theoretical Foundations and Research Topics in Machine Learning

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with the algorithmic and theoretical foundations of machine learning algorithms, as well as with recent advancements in the machine learning literature.

Fachkompetenzen: After successful completion of the module, students are able to:

- explain the theoretical foundations of machine learning;

- prove learning theoretical results and algorithmic properties of machine learning;
- apply learning algorithms correctly;
- compare and analyse learning algorithms; and
- explain, summarise, and present machine learning research papers.

Überfachliche Kompetenzen: Students acquire the ability to understand and apply machine learning in new application domains. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt:

- Empirical risk minimisation and regularisation;
- probably approximately correct (PAC) learning;
- Vapnik–Chervonenkis (VC) dimension;
- kernel-based learning and support vector machines;
- least squares regression;
- deep learning and graph neural network (GNN).

Erwartete Vorkenntnisse: Prior programming skills and fundamental maths skills are expected.

These prerequisites are covered in the module *Machine Learning*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Theoretical Foundations and Research Topics in Machine Learning

Theoretical Foundations of Deep Learning

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: This module deals with the theoretical foundations of deep learning.

Fachkompetenzen: After successful completion of the module, students are able to:

- explain various deep network architectures, including the scattering transform, and key components such as nonlinear transforms, pooling, convolutional structures, and training methods; and
- explain theoretical insights into the performance of deep networks, including topics like dictionary learning, early-layer transferability, energy decay with depth, Lipschitz continuity, depth's role in overcoming the curse of dimensionality, adversarial example construction, network geometry via random matrix theory, and invariance learning.

Überfachliche Kompetenzen: Students acquire foundational insights into deep learning technologies and develop the ability to use these insights to assess both the use-cases and limitations of deep learning across different application domains. Furthermore, students will be able to identify, articulate, and discuss issues concerning ethics, gender, and diversity in the context of the module's content.

Inhalt: The module contains the following topics:

- ingredients of deep learning,
- deep learning: application and approximation;
- exponential expressivity with depth;
- DNNs can overcome the curse of dimensionality;
- exponential growth of variance and correlation;
- variance of the Jacobian's spectrum;
- stochastic gradient descent and its extensions;
- optimization algorithms for training DNNs;
- topology of the loss landscape;
- loss landscape: impact of parameterization and architecture;
- visualising the filters in a CNN;
- the scattering transform;
- autoencoders;
- GANs and adversarial examples; and
- physics-informed neural networks.

Erwartete Vorkenntnisse: This module requires only basic knowledge of linear algebra and probability.

These prerequisites are taught in the module *Machine Learning*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Theoretical Foundations of Deep Learning

Theory of Graph Data

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse: The goal of this module is to provide a solid understanding of the foundations of the technologies for graph-structured data in order to compare their uses, limits and possibilities. Studying them through the lens of database theory, computational logic, and computational complexity, the students will achieve an understanding that abstracts from the concrete data models and systems, enabling the students to effectively leverage the potential of existing technologies and assess their limitations.

Fachkompetenzen: On successful completion of the module, students will be able to

- compare and critique modern technologies for graphically structured data,
- apply finite state automata methods to various aspects of graph-structured data,
- translate modelling and constraint languages for graph-structured data into description logics (DLs),
- evaluate the computational cost of different features offered by graph database technologies,
- compare different available technologies based on their expressiveness and computational cost, and
- assess the capabilities and limitations of new and emerging graph database technologies.

Überfachliche Kompetenzen: Furthermore, students are able to contrast different formalisms, establish relationships between them and assess their appropriateness for different problems. They will be able to identify common features of different types of formalisms and to abstract mathematical formulations that unify different languages. The material taught in this module does not have inherent gender or ethical aspects; the module focuses on foundational skills based on formal logic and mathematics. Teaching resources and methods will be developed with an awareness of diversity and ensuring a welcoming environment for students from underrepresented groups.

