fiw.thws
Faculty of Computer Science and
Business Information Systems
Technical University of
Applied Sciences
Würzburg-Schweinfurt

Module Handbook
Master Artificial Intelligence (M. Sc.)

Summer semester 2026
Winter semester 2025

Contents

fiw.thws
Faculty of Computer Science and
Business Information Systems
Technical University of
Applied Sciences
Würzburg-Schweinfurt

1. semester

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5171527
Adventure Capitalism: how to build a tech startup?

Module profile

Exam number
5171527

Duration
1 semester

Frequency
Irregular

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Group work

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Ivan Yamshchikov

Lecturer(s)
Prof. Dr. Ivan Yamshchikov

Applicability

Applicability	MAI, MDB, MIS
Semester according to SPO	1. and 2. semester
Type of module	FWPM

Required prerequisites for the participation in the module according to the SPO
none

Recommended prerequisites for the participation in the module
none

Content
The course is structured as a series of shark-tank events with founders, investors and developers that estimate current progress of the team and decide if the team can work further on the current project or has to pivot.

As the course progresses we cover following topics:

1 What is venture capital?
- a brief history of venture investment
- probabilistic approach to venture investment
- venture capital as innovation driver
- Pareto-principals

2 What is a product?
- Why is technology not a product?
- Paper prototyping and product market fit
- Customer development cycle
- Product-market fit
- Minimal Viable Prototype
- Price and value: elasticity, supply, demand, branding

3 What is a pitch deck?
- What are the key structural components of a good pitch?
- Principles of storytelling
- Unique selling proposition

4 How to manage people?
- Managing small teams
- Trade-off between discipline and creativity
- Motivation, empathy and discipline

5 What is your go-to-market strategy?
- Customer acquisition costs
- Lifetime value
- Distribution channels and partnerships
- Data-driven marketing

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Portfolio

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes

- Students the core principles of technological entrepreneurship and build a technologic business from scratch
- Students create and validate a customer development pipeline
- Students evaluate product market fit and unit economics of the technological product
- Students create a pitch deck for their project from scratch, evaluate the quality of the early-stage venture capital, and know how to implement a fund-raising plan
- Students create a Minimal Viable Prototype (MVP) by applying principles of paper prototyping and using frameworks for customer development
- Students understand the overall properties of venture capital markets and pitch their project to actual VCs.

Literature

I. Strebulaev, A. Dang "Venture Mindset"
B. Horowitz "The Hard Thing About Hard Things: Building a Business When There Are No Easy Answers"
P. Thiel "Zero to One: Notes on Startups, or How to Build the Future"
M. Weber "Protestant Ethic and the Spirit of Capitalism"
K.F. Lee "AI Superpowers: China, Silicon Valley and the New Word Order"
B. Christian, T. Griffiths "Algorithms to Live By"

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5171528
Autonomous Systems

Module profile

Exam number
5171528

Duration
1 semester

Frequency
Every winter semester

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Arndt Balzer

Lecturer(s)
Prof. Dr. Arndt Balzer,
Prof. Dr. Andreas Lehrmann

Applicability

Applicability	MAI, MDB
Semester according to SPO	1. and 2. semester
Type of module	FWPM

Required prerequisites for the participation in the module according to the SPO
none

Recommended prerequisites for the participation in the module
Affinity for technical applications

Content
The content of the course is adapted to current requirements.

Since 2020, the focus has been on the development of software for an autonomous vehicle based on NVIDIA hardware
Fundamentals of machine learning, including artificial neural networks
Machine vision, "classic" image processing

Until 2019, the focus was on developing software to control a quadrocopter
Programming of embedded systems
Control technology, in particular PID controllers
Sensor technology, telemetry
Mathematical basics: Cartesian and polar coordinates, Euler angles, complex numbers, quaternions, vector algebra
Signal processing: state estimators, Bayesian, Gaussian and Kalman filters
Position control, yaw control, telecommands

If required: development of software for MCU with current IDEs, semi-autonomous driving

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Multimedia presentation, Colloquium

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes
The students are able to
- Evaluate the necessity, market relevance and potential of embedded (mobile) systems,
- assess challenges in the construction of autonomous driving systems and design solutions,
- Describe the structure and functionality of the hardware and software of control systems using the example of a quadrocopter, including real-time requirements,
- implement parts of the system software,
- assess the mathematical methods used,
- design approaches to improve signal processing.

