Handbook of Modules
for the Degree Programme

Information Engineering and Computer Science, M.Sc.

Faculty of Communication and Environment

Version 1.6
30.07.2025

Dokumentenhistorie

Version	Datum	Verantw.	*Bemerkung*
0.1	2013-12-13	TH	*Initialversion*
0.2	2013-12-16	TH	*Weight towards final grade angepasst*
0.3	2013-12-17	TH	*Module M-IE_EA.02 und M-IE_3.01 eingefügt*
1.0	2014-01-13	TH	*Version zur Veröffentlichung*
1.1	2014-09-24	TH	*Bearbeitungszeit Masterarbeit laut PO angepasst*
1.2	2015-10-19	SLE	*Modulbeschreibungen gem. Akkreditierungsauflagen angepasst*
1.3	2015-10-19	TH	*deutsche Bezeichnungen ins Curriculum eingeführt, redaktionelle Änderungen*
1.4	2019-04-25	MS	*Bearbeitung für Reakkreditierungszwecke*
1.5	2021-01-27	MS	*Bearbeitung zur Auflagenerfüllung*
1.6	2025-07-30	PBB	*Bearbeitung für Reakkreditierungszwecke*

Explanation

Specification of the types of assessment

Assessments are regulated in the "general examination regulations for Bachelor's and Master's degree programmes at Rhein-Waal University of Applied Science" (RPO Rahmenprüfungsordnung der Hochschule Rhein-Waal). According to RPO there are two types of assessments: Certificates (according RPO §20) and Examinations (according to RPO §14). In individual module courses, certificates may be required as a prerequisite for participation in module examinations. This applies to modules in which both a certificate and an examination must be taken (PO §5). Examinations are also regulated in the examination regulation of the Master's degree program "Information Engineering and Computer Science" (PO Prüfungsordnung für den Masterstudiengang Information Engineering and Computer Science an der Hochschule Rhein-Waal).

Examinations (according RPO §14):
The purpose of course examinations is to assess whether students have become proficient in the essential content and methodology of a specific subject area and are able to autonomously and correctly apply their acquired knowledge and skills. Examinations are planned according to learning outcomes and usually take the form of written or electronic examinations (RPO §17, §17b), multiple choice examinations (RPO §17a), oral examinations (RPO §18) or assignments, term papers or projects (RPO §19). A combination thereof is also possible with approval of the Examination Board. For periods abroad considered relevant to the degree programme, a written examination may be substituted for an oral examination with approval of the Examination Board.

According to the examination regulation the Examination Board will generally specify and notify students of the type of examination, as well as of the duration in the case of written examinations, before the start of the corresponding course in consultation with the examiner(s), and in a uniform and binding manner for all participating students. The weight of grading of composite examination types is also announced at the beginning of the semester.

The following assessment scale is used for examinations (RPO §11(3)):

1 = Very Good	= Excellent
2 = Good	= Well above average
3 = Satisfactory	= Average
4 = Sufficient	= Meets minimum requirements despite shortcomings
5 = Failed	= Does not meet requirements due to significant shortcomings

Marks can be raised or lowered by 0.3 points for more precise assessment; 0.7, 4.3, 4.7 and 5.3 are not valid marks.

In the event of any discrepancy or doubt between the RPO and this document, the RPO version takes precedence.

Graded examination	According to RPO §14 (3), and PO §5(1)
Written / Oral examination	According to RPO §17, RPO §18, and PO §5
Assignments, term papers and projects	According to RPO §19, and PO §5(4)
Certificates	According to RPO §20, and PO §5

RPO Rahmenprüfungsordnung für die Studiengänge an der Hochschule Rhein-Waal
PO Prüfungsordnung des Studiengangs Information Engineering & Computer Science

List of abbreviations:
TU: teaching units (45 min) per semester
SWS: amount teaching units (45 min) per week
h: 60 min

Inhaltsverzeichnis

Curriculum of the Master Degree Programme Information Engineering and Computer Science, M.Sc.

Information Engineering and Computer Science, M.Sc.