Inhalt:

- Various models of finite state automata (deterministic, non-deterministic, alternating), including automata over words and automata over trees; conversions between selected models of automata
- regular expressions and their connection to automata;
- various models for graph-structured data;
- (labeled) trees as a special case of graph-structured data;
- navigational query languages for graph-structured data;
- notions of data and combined complexity for query languages;
- expressiveness and computational complexity of various features of query languages for graph-structured data;
- description logics (DLs) as languages for modeling graph-structured data;
- DLs as languages for integrity constraints over graph-structured data;
- basic algorithms and complexity results for reasoning tasks related to modelling graph-structured using DLs;
- basic algorithms and complexity results for constraint languages based on DLs;
- graph-structured data as (non-materialized) views over relational data sources;
- selected topics on recent advances in the area.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Theory of Graph Data

Virtual and Augmented Reality

Regelarbeitsaufwand: 6,0 ECTS

Lernergebnisse:
Fachkompetenzen: After successful completion of the module, students are able to:

- understand Tracking and display technologies;
- create 3D interaction in virtual environments;
- create distributed VR/AR systems;
- apply stereo rendering techniques; and
- understand the fundamental concepts of 3D input and output for interacting in virtual environments.

Überfachliche Kompetenzen: Students are able to:

- understand human perception in virtual environments (e.g., spatial understanding, human motion, embodiment, and agency);
- remember medical applications of VR/AR systems;
- analyze training and education applications with VR/AR systems; and
- understand ethical, gender, and diversity considerations in the design of VR/AR systems and 3D interactions, such as gender effects in cybersickness, human factors during immersion in virtual environments, and improving accessibility in VR/AR interfaces.

Inhalt:

- Virtual reality and the related areas, augmented reality and mixed reality;
- Application areas and current areas of research (incl. medical applications);
- 3D graphics hardware;
- VR hardware: input and output devices: tracking and display technologies, interaction devices;
- VR software: 3D graphics toolkits and standards, user interfaces and 3D interaction;
- Psychological aspects (presence, immersion).

Erwartete Vorkenntnisse: Knowledge of Multimedia.

These prerequisites are covered in the module *Multimedia*.

Angewendete Lehr- und Lernformen und geeignete Leistungsbeurteilung: Die angewendeten Lehr- und Lernformen sind im Informationssystem zu Studien und Lehre bei jeder Lehrveranstaltung vor Beginn des Semesters anzugeben; ebenso die Prüfungsmodalitäten.

Lehrveranstaltungen des Moduls:
6,0/4,0 VU Virtual and Augmented Reality

B Übergangsbestimmungen

1. Sofern nicht anders angegeben, wird im Folgenden unter Studium das *Masterstudium Logic and Artificial Intelligence (Studienkennzahl UE 066 931)* verstanden. Der Begriff neuer Studienplan bezeichnet diesen ab 1.10.2025 für dieses Studium an der Technischen Universität Wien gültigen Studienplan und alter Studienplan den bis dahin gültigen. Entsprechend sind unter neuen bzw. alten Lehrveranstaltungen solche des neuen bzw. alten Studienplans zu verstehen (alt inkludiert auch frühere Studienpläne). Mit Studienrechtlichem Organ ist das für das Masterstudium Logic and Artificial Intelligence zuständige Studienrechtliche Organ an der Technischen Universität Wien gemeint.

2. Die Übergangsbestimmungen gelten für Studierende, die den Studienabschluss gemäß neuem Studienplan an der Technischen Universität Wien einreichen und die vor dem 1.7.2025 zum Masterstudium Logic and Artificial Intelligence an der Technischen Universität Wien zugelassen waren. Das Ausmaß der Nutzung der Übergangsbestimmungen ist diesen Studierenden freigestellt.

3. Auf Antrag der_des Studierenden kann das Studienrechtliche Organ die Übergangsbestimmungen individuell modifizieren oder auf nicht von Absatz 2 erfasste Studierende ausdehnen.