Literature
Tom M. Mitchell, Machine Learning, http://www.cs.cmu.edu/~tom/mlbook.html
Christopher M. Bishop, Pattern Recognition and Machine Learning, online
Trevor Hastie et al, The Elements of Statistical Learning, online
Kevin P. Murphy, Machine learning, online
S. Thrun, W. Burgard, D. Fox: Probabilistic Robotics, The MIT Press, 2005

Documents of the University of Würzburg / Emqopter, 2019
A. Gelb, Applied Optimal Estimation, MIT Press, 1974
R. Kalman, A New Approach to Linear Filtering and Prediction Problems, Transaction of the ASME-Journal of Basic Engineering, 1960
P. Marwedel: Embedded System Design - Foundations of Cyber-Physical Systems, Springer, 2011
D. Gajski, F. Vahid: Specification and Design if Embedded Systems, Pearson, 2008
J. McClellan. R. Schafer: Signal Processing First, Pearson, 2003

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5171529
Foundations of Neuro-Symbolic AI

Module profile

Exam number
5171529

Duration
1 semester

Frequency
Irregular

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr.-Ing. Pascal Meißner

Lecturer(s)
Dr. Alex Goeßmann

Applicability

MAI

Semester according to SPO 1. semester

Type of module FWPM

Required prerequisites for the participation in the module according to the SPO
none

Recommended prerequisites for the participation in the module
basic familiarity with Python

Content
1. logical approaches [1]
- Semantics and syntax of Propositional Logic
- Logical inference algorithms
- Neural function decomposition and inference

2. probabilistic approaches [2]
- Independencies, Graphical Models and Sufficient Statistics
- Reasoning schemes and maximum likelihood estimation
- Causal models and inference

3. statistical models of knowledge graphs [3]
- Knowledge Graphs, Description Logic and Semantic Web Standards
- Query languages for inference
- Statistical Relational AI

4. quantum machine learning [4]
- Circuit model of computation and measurement schemes
- Deutsch-Jozsa Algorithm and application in Neuro-Symbolic AI
- Quantum advantages in sampling and contractions

All concepts will be introduced in a unifying tensor network formalism [5], which will be developed sequentially during the course.
The topics are accompanied by demonstrations and exercises based on the python library tnreason.

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Written exam (sP) according to § 23 APO

Examination - length/format
90 minutes

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes
Students will

- understand the challenges of robustness and explainability to be addressed in the next generation of AI
- be familiar with frameworks to implement neuro-symbolic models
- get a strong background in the logical and probabilistic foundations of AI
- be trained on the Python library tnreason towards conducting independent research projects

Successful students will be invited to join the tnreason development community and pursue a Master`s Thesis in collaboration with the Weierstrass Institute.

Literature
[1] Russell, Norvig: Artificial Intelligence - A Modern Approach (fourth edition), Pearson Education 2021
[2] Koller, Friedman: Probabilistic Graphical Models: Principles and Techniques, MIT Press 2009
[3] Antoniou et al: A Semantic Web Primer (third edition), MIT Press 2012
[4] Schuld, Petruccione: Machine Learning with Quantum Computers (second edition), Springer 2021
[5] Goessmann: The Tensor-Network Approach to Efficient and Explainable AI, Technical Report on the ENEXA Project 2025

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5173030
Introduction to Deep Learning

Module profile

Exam number
5173030

Duration
1 semester

Frequency
Every summer semester

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar-style instruction

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Magda Gregorová

Lecturer(s)
Prof. Dr. Magda Gregorová

Applicability

Applicability	MAI
Semester according to SPO	1. semester
Type of module	Compulsory module

Required prerequisites for the participation in the module according to the SPO
None

Recommended prerequisites for the participation in the module
None

Content
- Artificial neural networks (ANN) in machine learning (ML)
- Basic concepts of learning algorithms and typical tasks
- Model development workflow, hyperparameter tunning, performance measures and model selection
- Ethical and societal aspects (open access, data governance, fairness, transparency, reproducibility, safety and robustness, interpretability and human oversight/trust, ecological footprint)
- Basic ANN architectures
- Multilayer perceptron (feed forward)
- Convolutional neural networks
- Attention
- ANN model regularisation
- Norm penalties
- Data augmentation
- Early stopping
- Dropout
- ANN model optimisation
- (Stochastic) gradient descent
- Backpropagation
- Momentum methods
- Learning rate scheduling
- Major ANN applications and selected advanced models
- Computer vision (object detection, image classification, style transfer)
- Natural language processing (word2vec, BERT)
- Autoencoders
- Generative models
- Deep learning software packages
- PyTorch

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Portfolio

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes
Upon completion of the module students:

- can place artificial neural networks within the broader area of machine learning, understand their major advantages and disadvantages, and are aware of major applications of ANN as well as selected advanced models under research and their fundamental ideas
- understand and assess the critical differences between the basic ANN architectures (MLP, CNN), can implement them in standard deep learning software packages, and can train, test, and evaluate the ANN models over real data
- building on the experience of working with their own ANN implementations, can reuse publicly available implementations of more complex models to carry out experiments over real datasets, can compare the

performance of these across various models and their hyperparameter setups

- understand the importance of transparency and reproducibility in deep learning experimentation and can present in written as well as oral their learning and evaluation pipeline including relevant description of the selected software and hardware configuration
- are aware of the ethical and societal impacts of machine learning and deep learning and can critically assess deep learning reports along these lines

Literature
1 Prince, Simon J.D. Understanding Deep Learning. The MIT Press, 2023. http://udlbook.com.
2 Zhang, Aston, Zachary C. Lipton, Mu Li, and Alexander J. Smola. Dive into Deep Learning. https://d2l.ai/, 2021
3 Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. Deep Learning. MIT Press, 2016

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5173020
Machine Learning

Module profile

Exam number
5173020

Duration
1 semester

Frequency
Every summer semester

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar-style instruction

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Andreas Lehrmann

Lecturer(s)
Prof. Dr. Andreas Lehrmann

Applicability

Applicability	MAI
Semester according to SPO	1. semester
Type of module	Compulsory module

Required prerequisites for the participation in the module according to the SPO
None

Recommended prerequisites for the participation in the module
Knowledge in programming (Python) and mathematics (linear algebra, probability theory, multi-variable calculus).