Code	Module	SW	Type (Veranstaltungsart)						TE	CP	Sum CP	SS1	WS2	SS3
			L	SL	S	Ex	PT	Pro						
9511	System Simulation	4	2			2			E	5	5	4		9501 Master Thesis/Masterarbeit (27 CP) and 9502 Colloquium/Kolloquium (3 CP)
9512	Data Analysis & Information Engineering	4	2			2			E	5	5	4		
9513	Scientific and Technical Communication	4		4					E	5	5	4		
9515	Artificial Intelligence and its Application	4		4					E	5	5	4		
9521	Data Mining	4	2			2			E	5	5	4		
9524	Innovation Management	4	3			1			E	5	5		4	
9526	Applied Research Project	4					4		E	5	5		4	
9527	Advanced Applications of Artificial Intelligence	4		4					E	5	5		4	
9528	Machine Learning	4	2			1	1		E	5	5		4	
	Specialization Track: Elective 1	4	2			2			E	5	5	4		
	Specialization Track: Elective 2	4	2			2			E	5	5		4	
	Specialization Track: Elective 3	4	2			2			E	5	5		4	

	Semester hours per week (Semesterwochenstunden)	48								CP	60	24	24	30

48

90 CP

Electives Catalogue

Wahlpflichtkatalog*/**/***/**** für den Masterstudiengang Information Engineering and Computer Science, M.Sc.

Modulcode	Modulbezeichnung	CP	WL	Type	TE	Specialization Software and Systems	Specialization Environmental Sciences	Specialization Supply Chain
9531	Advanced System Security	5	150	SL	E	X		
9532	Mobile & Internet Computing	5	150	SL	E	X		
9534	Privacy in Distributed Systems	5	150	SL	E	X		
9535	Innovative Approaches in Applied Computer Science I	5	150	SL	E	X		
9536	Innovative Approaches in Applied Computer Science II	5	150	SL	E	X		
9537	Innovative Approaches in Applied Computer Science III	5	150	SL	E	X		
9541	Environmental Analysis, Impact and Risk	5	150	SL	E/C		X	
9543	Data Processing in Ecosystem Management	5	150	SL	E/C		X	
9544	Applied Geoinformatics	5	150	SL	E		X	
9545	Hands-on IoT Systems for Environmental Monitoring	5	150	SL	E		X	
9546	Environmental Analysis of Energy Production	5	150	SL	E		X	
9547	Applied Sustainability Research Project	5	150	SL	E		X	
9551	Logistics Network Modelling	5	150	SL	E			X
9552	Advanced Logistics Control	5	150	SL	E			X
9554	Supply Chain Planning & Optimization	5	150	SL	E			X
9555	Innovative Approaches in Supply Chains I	5	150	SL	E			X
9556	Innovative Approaches in Supply Chains II	5	150	SL	E			X
9557	Innovative Approaches in Supply Chains III	5	150	SL	E			X

* Die Fakultät behält sich das Recht vor, eine Mindestteilnehmerzahl für das Zustandekommen eines Wahlpflichtkurses festzulegen. Die Möglichkeit des Erreichens der vorgeschriebenen Kreditpunktanzahl aus dem Wahlpflichtbereich bleibt unberührt. / The faculty reserves the right to determine a minimum number of participants for offering an elective subject. The possibility to obtain the required number of credit points remains unaffected.

** Die Fakultät Kommunikation und Umwelt behält sich das Recht vor, das Modulangebot im Wahlpflichtbereich zu ändern. / The Faculty Communication and Environment reserves the right to change the catalogue of electives.

*** Aufgrund von stundenplantechnischen Randbedingungen ist nicht auszuschließen, dass Module verschiedener Fokusfelder sowie Module des Wahlpflichtbereichs zeitgleich angeboten werden. / Due to time tabling constraints subjects from different focus fields and electives may be offered concurrently.

**** Eine Spezialisierung besteht aus 3 Wahlpflichtfächern aus der oben angegebenen Liste. / A Specialization consists of 3 elective courses out of the list indicated above.