4. Zeugnisse über Lehrveranstaltungen, die inhaltlich äquivalent sind, können nicht gleichzeitig für den Studienabschluss eingereicht werden. Im Zweifelsfall entscheidet das Studienrechtliche Organ über die Äquivalenz.

5. Zeugnisse über alte Lehrveranstaltungen können, soferne im Folgenden nicht anders bestimmt, jedenfalls für den Studienabschluss verwendet werden, wenn die Lehrveranstaltung von der_dem Studierenden mit Stoffsemester Sommersemester 2025 oder früher absolviert wurde.

6. Überschüssige ECTS-Punkte aus den Pflichtmodulen können als Ersatz für zu erbringende Leistungen in Wahlmodulen sowie als Freie Wahlfächer und/oder Transferable Skills verwendet werden. Überschüssige ECTS-Punkte aus den Wahlmodulen können als Ersatz für zu erbringende Leistungen in den Freien Wahlfächern und/oder Transferable Skills verwendet werden.

7. Im Folgenden wird jede Lehrveranstaltung (*alt* oder *neu*) durch ihren Umfang in ECTS-Punkten (erste Zahl) und Semesterstunden (zweite Zahl), ihren Typ und ihren Titel beschrieben. Es zählt der ECTS-Umfang der tatsächlich absolvierten Lehrveranstaltung.

   Die Lehrveranstaltungen auf der linken Seite der nachfolgenden Tabelle bezeichnen die alten Lehrveranstaltungen. Auf der rechten Seite sind die Lehrveranstaltungen angegeben, für welche die alten Lehrveranstaltungen jeweils verwendet werden können. Lehrveranstaltungen, die unter demselben Punkt in den Äquivalenzlisten angeführt sind, gelten als äquivalent.

Alt	Neu
4,0/4,0 VO Discrete Mathematics 5,0/2,5 UE Discrete Mathematics	6,0/4,0 VU Discrete Mathematics
4,0/4,0 VO Discrete Mathematics	6,0/4,0 VU Discrete Mathematics
3,0/2,0 VU Database Theory	6,0/4,0 VU Database Theory
3,0/2,0 VU Description Logics and Ontologies	6,0/4,0 VU Decidable Logics for Knowledge Representation
3,0/2,0 VU Deontic Logic for Normative Reasoning	6,0/4,0 VU Deontic Logic for Normative Reasoning
6,0/4,0 VU Formal Methods in Computer Science	6,0/4,0 VU Formal Methods in Systems Engineering
3,0/2,0 VO History of Logic	6,0/4,0 VU History of Logic
3,0/2,0 VU Proof Systems in Modal Logic	6,0/4,0 VU Modal Logics
3,0/2,0 VU Non-classical Logics	6,0/4,0 VU Non-classical Logics
3,0/2,0 VO Refutation Systems	6,0/4,0 VU Nonstandard Deduction Systems
3,0/2,0 VU Quantum Computing	6,0/4,0 VU Quantum Computing
3,0/2,0 VU SAT Solving and Extensions	6,0/4,0 VU SAT Algorithms, Applications, and Extensions
3,0/2,0 VU Modeling and Solving Constrained Optimization Problems	6,0/4,0 VU Algorithmic Encoding Techniques
4,5/3,0 VU Algorithmic Geometry	6,0/4,0 VU Algorithmic Geometry
4,5/3,0 VU Algorithms in Graph Theory	6,0/4,0 VU Algorithms in Graph Theory
3,0/2,0 VU Approximation Algorithms und/oder 3,0/2,0 VU Randomized Algorithms	6,0/4,0 VU Beyond Exact Algorithms
3,0/2,0 VU Complexity Theory	6,0/4,0 VU Complexity Theory
4,5/3,0 VU Fixed-Parameter Algorithms and Complexity	6,0/4,0 VU Fixed-Parameter Algorithms and Complexity
4,5/3,0 VU Graph Drawing Algorithms	6,0/4,0 VU Graph Drawing Algorithms
4,5/3,0 VU Heuristic Optimization Techniques	6,0/4,0 VU Heuristic Optimization Techniques
3,0/2,0 VU Mathematical Programming und/oder 3,0/2,0 VU Optimization in Transport and Logistics	6,0/4,0 VU Mathematical Programming and Optimization in Logistics
3,0/2,0 VU Structural Decompositions und/oder 3,0/2,0 VU Algorithmic Meta-Theorems	6,0/4,0 VU Structural Decompositions and Algorithmic Meta-Theorems
6,0/4,0 VU Knowledge-based Systems	6,0/4,0 VU Logic-based Artificial Intelligence
4,5/3,0 VU Abstract Argumentation	6,0/4,0 VU Abstract Argumentation
3,0/2,0 VU Knowledge Graphs	6,0/4,0 VU Knowledge Graphs