Content
This course provides a comprehensive introduction to the field of machine learning. Starting from basic principles, we are going to develop a data-driven framework that allows us to express representation and prediction tasks as learning problems, either supervised or unsupervised.

In both cases, our discussion of the relationship between data and model will lead to a broad spectrum of approaches with different properties: linear vs. non-linear, parametric vs. non-parametric, deterministic vs. non-deterministic, and classification vs. regression. We are going to explore how these models are formulated, how they can be optimised, and how they can be applied to new data.

In a parallel track, we are going to explore theoretical properties of machine learning models, including their robustness, complexity, and meta-level behaviour.

In particular, the course covers the following topics:

- Data: collection & representation
- Data: statistical & visual exploration
- (Linear/Probabilistic/Non-parametric) classification
- (Linear/Non-Linear/Robust) regression
- Meta learning: ensembling & boosting
- clustering
- Outlier detection
- (Stochastic) gradient descent
- (Feature/Model) selection
- Regularisation
- Convolutions
- Kernel Trick
- Maximum likelihood & maximum a-posteriori
- Principal component analysis
- Gaussian processes
- Multi-dimensional scaling
- Neural networks & deep learning

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Written exam (sP) according to § 23 APO

Examination - length/format
90 minutes

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes
Upon completion of this module the students have a broad understanding of machine learning and its subfields, including the following:

- They can independently collect/analyze data and take the necessary steps to prepare them for learning and inference tasks.
- They are familiar with a variety of supervised/unsupervised models and understand their principles and properties.
- They can select an appropriate model for a given task and design, implement, optimize, run, and analyse the corresponding machine learning pipeline.
- They understand the balance between expressiveness and generalisation. They are able to employ selection, regularisation, and meta-learning techniques to maximize model performance.

Literature
1 Bishop, Christopher M.: Pattern Recognition and Machine Learning. Springer, 2006.
2 Murphy, Kevin P.: Probabilistic Machine Learning: An Introduction. The MIT Press, 2022.
3 Hastie, Trevor and Tibshirani, Robert and Friedman, Jerome: The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Springer, 2009.

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5172010
Mathematical Foundations of AI

Module profile

Exam number
5172010

Duration
1 semester

Frequency
Every summer semester

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar-style instruction

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Martin Storath

Lecturer(s)
Prof. Dr. Martin Storath

Applicability

MAI

Semester according to SPO 1. semester

Type of module Compulsory module

Required prerequisites for the participation in the module according to the SPO
None

Recommended prerequisites for the participation in the module
None

Content
1. advanced vector calculus
- Multivariate derivatives and chain rule
- Backpropagation and automatic differentiation
- Linearisation and multivariate Taylor series

2. advanced linear algebra
- Eigenvalues and eigenvectors
- Singular value decomposition
- Matrix approximation

3. continuous optimisation
- Gradient descent
- Constrained optimization and Lagrange multipliers
- Convex Optimisation

4. models and data
- Change of variables
- Empirical risk minimisation
- Parameter estimation
- Probabilistic modelling and inference
- Model selection

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Written exam (sP) according to § 23 APO

Examination - length/format
90 minutes

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes

- Students refresh and develop further their knowledge and skills on the necessary mathematical foundations for understanding and developing algorithms for AI; in particular, linear algebra, calculus, probability.
- Students understand the principles of continuous optimization (constrained and unconstrained), are able to select appropriate approaches and they apply them for problems in AI.
- Students are able to apply and evaluate the principles of probabilistic modelling and inference, and they create probabilistic models for frequently occurring kinds of data.
- Students use the acquired mathematical skills to design and create frequently occurring building blocks of AI systems, such as linear regression, PCA, Gaussian mixture models and support vector machines.

Literature

1 M. P. Deisenroth, A. A. Faisal, Cheng Soon Ong: Mathematics for Machine Learning, Cambridge University Press, 2020
2 C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006
3 G. James, D. Witten, T. Hastie, R. Tibshirani: An Introduction to Statistical Learning, Second Edition, Springer, 2021

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5171040
Reasoning and Decision Making under Uncertainty

Module profile

Exam number
5171040

Duration
1 semester

Frequency
Every summer semester

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar-style instruction

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Frank Deinzer

Lecturer(s)
Prof. Dr. Frank Deinzer

Applicability

MAI

Semester according to SPO 1. semester

Type of module Compulsory module

Required prerequisites for the participation in the module according to the SPO
none

Recommended prerequisites for the participation in the module
none

Content
The course is composed of 2 thematic blocks.