Abbreviations (Abkürzungen)

SW (SWS)	Semester hours per week (Semesterwochenstunden)
L	Lecture (Vorlesung)
SL	Seminaristic lecture (Seminaristische Lehrveranstaltung)
S	Seminar
Ex	Exercise (Übung)
PT	Practical training (Praktikum)
Pro	Project (Projekt)
TE	Type of examination (Prüfungsform)
CP	Credit points (= ECTS points)
WS	Winter semester (Wintersemester)
SS	Summer semester (Sommersemester)
E	Examination (Prüfung)
C	Certificate (Testat)

9501 Master Thesis and 9502 Colloquium

Code 9501/9502	**Workload** 810 h	**Credits** 30 CP (27 + 3 CP)	**Level of module** 3rd semester	**Frequency of offer** Summer semester
Duration 20 weeks	**Courses** 9501 Master Thesis: 27 CP 9502 Colloquium: 3 CP	**Teaching time** Depending on individual needs	**Self-study**	**Planned group size**

Learning outcomes / Competences and qualifications profile

Students have worked on a research topic of interest to them within the scientific fields of Information Engineering and Computer Science. They conducted intensive literature reviews and developed their research questions. They have also developed appropriate methodological strategies to address this question. They have adopted an approach that focuses on specific details of the question, analysed the results, and transferred their findings to a broader perspective within the field. They have critically reflected on their work and findings and come up with further research questions. They have proven that they can analyse a complex field of work, identify specific new research questions, and answer them.

During the colloquium, students presented their work, proving their expertise in the field. They were able to defend their topic and reflect on its impact on real-life problems professionally.

Content

- Researching and evaluating literature
- Developing a research question and deriving hypotheses
- Operationalizing constructs
- Analyzing methodological strengths and weaknesses of different research approaches
- Developing research designs
- Conducting the studies
- Evaluating the results
- Writing the thesis
- Presenting and defending the findings

Teaching methods

Individual supervision and support

Entry requirements

50 credits points achieved in other courses of the curriculum

Types of assessment

Written Master thesis and oral disputation
Requirements for the award of credit points Passed Master thesis and disputation as well as successful completion of all other modules of the curriculum
Use of module (in other study programs) - -
Weight towards final grade 33,3%
Person in charge of module All professors of the faculty
Additional Information

9511 System Simulation

Code	Workload	Credits	Level	Frequency
9511	150 h	5 CP	1st semester	Summer semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Group size** Lecture: open Exercise: 25 students / working group

Learning outcomes / Competences and qualification profile

This module equips students with the ability to model, analyze, and understand complex real-world systems from technical, natural, and economic domains. Students learn foundational and advanced concepts of modelling and simulation, enabling them to translate real-world phenomena into formal representations and evaluate system behaviour using appropriate simulation techniques. The course emphasizes both methodological knowledge and practical application, while also fostering critical reflection on the validity and limitations of simulation-based analyses.

- formulate real-world problems mathematically and select suitable modelling and simulation approaches for different types of systems;
- apply fundamental and contemporary modelling techniques to investigate system dynamics, generate predictions, and explore system behaviour under varying conditions;
- design and implement simulation experiments, including the definition of parameters, model assumptions, and validation strategies;
- critically evaluate the accuracy, applicability, and limitations of models and simulations in relation to real-world constraints and data availability;
- use simulation tools and software environments to analyze technical, natural, or economic systems and derive meaningful insights;
- differentiate between model types and simulation paradigms and justify the selection of specific methods for particular research questions;
- develop and adapt their own modelling and simulation ideas to address practical problems and emerging challenges in various application domains;
- collaborate effectively in teams to design, execute, and interpret simulation studies, and communicate findings clearly in written and oral form.