... Fortsetzung

Alt	Neu
3,0/2,0 VU Nonmonotonic Reasoning	6,0/4,0 VU Nonmonotonic Reasoning
3,0/2,0 VU Preferences in Artificial Intelligence	6,0/4,0 VU Preferences in Artificial Intelligence
3,0/2,0 VU Theory of Knowledge Representation und/oder 3,0/2,0 VU Complexity Analysis	6,0/4,0 VU Principles of Knowledge Representation
3,0/2,0 VU Probabilistic Reasoning	6,0/4,0 VU Probabilistic Reasoning
3,0/2,0 VU Semantic Technologies	6,0/4,0 VU Theory of Graph Data
3,0/2,0 VU Processing of Declarative Knowledge und/oder 3,0/2,0 VU Deductive Databases	6,0/4,0 VU Processing of Declarative Knowledge
3,0/2,0 VU Problem Solving and Search in Artificial Intelligence	6,0/4,0 VU Problem Solving and Search in Artificial Intelligence
4,5/3,0 VU Machine Learning	6,0/4,0 VU Machine Learning
3,0/2,0 VU Advanced Reinforcement Learning	6,0/4,0 VU Advanced Reinforcement Learning
3,0/2,0 VU Generative AI	6,0/4,0 VU Generative AI
3,0/2,0 VU Theoretical Foundations and Research Topics in Machine Learning	6,0/4,0 VU Theoretical Foundations and Research Topics in Machine Learning
3,0/2,0 VO Critical Theory of Media and Informatics und/oder 3,0/2,0 UE Critical Theory of Media and Informatics	6,0/4,0 VU Critical Theory of Media and Informatics
3,0/2,0 VO Information Visualization und/oder 1,5/1,0 UE Information Visualization	6,0/4,0 VU Information Visualization
4,0/3,0 VU AI/ML in the Era of Climate Change	6,0/4,0 VU Introduction to Computational Sustainability
2,0/2,0 VO Virtual and Augmented Reality und/oder 4,0/3,0 UE Virtual and Augmented Reality	6,0/4,0 VU Virtual and Augmented Reality
3,0/2,0 VU Computer Aided Verification und/oder 3,0/2,0 UE Computer Aided Verification	6,0/4,0 VU Computer Aided Verification
3,0/2,0 VU Program Analysis	6,0/4,0 VU Program Analysis

... Fortsetzung

Alt	Neu
3,0/2,0 VU Modern Applications of Logic in Machine Learning	6,0/4,0 VU Neurosymbolic Reasoning
3,0/2,0 SE Seminar in Knowledge Representation and Reasoning	3,0/2,0 SE Seminar in Logic
3,0/2,0 SE Seminar in Knowledge Representation and Reasoning	3,0/2,0 SE Seminar in Artificial Intelligence
3,0/2,0 SE Seminar in Knowledge Representation and Reasoning	3,0/2,0 SE Seminar in Theoretical Computer Science

8. Sämtliche Lehrveranstaltungen, die im alten Studienplan in einem Vertiefungsmodul vorkommen welches auf der linken Seite der nachfolgenden Tabelle angeführt ist, und die keine Übereinstimmungen im neuen Studienplan haben, können als Wahlmodule in jenem Prüfungsfach verwendet werden, welches auf der korrespondierenden rechten Seite der Tabelle steht. Lehrveranstaltungen mit Typ SE sind je nach thematischer zugehörigkeit einem der Module *Seminar in Artificial Intelligence*, *Seminar in Logic* oder *Seminar in Theoretical Computer Science* zuzuordnen.