Block A: Reinforcement Learning
1. basic reinforcement learning concepts
- Actions and States
- Goals, Rewards, Returns and Episodes
- Policies and Value Functions

2. basic reinforcement learning methods
- Finite Markov Decision Processes
- Dynamic Programming
- Monte Carlo Methods

3. advanced tabular learning methods
- Temporal-Difference Learning
- Bootstrapping Methods

4. learning in continuous state and action spaces
- On-Policy Approximation
- Value-function Approximation
- Off-Policy Approximation
- Approximate Eligibility Traces

5. value function approximation case studies
- Computer Vision: Action planning
- Mastering Games: Backgammon, Go

6 Applications and Exercises

Block B: Sensor Fusion
1. using Bayes for Sensor Data Fusion
- Modelling and Estimation of Densities
- Sensor Fusion over Time

2 Hidden Markov Models and Viterbi Algorithm
3. recursive state estimation
- Gaussian Filters
- Nonparametric Filters

4. applications

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Portfolio

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes

- Students develop further knowledge and skills on the necessary mathematical foundations for understanding and developing algorithms for AI.
- Students can apply the principles of reinforcement learning algorithms
- Students can use the principles of modelling gents, environments and rewards.
- Students understand the necessity of function approximations in learning.
- Students understand the concepts of statiscal sensor fusion
- Students can realise sensor fusion applications
- Students build on their acquired knowledge to master learning problems.

Literature

1 Sutton, Barto. Reinforcement Learning - An Introduction. Bradford Books, 2018
2 Thorp. Beat the Dealer. Random House. 1966
3 Mitchell. Data Fusion: Concepts and Ideas. Springer. 2014
4 Thrun, Burgard, Fox: Probabilistic Robotics. MIT Press. 2005
5 Johnson, Freund, Miller. Miller & Freund's Probability and Statistics for Engineers. Pearson

Further specialised literature will be announced in the course.

Module: 5171110
Scientific seminar

Module profile

Exam number
5173110

Duration
1 semester

Frequency
Every summer semester

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Magda Gregorová

Lecturer(s)
Prof. Dr. Magda Gregorová,
Dr. Maryam Bagheri

Applicability

Applicability	MAI
Semester according to SPO	1. semester
Type of module	Compulsory module

Required prerequisites for the participation in the module according to the SPO
None

Recommended prerequisites for the participation in the module
The course is designed for full time MAI students. Not suitable for incoming visiting students!

Content
Studying and working in Germany
- THWS study system, MAI programme and structure, examination rules, SPO, APO
- getting a job in Germany, support structures in THWS, academic CV, networking options
- academic good conduct, plagiarism rules, use of AI

Practical research and scientific work skills and principles of good scientific conduct.
- Academic writing on AI topics in English (for non-native speakers)
- Standard structure of academic texts - project proposal, theses, technical reports, research articles
- Specific grammar features and word choices of English academic text and common pitfalls for non-native speakers
- Literature review (dblp, google scholar, journals and conferences, predatory publishers)
- Visual support of technical text (visual display of quantitative data, visual communication), academic presentations and poster design
- Analysis of academic text, critical evaluation, peerreview process and principles
- Academic and research support software tools and bibliography systems (Zotero, Mendeley, ...)
- Academic talk structure, audience targeting, academic exchange of knowledge and experience, constructive feedback and academic research discussion
- Good conduct in academic writing (citations, acknowledgements, plagiarism), open science, transparency, reproducibility

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Portfolio

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes
Upon completion of the seminar students:

- can write English academic texts on AI topics taking into account the expected format (using appropriate mathematical typographical software - LaTex), structure, and the target audience; can adapt the language and visual support accordingly (article vs. presentation, etc.).
- understand the importance of good academic conduct, the boundaries and consequences of plagiarism, and the benefits of open science, transparency and reproducibility, they can design their communication strategy accordingly (open access / open source, experimental documentation, etc.)
- can conduct relevant literature search, analyse the quality of texts, can create and maintain a relevant bibliography in standard software tools and correctly reference previous work in their academic outputs
- are aware of selected recent trends in AI research and main opportunities and challenges in transferring them to practical applications
- can critically analyse academic text and provide constructive feedback, can interact with senior researchers in an informed discussion

Literature
To be defined in seminar

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

2. semester

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5171526
Advanced Information Modelling

Module profile

Exam number
5171526

Duration
1 semester

Frequency
Irregular

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar, Project

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Dr. h. c. Robert Grebner

Lecturer(s)
Prof. Dr. Dr. h. c. Robert Grebner

Applicability

MAI, MDB

Semester according to SPO 2. and 1. semester

Type of module FWPM

Required prerequisites for the participation in the module according to the SPO
none

Recommended prerequisites for the participation in the module
none

Content
Human intelligence manifests itself through a number of highly specialised but interrelated competences and skills. Assuming that the basis for these abilities is an extraordinary well-organised associative memory, information and knowledge modelling takes on a special position for Strong Artificial Intelligence also called Artificial General Intelligence (AGI).