Content

Introduction: to modelling and simulation, motivation, meaning of modelling and simulation in the context of technical, natural or economical systems, practical examples from everyday life, typical questions, different categories of simulations, steps of the simulation process

Continuous simulations

- e.g. Growth processes (exponential, logistic), predator-prey relationships, stepwise extension (e.g. by intraspecific competition, different predator or prey species),
- Introduction of dimensionless variables
- Implementation e.g. with Python, R, Octave/Matlab/Simulink, Scilab/Xcos, Comsol...
- Transfer of the methods learned to other situations and technical systems
- Fundamentals of numerical methods in the context of differential equations

- Repetition: Ordinary differential equations (ODE): discretization, Euler method, Runge-Kutta method and subsequent implementation of examples, stability of methods, built-in solvers in modern tools
- Partial differential equations (e.g. heat conduction equation via FEM or FDM, solution of the one-dimensional advection-diffusion equation via FDM)

Discrete and Stochastic simulations

- e.g. Monte Carlo simulations (e.g. simulation radioactive decay using MC Simulations, MC integration, forest-fire-simulations, . . .)

Modelling and simulations in **data science** and **machine learning**
(e.g. PIML (Physics-informed Machine Learning))
Modelling and Simulation in **3D-Tools**, such as Blender, Houdini etc.

Teaching methods

Tuition in seminars, lectures and practical trainings. Students work individually and in teams.

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Frank Zimmer

Additional information

Recommended readings:

Campbell, S.L., Chancelier, J.-P., & Nikoukhah, R. (2009): *Modeling and Simulation in Scilab/Scicos with ScicosLab 4.4*, ISBN 978-1441955265, Springer, Berlin, 2nd ed., 2009.

Chapra, S.C.; Canale, R.P. (2022): *ISE Numerical Methods for Engineers*, ISBN 978-1260571387, McGraw-Hill Education, 8th ed., 2022.

Chapra, S.C. (2022): *Applied Numerical Methods with MATLAB for Engineers and Scientists ISE*, ISBN 978-1265148225, McGraw-Hill Education, 5th ed., 2022

Chapra, S.C. (2021): *Applied Numerical Methods with Python for Engineers and Scientists ISE*, ISBN 978-1265017965, McGraw-Hill Education, 2021

Gilat, A., Subramaniam, V. (2014): *Numerical Methods for Engineers and Scientists: An Introduction with Applications Using MATLAB*, ISBN 978-1118554937, John Wiley & Sons Inc., 3rd ed., 2014

Gustafsson, B. (2013): *Fundamentals of Scientific Computing*, ISBN 978-3642268649, Springer, 2013

Imboden, D. M., & Pfenniger, S. (2012): *Introduction to Systems Analysis: Mathematically Modeling Natural Systems*, ISBN 978-3642306389, Springer, 2012

Klee, H., & Allen, R. (2018): *Simulation of Dynamic Systems with MATLAB® and Simulink®*, ISBN 978-1032241951, CRC Press, 3rd ed., 2018

Kreyszig, E. (2025): *Advanced Engineering Mathematics*, International Adaption, ISBN 978-1394319466, John Wiley & Sons, 11th ed., 2025

Jones, O., Maillardet, R., & Robinson, A. (2014): *Introduction to Scientific Programming and Simulation Using R*, ISBN 978-1466569997, CRC Press, Taylor & Francis Group, Boca Raton, FL, 2nd new edition, 2014

Hill, C. (2020): *Learning Scientific Programming with Python*, ISBN 978-1108745918, Cambridge University Press, 2nd ed., 2020

Neuer, M. J. (2024): *Machine Learning for Engineers: Introduction to Physics-Informed, Explainable Learning Methods for AI in Engineering Applications*, ISBN 978-3662699942, Springer, 2024

Quarteroni, A. M., Saleri, F., & Gervasio, P. (2016): *Scientific Computing with MATLAB and Octave*, ISBN 978-3662517581, Springer, Berlin, 4th ed., 2016

Rongpeng, L., & Nakano, A. (2022): *Simulation with Python: Develop Simulation and Modeling in Natural Sciences, Engineering, and Social Sciences*, ISBN 978-1484281840, Apress, 2022

Stroud, K.A., & Booth, D.J. (2020): *Engineering Mathematics*, ISBN 978-1352010275, Bloomsbury Academic, 8th ed., 2020

Stroud, K.A., & Booth, D.J. (2020): *Advanced Engineering Mathematics*, ISBN 978-0230275485, Bloomsbury Academic, 6th ed., 2020