LV in altem Vertiefungsmodul	Modul in neuem Prüfungsfach
Algorithms and Complexity	Algorithms and Complexity
Knowledge Representation and Artificial Intelligence	Symbolic Artificial Intelligence
Logic, Mathematics, and Theoretical Computer Science	Logic and Theory
Programming Languages and Verification	Safe and Trustworthy Systems

9. Für den Studienabschluss ist entweder das Modul *Formal Methods in Systems Engineering* oder das Modul *Machine Learning* zu absolvieren.

10. Studierende können im Rahmen dieser Übergangsbestimmungen ihr Studium mit der ursprünglichen Bezeichnung „Logic and Computation“ abschließen, wenn sie dies beim Einreichen des Studienabschlusses dem Studienrechtlichen Organ durch eine schriftliche Erklärung bekanntgeben.

C Semestereinteilung der Lehrveranstaltungen

Das dritte Semester ist als Mobilitätssemester empfohlen.

1. Semester (WS)

6,0 VU Algorithmics
6,0 VU Discrete Mathematics
6,0 VU Logic and Computability

2. Semester (SS)

6,0 VU Logic-based Artificial Intelligence
6,0 VU Machine Learning

D Prüfungsfächer mit den zugeordneten Modulen und Lehrveranstaltungen

Die mit einem Stern markierten Module sind Wahl-, die übrigen Pflichtmodule.

Prüfungsfach „Logic and Theory“

Modul „Discrete Mathematics“ (6,0 ECTS)
6,0/4,0 VU Discrete Mathematics

Modul „Logic and Computability“ (6,0 ECTS)
6,0/4,0 VU Logic and Computability

***Modul „Automata and Logic“ (6,0 ECTS)**
6,0/4,0 VU Automata and Logic

***Modul „Automated Deduction“ (6,0 ECTS)**
6,0/4,0 VU Automated Deduction

***Modul „Database Theory“ (6,0 ECTS)**
6,0/4,0 VU Database Theory

***Modul „Decidable Logics for Knowledge and Data“ (6,0 ECTS)**
6,0/4,0 VU Decidable Logics for Knowledge and Data

***Modul „Deontic Logic for Normative Reasoning“ (6,0 ECTS)**
6,0/4,0 VU Deontic Logic for Normative Reasoning

***Modul „Gödel's Incompleteness Theorems“ (4,5 ECTS)**
3,0/2,0 VO AKLOG Gödel's Incompleteness Theorems
1,5/1,0 UE AKLOG Gödel's Incompleteness Theorems

***Modul „History of Logic“ (6,0 ECTS)**
6,0/4,0 VU History of Logic

***Modul „Logical Foundations of Inductive Theorem Proving“ (4,5 ECTS)**
4,5/3,0 VO AKLOG Logical Foundations of Inductive Theorem Proving
1,5/1,0 UE AKLOG Logical Foundations of Inductive Theorem Proving

***Modul „Modal Logics“ (6,0 ECTS)**
6,0/4,0 VU Modal Logics

***Modul „Nonclassical Logics“ (6,0 ECTS)**
6,0/4,0 VU Nonclassical Logics

∗Modul „Nonstandard Deduction Systems“ (6,0 ECTS)

6,0/4,0 VU Nonstandard Deduction Systems

∗Modul „Proof Theory“ (6,0 ECTS)

3,0/2,0 VO Proof Theory 1
3,0/2,0 VO Proof Theory 2

∗Modul „Quantum Computing“ (6,0 ECTS)