A lot of commercial software systems use basic information modelling techniques, like Entity Relationship Diagrams (ERD) or Uniform Modelling Language (UML), which has strengths but also weaknesses. Some techniques are designed to model more dynamic events like the Business Process Modelling Language (BPML). Further developed modelling techniques are used to describe information in a more sophisticated way and even used to model knowledge represented in computer systems and AI systems. One example is the Knowledge Modelling and Description Language (KMDL).

This course provides three main topics:
a) The phenomenon of data, information and knowledge and advanced approaches to structure information for intelligent systems.
b) The modelling of different aspects like time and space within those information models in different ways.
c) Development of a custom modelling language providing an orthogonal integration of the discussed aspects.
d) Implementing of parsers to compile the languages into adequate information and knowledge structures.

The learned techniques are used to model the dynamic movement of a robot within a room with no coordinate system, but only based on relative and spontaneously received position information of detected items.

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Oral exam

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes
Understanding what information is and how common information modelling languages work. Apply those languages for special situations. Analyse the structure of modelling languages regarding the value for intelligent systems. Create an individual information and knowledge modelling language. Create a parser for that language. Create a description for freely moving robots.

Literature
Bagui, Sikha; Earp, Richard; Database Design Using Entity-Relationship Diagrams (Foundation of Database Design); Auerbach Publications; 2011
Booch, Grady; Rumbaugh, James; Jacobson, Ivar; The Unified Modelling Language User Guide; Addison-Wesley Professional; 2017
OMG et al; OMG Meta Object Facility (MOF) Core Specification, Version 2.5.1; 2019; https://www.omg.org/spec/MOF/2.5.1/PDF
OMG et al; OMG Unified Modelling Language (OMG UML), Version 2.5.1; 2017; https://www.omg.org/spec/UML/2.5.1/PDF
OMG et al; Business Process Model and Notation (BPMN), Version 2.0.2; 2014; https://www.omg.org/spec/BPMN/2.0.2/PDF
ISO/IEC; Information technology - Syntactic metalanguage - Extended BNF; 1996; 2023 last review; https://www.iso.org/standard/26153.html

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5173100
Computer Vision

Module profile

Exam number
5173100

Duration
1 semester

Frequency
Every winter semester

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar-style instruction

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Dominik Seuß

Lecturer(s)
Prof. Dr. Dominik Seuß

Applicability	MAI
Semester according to SPO	2. semester
Type of module	Compulsory module

Required prerequisites for the participation in the module according to the SPO
None

Recommended prerequisites for the participation in the module
None

Content
This lecture course provides a foundational and comprehensive introduction to the field of Computer Vision, covering both traditional image processing techniques and modern Deep Learning-based approaches. The focus is on understanding the theoretical principles underlying key algorithms, while also examining their applicability to real-world problems.
Students will explore the strengths, limitations, and use cases of classical methods-such as edge detection, feature extraction, and image segmentation-as well as state-of-the-art machine learning techniques, including Convolutional Neural Networks (CNNs) and other deep learning architectures.
A strong emphasis is placed on bridging theory and practice. Real-world examples are drawn from domains such as medical image analysis, industrial inspection, and other safety-critical applications, where factors like robustness and explainability play a central role. Concepts from Explainable AI (XAI) are discussed in the context of interpreting and validating model behaviour, particularly in high-stakes environments.
Theoretical knowledge is reinforced through practical exercises and programming assignments, enabling students to implement core algorithms and develop their own solutions to defined tasks. This integrated approach supports the development of both analytical thinking and technical proficiency.

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Portfolio

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes
By the end of this course, the students will be able to:
- Remember fundamental principles and key terminology related to traditional and deep learning-based computer vision methods.
- Understand the theoretical foundations and practical implications of major Computer Vision algorithms in various application contexts.
- Apply established computer vision techniques to solve basic real-world problems through programming assignments and projects.
- Analyse the strengths, limitations, and suitability of traditional versus deep learning approaches across diverse tasks.
- Evaluate and compare different computer vision models based on performance, computational efficiency, and application constraints.
- Create adapted or novel solutions by integrating existing algorithms into practical systems tailored to specific use cases.
- Apply research-informed methodologies to bridge the gap between theoretical models and industry-level implementations.