Turner, P.R., Arildsen, T., & Kavanagh, K. (2018): *Applied Scientific Computing: With Python*, ISBN 978-3319895741, Springer, Berlin, 2018

Wouwer, A.V., Saucez, P., & Vilas, C. (2014): *Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications*, ISBN 978-3319067896, Springer, Berlin, 2014

9512 Data Analysis & Information Engineering

Code 9512	**Workload** 150 h	**Credits** 5 CP	**Level of module** 1st semester	**Frequency of offer** Summer semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** Lecture: open Exercise: 25 students / working group

Learning outcomes / Competences and qualification profile

This module introduces students to the theoretical and philosophical foundations of Information Theory as well as the practical methods of modern data analysis. It connects epistemological concepts with statistical measures of information and equips students with analytical and computational skills to transform raw data into structured information and knowledge. Through hands-on exercises in R and Python, students develop the ability to apply statistical techniques, evaluate data quality, and understand the broader system-science perspective of Information Engineering.

- explain the epistemological foundations of Information Theory and relate them to concepts of knowledge formation and information processing;
- describe and apply key theoretical measures of information, such as Shannon entropy and Kolmogorov complexity;
- analyze the role of Markov chains in modelling stochastic processes relevant to information processing;
- distinguish between data, information, and knowledge within the knowledge pyramid and describe the value-adding processes involved;
- identify suitable criteria and methods for collecting high-quality data as input for statistical and information-theoretic analyses;
- apply fundamental and selected advanced statistical methods using R and Python to analyze, interpret, and visualize data;
- evaluate statistical findings critically in terms of validity, reliability, and limitations, and reflect on the complexity of information engineering as a system science;
- use computational tools to implement data-processing workflows and derive well-founded conclusions from empirical datasets.

Prerequisites:
Good understanding of descriptive statistics, probability theory, and inferential statistics, including random variables and probability distributions, moments of one random variable, parametric distributions, and sampling distributions.

Content

- Philosophical Foundations of Information Theory
- Basics of Information and Complexity Theory
- Markov Chains and Processes
- Data & Information Retrieval

- Gaining Quality Data from different sources
- Data Processing and Analysis with R / Python

Teaching methods

Tuition in seminars, lectures and (partially self-organized) practical trainings. Students work individually and in teams.

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Michael Schwind

Additional Information

Recommended readings:

Adriaans, P. (2024): *Information*, in: The Stanford Encyclopedia of Philosophy (Summer 2024 Edition), Edward N. Zalta & Uri Nodelman (Eds.), verfügbar unter: `https://plato.stanford.edu/archives/sum2024/entries/information/`

Batini, C.; Scannapieco, M. (2016): *Data and Information Quality*, ISBN 978-3319241036, Springer, 2016.

Brookes, C. B. (1980): *The Foundations of Information Science. Part I. Philosophical Aspects*, Journal of Information Science, Vol. 2(3–4), pp. 125–133, SAGE, 1980.

Fan, J.; Li, R.; Zhang, C.; Zou, H. (2020): *Statistical Foundations of Data Science*, ISBN 978-1138492530, CRC Press, 2020.

Field, A.; Miles, J.; Field, Z. (2012): *Discovering Statistics with R*, ISBN 978-1446200469, SAGE, 2012.

Floridi, L. (2011): *The Philosophy of Information*, ISBN 978-0199232383, Oxford University Press, 2011.

Hastie, T.; Tibshirani, R.; Friedman, J. (2017): *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*, ISBN 978-0387848570, Springer, 2nd ed., 2017.

James, G.; Witten, D.; Hastie, T.; Tibshirani, R. (2017): *An Introduction to Statistical Learning with Applications in R*, ISBN 978-1461471370, Springer, 2017.

McKinney, W. (2017): *Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython*, ISBN 978-1491957663, O'Reilly, 2nd ed., 2017.

Pardoux, E. (2008): *Markov Processes and Applications: Algorithms, Networks, Genome and Finance*, ISBN 978-0470721875, Wiley, 2008.