6,0/4,0 VU Quantum Computing

∗Modul „SAT Algorithms, Applications and Extensions“ (6,0 ECTS)

6,0/4,0 VU SAT Algorithms, Applications and Extensions

Prüfungsfach „Algorithms and Complexity“

Modul „Algorithmics“ (6,0 ECTS)

6,0/4,0 VU Algorithmics

∗Modul „Advanced Research in Algorithmics“ (6,0 ECTS)

6,0/4,0 VU Advanced Research in Algorithmics

∗Modul „Algorithmic Encoding Techniques“ (6,0 ECTS)

6,0/4,0 VU Algorithmic Encoding Techniques

∗Modul „Algorithmic Geometry“ (6,0 ECTS)

6,0/4,0 VU Algorithmic Geometry

∗Modul „Algorithms in Graph Theory“ (6,0 ECTS)

6,0/4,0 VU Algorithms in Graph Theory

∗Modul „Beyond Exact Algorithms“ (6,0 ECTS)

6,0/4,0 VU Beyond Exact Algorithms

∗Modul „Complexity Theory“ (6,0 ECTS)

6,0/4,0 VU Complexity Theory

∗Modul „Fixed-Parameter Algorithms and Complexity“ (6,0 ECTS)

6,0/4,0 VU Fixed-Parameter Algorithms and Complexity

∗Modul „Graph Drawing Algorithms“ (6,0 ECTS)

6,0/4,0 VU Graph Drawing Algorithms

∗Modul „Heuristic Optimization Techniques“ (6,0 ECTS)

6,0/4,0 VU Heuristic Optimization Techniques

∗Modul „Mathematical Programming and Optimization in Transport Logistics“ (6,0 ECTS)

6,0/4,0 VU Mathematical Programming and Optimization in Transport Logistics

∗Modul „Structural Decompositions and Meta Theorems“ (6,0 ECTS)

6,0/4,0 VU Structural Decompositions and Meta Theorems

Prüfungsfach „Symbolic Artificial Intelligence“

Modul „Logic-based Artificial Intelligence“ (6,0 ECTS)

6,0/4,0 VU Logic-based Artificial Intelligence

∗Modul „Abstract Argumentation“ (6,0 ECTS)

6,0/4,0 VU Abstract Argumentation

∗Modul „Algorithmic Social Choice“ (6,0 ECTS)

6,0/4,0 VU Algorithmic Social Choice

∗Modul „Knowledge Graphs“ (6,0 ECTS)

6,0/4,0 VU Knowledge Graphs

∗Modul „Management of Graph Data“ (6,0 ECTS)

6,0/4,0 VU Management of Graph Data

∗Modul „Nonmonotonic Reasoning“ (6,0 ECTS)

6,0/4,0 VU Nonmonotonic Reasoning

∗Modul „Preferences in Artificial Intelligence“ (6,0 ECTS)

6,0/4,0 VU Preferences in Artificial Intelligence

∗Modul „Principles of Knowledge Representation“ (6,0 ECTS)

6,0/4,0 VU Principles of Knowledge Representation

∗Modul „Probabilistic Reasoning“ (6,0 ECTS)

6,0/4,0 VU Probabilistic Reasoning

∗Modul „Problem Solving and Search in Artificial Intelligence“ (6,0 ECTS)

6,0/4,0 VU Problem Solving and Search in Artificial Intelligence

∗Modul „Processing of Declarative Knowledge“ (6,0 ECTS)

6,0/4,0 VU Processing of Declarative Knowledge

∗Modul „Theory of Graph Data“ (6,0 ECTS)

6,0/4,0 VU Theory of Graph Data

Prüfungsfach „Machine Learning“

Modul „Machine Learning“ (6,0 ECTS)