Literature

- Szeliski, R. (2022). Computer vision: Algorithms and applications (2nd ed.). Springer.
- Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep learning. MIT Press.
- Chollet, F. (2021). Deep learning with Python (2nd ed.). Manning.
- Zhang, A., Lipton, Z. C., Li, M., & Smola, A. J. (2023). Dive into deep learning (2nd ed.). Retrieved from https://d2l.ai
- Khan, S., Rahmani, H., Shah, S. A. A., & Bennamoun, M. (2018). A guide to convolutional neural networks for computer vision. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 49(1), 1-20. https://doi.org/10.1109/TSMC.2018.2882141

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5172080
Fundamentals of Mobile Robotics

Module profile

Exam number
5172080

Duration
1 semester

Frequency
Every winter semester

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar-style instruction

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr.-Ing. Pascal Meißner

Lecturer(s)
Prof. Dr.-Ing. Pascal Meißner

Applicability

MAI

Semester according to SPO 2. semester

Type of module Compulsory module

Required prerequisites for the participation in the module according to the SPO
None

Recommended prerequisites for the participation in the module
None

Content
01. introduction - nomenclature, history, state of the art, module logistics
02 Linear Algebra and Probability Primer - Vectors and operations, matrices and operations, axioms of probability, independent events, Bayes rule
03 Bayes Filter - Recursive Bayesian updating, state transitions, Markov property, derivation
04. probabilistic modelling - odometry- and velocity-based motion models, beam- and scan- based sensor models
05. localisation with Nonparametric Filters - Discrete Bayes filter, importance sampling, particle filter
06. localisation with Gaussian Filters - Kalman filter, Extended Kalman filter
07. mapping with known poses - occupancy maps, reflection probability maps
08. landmark-based SLAM - SLAM problem, EKF SLAM, loop closing, Rao-Blackwellisation, FastSLAM
09. grid-based SLAM - scan matching, FastSLAM, improved proposals, selective resampling
10. motion and path planning - configuration spaces, combinatorial planning, search algorithms, A* with extensions, collision avoidance
11. markov decision processes - MDP definition, utility, value iteration, policy iteration

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Oral exam

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes

- Apply the Bayes (filter) formula and sample from probability density functions
- Determine and apply probabilistic sensor and motion models
- Discuss the steps and components of realisations of Bayes filters
- Implement realisations of Bayes filters and compute location estimates for robots
- Build and analyse grid maps
- Differentiate between localisation and SLAM systems as well as outline auxiliary techniques for SLAM solutions
- Assess and implement components of landmark- and grid-based solutions to the SLAM problem
- Differentiate between different path planning techniques and discuss the steps of collision avoidance solutions
- Apply and implement graph-search techniques for path planning
- Assess the Markov Decision Process definition as well as the concepts of Utility and Policy
- Apply dynamic programming on Markov Decision Problems to compute value functions and optimal policies

Literature

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

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5173080
Introduction to the Ethics and Regulation of AI

Module profile

Exam number
5173080

Duration
1 semester

Frequency
Every winter semester

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar-style instruction

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Markus Oermann

Lecturer(s)
Prof. Dr. Markus Oermann

Applicability

MAI

Semester according to SPO 2. semester

Type of module Compulsory module

Required prerequisites for the participation in the module according to the SPO
None

Recommended prerequisites for the participation in the module
None

Content
The module introduces core ethical theories and explores key AI-related ethical challenges, such as agency, bias, data protection, democracy, job transformation, and sustainability. It examines methods and standards for integrating ethical assessment into AI development, referencing major international guidelines (EU, OECD, UNESCO, Council of Europe, G7) and the new EU AI Act. Current legal debates are covered, including copyright in training data, for AI-generated content, and evolving EU liability frameworks for AI.

Overview on the content of the module:
- Ethics 101 and the traditional schools of ethics
- Clusters of ethical challenges related to AI:

- agency and human/machine relation
- power and responsibility
- biases and discrimination
- data ownership/data protection (including basics structures of data protection law)
- democracy, election integrity, free discourse and the problem of AI driven malinformation, disinformation and deep fakes
- AI as catalyst of radical transformation?: job displacement/ transformation of work
- AI and sustainability

- Approaches and standards on how to integrate ethical assessment in professional workstreams/development of AI and AI applications
- Selected established international ethical guidelines and their take on these challenges: EU, OECD, UNESCO, Council of Europe, G7
- Overview on the EU AI Act
- Further current legal and regulatory discussions on AI:

- How to deal with the use of copyright protected material as training data?
- How to deal with AI's output in terms of copyright law?
- What's ahead: status quo of the reform of the liability regime for AI in the EU

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Written exam (sP) according to § 23 APO

Examination - length/format
90 minutes

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes
After completing the module, students will be able to...

- critically analyse central clusters of ethical challenges of AI, compare their effects on different areas of application and develop recommendations for dealing with these challenges
- integrate an ethical assessment into professional workstreams/AI development processes
- evaluate requirements of data protection law for AI and analyse gaps in the EU General Data Protection Regulation in the context of AI
- evaluate international guidelines on ethical AI in a differentiated manner, work out similarities and differences and formulate well-founded proposals for their implementation in their own professional environment
- evaluate basic legal requirements of the EU AI Act on AI systems and General Purpose AI-Models
- critically assess current legal debates on the use of copyrighted material as training data and the protection of AI outputs and develop and defend their own points of view
- assess AI practices based on basic structures of civil liability and have insights on the status quo of next phase of the EU's regulation of AI regarding the liability regime for AI
- communicate and cooperate better with ethical and legal professionals in their future professional environment

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

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5173090
Natural Language Processing

Module profile

Exam number
5173090

Duration
1 semester

Frequency
Every winter semester

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar-style instruction

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Ivan Yamshchikov

Lecturer(s)
Prof. Dr. Ivan Yamshchikov

Applicability

MAI

Semester according to SPO 2. semester

Type of module Compulsory module

Required prerequisites for the participation in the module according to the SPO
None

Recommended prerequisites for the participation in the module
Mathematical Foundations of AI
Artificial Intelligence and Machine Learning
Artificial Neural Networks and Cognitive Models

Content
The model is implementing a learning-by-doing approach. The students read a variety of scientific publications that are fundamental for the topic, present and discuss these contributions as the course unfolds. They participate in a Kaggle-like NLP competition as well as submit several tutorials and the final capstone project.