Shannon, C. E. (1948): *A Mathematical Theory of Communication*, Bell System Technical Journal, Vol. 27, pp. 379–423 & 623–656, 1948.

9513 Scientific and Technical Communication

Code	Workload	Credits	Level	Frequency
9513	150 h	5 CP	1st semester	Summer semester
Duration	**Courses**	**Teaching time**	**Self-study**	**Group size**
1 semester	Seminaristic Lecture: 60 TU / 4 SWS	60 TU / 4 SWS	105 h	25 students/ working group

Learning outcomes / Competences and qualification profile

This module familiarizes students with effective strategies for scientific and technical communication in the context of information engineering and computer science. Students learn how to adapt language, structure, and presentation style to different audiences and purposes, and how to apply formal conventions of academic writing and responsible scholarly conduct. Through practical exercises, they gain experience in writing, revising, and presenting technical content, and learn to use illustrations, tables, and data visualizations to support clear and professional communication.

- adapt linguistic register, tone, and structure to communicate technical information effectively across different audiences, contexts, and media;
- apply principles of scientific writing, including clarity, conciseness, coherence, and appropriate academic style;
- conduct systematic reviews of scholarly literature and follow established citation and referencing conventions to ensure academic integrity and avoid plagiarism or misuse of AI-based tools;
- plan, structure, draft, and revise technical reports, manuals, and academic publications in the field of information engineering and computer science;
- integrate illustrations, tables, and data visualizations appropriately and professionally into scientific and technical documents;
- prepare and deliver well-structured peer presentations, demonstrating proficiency in verbal and non-verbal communication, stance, and storytelling;
- reflect critically on the communication needs of scientific and engineering contexts and use feedback constructively to improve their own communication practices.

Content

- Writing styles and registers
- Formal conventions in academic publishing
- Presentation techniques

Teaching methods

Tuition in lectures and practical trainings. Students work individually and in teams.

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of moodule (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Alexander Gerber

Additional information

Recommended readings:

Billig, M. (2013): *Learn to Write Badly: How to Succeed in the Social Sciences*, ISBN 978-0521169252, Cambridge University Press, 2013.

Filshie Browning, J. (2021): *Scientifically Speaking: How to Speak About Your Research with Confidence and Clarity*, ISBN 978-1788602556, Practical Inspiration Publishing, 2021.

Hofmann, A. H. (2010): *Scientific Writing and Communication: Papers, Proposals, and Presentations*, ISBN 978-0195390056, OUP USA, 2010.

Jensen, E. A.; Laurie, C. (2016): *Doing Real Research: A Practical Guide to Social Research*, ISBN 978-1446273883, Sage, 2016.

Katz, M. J. (2009): *From Research to Manuscript: A Guide to Scientific Writing*, ISBN 978-1402094668, Springer, 2nd ed., 2009.

Meenakshi, R.; Sharma, S. (2015): *Technical Communication: Principles and Practice*, ISBN 978-0199457496, OUP India, 3rd ed., 2015.

Zinsser, W. (2006): *On Writing Well: The Classic Guide to Writing Nonfiction*, ISBN 978-0060891541, Collins, 7th ed., 2006.

9515 Artificial Intelligence and its Application

Code 9515	**Workload** 150 h	**Credits** 5 CP	**Level of module** 1st semester	**Frequency of offer** Summer semester
Duration 1 semester	**Courses** Seminaristic Lecture: 60 TU / 4 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students / working group

Learning outcomes / Competences and qualification profile

This module introduces students to the foundational concepts, methods, and application domains of artificial intelligence. After an initial overview of the major areas of AI, the course focuses on knowledge representation, inference and reasoning, and autonomous planning. These topics are explored through examples from smart environments, assistive systems, and Industry 4.0 scenarios. Students gain both theoretical insights and practical skills to understand, design, and evaluate AI systems in a variety of contexts.