6,0/4,0 VU Machine Learning

***Modul „Advanced Reinforcement Learning“ (6,0 ECTS)**

6,0/4,0 VU Advanced Reinforcement Learning

***Modul „Algorithms for Data Science“ (6,0 ECTS)**

6,0/4,0 VU Algorithms for Data Science

***Modul „Applied Generative AI and LLM-based Systems“ (6,0 ECTS)**

6,0/4,0 VU Applied Generative AI and LLM-based Systems

***Modul „Deep Learning for Natural Language Processing“ (6,0 ECTS)**

6,0/4,0 VU Deep Learning for Natural Language Processing

***Modul „Generative AI“ (6,0 ECTS)**

6,0/4,0 VU Generative AI

***Modul „Machine Learning for Optimization“ (6,0 ECTS)**

6,0/4,0 VU Machine Learning for Optimization

***Modul „Neurosymbolic Reasoning“ (6,0 ECTS)**

6,0/4,0 VU Neurosymbolic Reasoning

***Modul „Reinforcement Learning“ (6,0 ECTS)**

6,0/4,0 VU Reinforcement Learning

***Modul „Stochastic Foundations of Cyber-Physical Systems“ (6,0 ECTS)**

6,0/4,0 VU Stochastic Foundations of Cyber-Physical Systems

***Modul „Theoretical Foundations and Research Topics in Machine Learning“ (6,0 ECTS)**

6,0/4,0 VU Theoretical Foundations and Research Topics in Machine Learning

***Modul „Theoretical Foundations of Deep Learning“ (6,0 ECTS)**

6,0/4,0 VU Theoretical Foundations of Deep Learning

Prüfungsfach „Artificial Intelligence and Society“

∗Modul „AI Ethics“ (6,0 ECTS)
6,0/4,0 VU AI Ethics

∗Modul „Critical Algorithm Studies“ (6,0 ECTS)
6,0/4,0 VU Critical Algorithm Studies

∗Modul „Critical Theory of Media and Informatics“ (6,0 ECTS)
6,0/4,0 VU Critical Theory of Media and Informatics

∗Modul „Digital Humanism“ (3,0 ECTS)
3,0/2,0 VU Digital Humanism

∗Modul „Explainable AI“ (6,0 ECTS)
6,0/4,0 VU Explainable AI

∗Modul „Human-Centered AI“ (6,0 ECTS)
6,0/4,0 VU Human-Centered AI

∗Modul „Information Visualization“ (6,0 ECTS)
6,0/4,0 VU Information Visualization

∗Modul „Introduction to Computational Sustainability“ (6,0 ECTS)
6,0/4,0 VU Introduction to Computational Sustainability

∗Modul „Responsible Digital Ethics“ (6,0 ECTS)
6,0/4,0 VU Responsible Digital Ethics

∗Modul „Virtual and Augmented Reality“ (6,0 ECTS)
6,0/4,0 VU Virtual and Augmented Reality

Prüfungsfach „Safe and Trustworthy Systems“

∗Modul „Advanced Cryptography“ (6,0 ECTS)
6,0/4,0 VU Advanced Cryptography

∗Modul „Advanced Privacy Enhancing Technologies“ (6,0 ECTS)
6,0/4,0 VU Advanced Privacy Enhancing Technologies

∗Modul „Computer-Aided Verification“ (6,0 ECTS)
6,0/4,0 VU Computer-Aided Verification

∗Modul „Cryptocurrencies“ (6,0 ECTS)
6,0/4,0 VU Cryptocurrencies

∗Modul „Formal Methods for Security and Privacy“ (6,0 ECTS)

6,0/4,0 VU Formal Methods for Security and Privacy

∗Modul „Formal Methods in Systems Engineering“ (6,0 ECTS)

6,0/4,0 VU Formal Methods in Systems Engineering

∗Modul „Program Analysis“ (6,0 ECTS)

6,0/4,0 VU Program Analysis

∗Modul „Smart Contracts“ (6,0 ECTS)

6,0/4,0 VU Smart Contracts

∗Modul „Symmetric Cryptography“ (6,0 ECTS)