The course covers the following set of topics:

1. Natural Language and Semantics:
- Introduction and Natural Language Processing Applications
- Text and Speech Basics
- Verbal Intelligence
- Information theory foundations
- Text representations

2. research methodology:
- Reading scientific papers
- Scientific reproducibility
- Empirical Methods

3. tokenisation
- BPE
- Information-theoretic approach to tokenisation
- Unigram
- Modern tokenisation methods

4. word embeddings
- Embeddings
- Global and local representations
- Distributed representations

5. early language models
- Markov Chains
- Recurrent neural networks for text processing
- Autoencoders

5 Foundations of Large Language Models

- Transformers
- Large Language Models
- Pretraining
- RLHF
- Other forms of fine-tuning

5. advanced chapters of Large Language Models

- LLM bias
- LLM safety
- Agentic frameworks

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Portfolio

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes
After successfully completing the module:
- students learn how to develop and apply the methods of Natural Language Processing.
- students are able to develop result-oriented applications that integrate suitable Natural Language Processing methods.
- students are able to analyse concrete industry tasks in the field of natural language processing from and RnD perspective, evaluate and select suitable methods and software components from the field of natural language processing to develop them further and fit for the suggested task.
- students organise themselves and their team independently in the application of learned methods of Natural Language Processing.

Literature

- Kamath, Uday, John Liu, and James Whitaker. Deep learning for NLP and speech recognition. Vol. 84 Cham: Springer, 2019.
- Chris Manning and Hinrich Schütze, Foundations of Statistical Natural Language Processing, MIT Press. Cambridge, MA: May 1999.

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5171060
Project Module

Module profile

Exam number
5171060

Duration
1 semester

Frequency
Every winter semester

Credit hours (SWS)
8

ECTS-Credits (CP)
10.0

Workload
Guided study time:
Presence time: 15 hrs

Self-study: 285 hrs

Total: 300 hrs

Teaching format
Project

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Magda Gregorová

Lecturer(s)
Prof. Dr. Frank Deinzer,
Prof. Dr. Dr. h. c. Robert Grebner,
Prof. Dr. Frank-Michael Schleif,
Prof. Dr. Magda Gregorová,
Prof. Dr.-Ing. Pascal Meißner,
Prof. Dr. Dominik Seuß,
Prof. Dr. Andreas Lehrmann

Applicability

Applicability	MAI
Semester according to SPO	2. semester
Type of module	Compulsory module

Required prerequisites for the participation in the module according to the SPO
None

Recommended prerequisites for the participation in the module
Scientific Seminar

Content
The students will work in groups to solve projects using AI techniques (supervised by at least one professor). The topics are provided by professors of the FIW, other faculties or external partners. In general the project will contain a software development (potentially accompanied by a technical solution) and a respective documentation or other form or presentation.

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
error

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes
Students can methodically process and solve comprehensive tasks. The students can develop and implement suitable solution strategies in a team. They know how team processes work and can assess how to contribute their own personality. The students can independently set up, implement, accompany and present a small AI project in a team. They can select and use appropriate development technologies and test and document their code.

Literature
Literature will be distributed based on the respective project tasks.

fiw.thws
Faculty of Computer Science and
Business Information Systems
Technical University of
Applied Sciences
Würzburg-Schweinfurt

3. semester

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5171530
Advanced Topics in Robotics

Module profile

Exam number
5171530

Duration
1 semester

Frequency
Irregular

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr.-Ing. Erik Schaffernicht

Lecturer(s)
Prof. Dr.-Ing. Erik Schaffernicht

Applicability

MAI

Semester according to SPO 3. semester

Type of module FWPM

Required prerequisites for the participation in the module according to the SPO
none

Recommended prerequisites for the participation in the module
Fundamentals in Mobile Robotics
Artificial Intelligence and Machine Learning
Reasoning and decision making under uncertainty

Content
This course is aimed at those students who are interested in diving deeper into embodied artificial intelligence and robotics. While the course has several distinct topics that it will cover, the overall goal is gain a better insight how AI techniques tought in the programme are being used in robotics to make robots act in intelligent ways.