- describe the main components, historical development, and core paradigms of artificial intelligence;
- explain concepts and formalisms of knowledge representation and use them to model information about a given domain;
- apply inference and reasoning techniques to derive new knowledge and support decision-making processes;
- design planning components for autonomous systems in fully observable, deterministic environments;
- develop approaches for planning and reasoning in partially observable or nondeterministic settings with uncertain knowledge;
- integrate knowledge representation, inference methods, and planning mechanisms into coherent AI system designs;
- apply AI concepts to real-world domains such as smart environments, assistive technologies, and Industry 4.0 applications;
- critically reflect on the societal and ethical implications of AI technologies.

Content

- What is AI?: The history, vision, aspects and chances of AI in different domains
- Intelligent environments: Type of environments, typical elements, Context-its value and inferring it from data
- Knowledge and reasoning: Propositional Logic, First-Order Logic, Inference in First-Order Logic, Knowledge Representation (Ontological Engineering)
- Planning with search: a) Using search algorithms to find action sequences: uniformed and informed strategies, heuristic functions, nondeterministic actions, partial observation
  b) Optimization problems, c) Constraint Satisfaction Problems, PDDL/ADL, Schedules and Resources, Hierarchical planning, Multiagent Planning,
- Uncertain knowledge and reasoning: Probability Notation, Full joint distributions (and inferences), Independence, Bayes' Rule, Bayesian networks, Inference in Bayesian Networks, Relational and first- order probability models, Utility Theory, Decision Networks

- Outlook, ethical and social impacts

Teaching methods

Tuition in seminars, lectures and practical classes

Entry requirements

None

Recommendation: It is strongly recommended that students attending this module have advanced knowledge in (object oriented) programming. Most examples presented to the students are Java, Pythen based. The ability to use higher mathematical concepts is expected. Furthermore, students attending this course should have an elementary knowledge in algorithms.

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Christian Ressel

Additional Information

Recommended readings:

Russell, S.; Norvig, P. (2010): *Artificial Intelligence: A Modern Approach*, ISBN 978-0136042594, Pearson, Prentice Hall, 3rd ed., 2010.

Corchado, J. M.; Tapia, D. I.; Bravo, J. (Eds.) (2010): *Ambient Intelligence and Future Trends – International Symposium on Ambient Intelligence*, ISBN 978-3642140428, Springer, Berlin, 2010.

Omatu, S.; Rocha, M. P.; Bravo, J.; Fernández-Caballero, A.; González, S. R.; Faria, P. M. (Eds.)

(2009): *Distributed Computing, Artificial Intelligence, Bioinformatics, Soft Computing, and Ambient Assisted Living: 10th International Work-Conference*, ISBN 978-3642027101, Springer, Berlin, 2009.

9521 Data Mining

Code 9521	**Workload** 150 h	**Credits** 5 CP	**Level of module** 1st semester	**Frequency of offer** Summer semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** Lecture: open Exercise: 25 students / working group

Learning outcomes / Competences and qualification profile

This module introduces students to the principles, methods, and practical applications of data mining. It equips them with the ability to extract meaningful patterns and knowledge from complex datasets by combining theoretical foundations with hands-on implementation using modern data mining tools.

- identify and formulate problems that are suitable for data mining approaches and select appropriate techniques for given application contexts;
- explain fundamental concepts, data types, models, and algorithms that underpin data mining processes;
- organize, preprocess, and transform data, including data cleaning, feature engineering, and preparation for analysis;
- apply data mining algorithms using Python-based libraries (e.g., `pandas`, `scikit-learn`, `mlxtend`) to analyze, model, and interpret datasets;
- evaluate the strengths, limitations, and assumptions of different data mining techniques with respect to data characteristics and domain-specific requirements;
- design scalable data workflows and reproducible pipelines for extracting insights from large and heterogeneous datasets;
- develop and implement data mining solutions for real-world datasets from diverse application domains;
- critically assess the ethical and risk-related implications associated with data mining, including privacy concerns and responsible data use, balancing utility against potential harm.

Content

Recent technological advances have led to a rapid growth in data. This has created a need for cost-efficient, scalable techniques to analyze data. Thus, special focus is placed on the impact of data models for data mining, as well as on the extraction, transformation, and loading (ETL) steps in data mining processes.