6,0/4,0 VU Symmetric Cryptography

Prüfungsfach „Methods in Logic and Artificial Intelligence“

∗Modul „Seminar in Logic“ (3,0 ECTS)

3,0/2,0 SE Seminar in Theoretical Computer Science

∗Modul „Seminar in Artificial Intelligence“ (3,0 ECTS)

3,0/2,0 SE Seminar in Artificial Intelligence

∗Modul „Seminar in Theoretical Computer Science“ (3,0 ECTS)

3,0/2,0 SE Seminar in Theoretical Computer Science

∗Modul „Project in Logic and Artificial Intelligence“ (6,0–12,0 ECTS)

6,0/4,0 PR Project in Logic and Artificial Intelligence 1
6,0/4,0 PR Project in Logic and Artificial Intelligence 2

Prüfungsfach „Extension“

∗Modul „Extension“ (up to 12,0 ECTS)

Prüfungsfach „Freie Wahlfächer und Transferable Skills“

Modul „Freie Wahlfächer und Transferable Skills“ (9,0 ECTS)

Prüfungsfach „Diplomarbeit“

1,5/1,0 SE Seminar für Diplomand_innen
27,0 ECTS Diplomarbeit
1,5 ECTS Kommissionelle Abschlussprüfung

E Wahlfachkatalog „Transferable Skills“

Die Lehrveranstaltungen, die im Modul *Freie Wahlfächer und Transferable Skills* aus dem Themenbereich „Transferable Skills“ zu wählen sind, können unter anderem aus dem folgenden Katalog gewählt werden.

3,0/2,0 SE Coaching als Führungsinstrument 1
3,0/2,0 SE Coaching als Führungsinstrument 2
3,0/2,0 SE Didaktik in der Informatik
1,5/1,0 VO EDV-Vertragsrecht
3,0/2,0 VO Einführung in die Wissenschaftstheorie I
3,0/2,0 VO Einführung in Technik und Gesellschaft
3,0/2,0 SE Folgenabschätzung von Informationstechnologien
3,0/2,0 VU Forschungsmethoden
3,0/2,0 VO Frauen in Naturwissenschaft und Technik
3,0/2,0 SE Gruppendynamik
3,0/2,0 VU Kommunikation und Moderation
3,0/2,0 SE Kommunikation und Rhetorik
1,5/1,0 SE Kommunikationstechnik
3,0/2,0 VU Kooperatives Arbeiten
3,0/2,0 VU Präsentation und Moderation
1,5/1,0 VO Präsentation, Moderation und Mediation
3,0/2,0 UE Präsentation, Moderation und Mediation
3,0/2,0 VU Präsentations- und Verhandlungstechnik
4,0/4,0 SE Privatissimum aus Fachdidaktik Informatik
3,0/2,0 VU Rhetorik, Körpersprache, Argumentationstraining
3,0/2,0 VU Softskills für TechnikerInnen
3,0/2,0 VU Techniksoziologie und Technikpsychologie
3,0/2,0 VO Theorie und Praxis der Gruppenarbeit
3,0/2,0 VO Zwischen Karriere und Barriere

F Erweiterungsstudium Innovation

Studierende, die ihre im Masterstudium erworbenen Kompetenzen für die Gründung eines Startups bzw. im Management eines Unternehmens oder für Projekttätigkeit im universitären Umfeld anwenden wollen, können die für diese Tätigkeiten notwendigen zusätzlichen Kompetenzen im Rahmen des Erweiterungsstudiums *Innovation* erwerben, welches begleitend zum Masterstudium absolviert werden kann.

Der (zusätzliche) Arbeitsaufwand für das englischsprachige Erweiterungsstudium *Innovation* beträgt 30 ECTS-Punkte (dies entspricht einem Semester). Der Abschluss des Erweiterungsstudiums *Innovation* kann auch noch nach Abschluss des Masterstudiums erfolgen.