Specific topics covered:
Control Architectures: Cognitive Architectures, reactive vs. proactive, policies vs. plans, subsumption architecture, task-switching policy representations (e.g. finite state machines or behaviour trees which are also used to control agents in computer games),

Robot learning: imitation learning & learning from demonstrations, the sim2real problem, foundation models in robotics

Mobile robot olfaction - robots with a sense of smell: electronic noses, tasks and challenges in robot olfaction, machine learning for olfaction tasks

When possible, the course will incorporate and discuss recent scientific publications related to the specific topics.
Depending on the interests of the participating students, other topics may be discussed in the course.

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
none

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Portfolio

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
none

Learning outcomes
After completing the course students are able to

- describe and compare different ways of representing robot actions
- design and implement action framworks for a robot
- justify the trade-off between implementing behaviours or skills by hand vs. learning data/interactions them
- understand and explain the capabilities and limitations of robots when performing olfactions tasks
- explain tasks like gas source localisation and gas distribution mapping and their associated challenges
- read and understand current scientific literature in robotics

Literature
There will be reading assignments for different topics handed out during the course, but there is no traditional course book to follow.

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5171130
Master Thesis

Module profile

Exam number
5171130

Duration
1 semester

Frequency
Every semester

Credit hours (SWS)
0

ECTS-Credits (CP)
25.0

Workload
Guided study time:
Presence time: 0 hrs

Self-study: 750 hrs

Total: 750 hrs

Teaching format
Self-study

Language of instruction
German/English

Organisation

Responsible lecturer
Prof. Dr.-Ing. Pascal Meißner

Lecturer(s)
Prof. Dr. Arndt Balzer,
Prof. Dr. Frank Deinzer,
Prof. Dr. Dr. h. c. Robert Grebner,
Prof. Dr. Frank-Michael Schleif,
Prof. Dr. Magda Gregorová,
Prof. Dr.-Ing. Pascal Meißner,
Prof. Dr. Ivan Yamshchikov,
Prof. Dr. Dominik Seuß,
Prof. Dr. Andreas Lehrmann

Applicability

Applicability	MAI
Semester according to SPO	3. semester
Type of module	Compulsory module

Required prerequisites for the participation in the module according to the SPO
50 ECTS points

Recommended prerequisites for the participation in the module
Regarding the actual writing of the thesis it is strongly recommended that the Scientific Seminar is already completed.

Content
Independent preparation of a thesis and processing of a theoretical or practical task according to scientific methods.

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Thesis

The concrete length/format of the examination will be determined in the study plan.

Language of examination
German/English

Condition for the award of credit points
None

Learning outcomes
With the submission of a Master's thesis and the successful assessment, students document that they
have understood the teaching content of the previous semesters and are able to apply it to tasks independently and successfully.

They are able to derive an innovative research question on a selected research area, which includes a sufficiently
significant and as yet unresearched research field.

They can work on this research question largely independently with an appropriate and meaningful
research design and lead to an objectively comprehensible, reliable and valid result.

The written result is at the level of international standards of scientific publications and, upon
successful completion, demonstrates the competences in terms of connectivity in the direction of doctoral projects.

Literature
Is provided based on the topic, but also needs to be identified by the student as part of the master thesis.

fiw.thws
Faculty of Computer Science and Business Information Systems
Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 5171525
Strong Artificial Intelligence

Module profile

Exam number
5171525

Duration
1 semester

Frequency
Irregular

Credit hours (SWS)
4

ECTS-Credits (CP)
5.0

Workload
Guided study time:
Presence time: 60 hrs

Self-study: 90 hrs

Total: 150 hrs

Teaching format
Seminar

Language of instruction
English

Organisation

Responsible lecturer
Prof. Dr. Dr. h. c. Robert Grebner

Lecturer(s)
Prof. Dr. Dr. h. c. Robert Grebner

Applicability	MAI, MDB
Semester according to SPO	3. semester
Type of module	FWPM

Required prerequisites for the participation in the module according to the SPO
Basic knowledge in the architecture of digital machines, formal languages, modelling notations and tools.

Recommended prerequisites for the participation in the module
none

Content
Strong artificial intelligence deals about the question how to design and build human like thought machines. In the course we elaborate the basics of human thinking including naming, numbering, abstracting, conceptualizing and what is needed to build a digital machine that is able to think and act like an individual and is able to interact with other individuals. A variety of interconnected and adopted concepts and theories are necessary to implement human like skills and behaviour. A selection of these, like theory of information, action, time and space as well as a theory of thinking is discussed and developed in the course.

Examination

Required prerequisites for the participation in the examination according to the SPO appendix
None

Examination - type
Other exam (soP) according to §§ 26, 27 APO

Examination - length/format
Oral exam

The concrete length/format of the examination will be determined in the study plan.

Language of examination
English

Condition for the award of credit points
None

Learning outcomes
Learning and understanding the basic mechanisms of thinking. Applying concepts and theories of thinking. Analysing architectures of thought machines. Evaluating different basic theories needed to implement thought machines. Design own theories of information and thoughts.

Literature
Stanford Encyclopedia of Philosophy (https://plato.stanford.edu/index.html); Logic - An introduction to elementary logic, Wilfried Hodges, 2001;