- Introduction to data mining.
- Data preparation and feature engineering.
- Core data mining techniques.
  - Clustering (e.g. k-means, DBSCAN, hierarchical methods).
  - Association rule mining (e.g. Apriori, FP-Growth).
  - Classification and regression (overview with examples).
  - Anomaly detection.

- ETL process and scalable pipeline design.
- Application domains.
- Introduction to web and text mining.
- Responsible use of data: data privacy and legal considerations.
- Introduction to big data and cloud-based mining.
- Introduction to distributed frameworks (e.g. Hadoop, Spark)

Teaching methods

Tuition in seminars, lectures and (partially self-organized) practical trainings. Students work individually and in teams.

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Patrick-Benjamin Bök

Additional Information

Recommended readings:

Barocas, S., Hardt, M., & Narayanan, A. (2023): *Fairness and Machine Learning: Limitations and Opportunities*. Available online: `https://fairmlbook.org`

Han, J., Kamber, M., & Pei, J. (2022): *Data Mining: Concepts and Techniques*, ISBN 978-0128181487, Morgan Kaufmann, 4th revised ed.

Müller, A. C., & Guido, S. (2016). *Introduction to Machine Learning with Python: A Guide for Data Scientists*. O'Reilly Media.

Nisbet, R., Elder, J., & Miner, G. (2009): *Handbook of Statistical Analysis and Data Mining Applications*, ISBN 978-0123747655, Academic Press, Elsevier Inc.

Russell, M.A. (2018): *Mining the Social Web: Data Mining Facebook, Twitter, LinkedIn, Google+, GitHub, and More*, ISBN 978-1491973533, O'Reilly Media, 3rd ed.

Tan, P.-N., Steinbach, M., & Kumar, V. (2019): *Introduction to Data Mining*, ISBN 978-0133128901, Addison Wesley, Boston, 2nd ed.

White, T. (2015): *Hadoop: The Definitive Guide*, ISBN 978-1491901635, O'Reilly Media, Inc., 4th ed.

Witten, I.H., Frank, E., & Hall, M.A. (2025): *Data Mining: Practical Machine Learning Tools and Techniques*, ISBN 978-0128042914, Morgan Kaufmann, 3rd ed.

9524 Innovation Management

Code	Workload	Credits	Level of module	Frequency of offer
9524	150 h	5 CP	2nd semester	Winter semester
Duration	**Courses**	**Teaching time**	**Self-study**	**Planned group size**
1 semester	Lecture: 45 TU / 3 SWS Exercise: 15 TU / 1 SWS	60 TU / 4 SWS	105 h	Lecture: open Exercise: 25 students / working group

Learning outcomes / Competences and qualification profile

This module introduces students to the principles, strategies, and practices of innovation management, with a focus on customer-driven and user-driven approaches. Students explore the economic, marketing, legal, and financial aspects of innovation, and learn how to identify opportunities, generate ideas, and develop concepts for new products and services. The course emphasizes both analytical and creative skills, enabling students to balance functional and non-functional requirements, assess risks, and develop business plans that transform innovative ideas into viable solutions.

- explain key theories, concepts, and frameworks of innovation management, including economic and econometric growth models, marketing-oriented product design, innovation portfolios, and financing strategies for startups;
- identify innovation opportunities and transform them into clear requirements and concepts for products or services;
- develop innovative business ideas and translate them into comprehensive business plans that balance stakeholder needs and functional/non-functional requirements;
- apply principles and methods of design management across different disciplines to support structured and creative innovation processes;
- evaluate the trade-offs between incremental, sustainable innovation and disruptive, breakthrough innovation, and reflect critically on the potential impact of innovation decisions;
- demonstrate teamwork and collaboration skills in ideation, concept development, and project execution within innovation-focused settings;
- communicate innovative concepts and strategies effectively to diverse audiences through presentations, reports, and visualizations.

Content

- Types of Innovation: Incremental / Disruptive
- Open innovation and user-centered innovation Scaling, Gradient Descent, Learning Rate, and Hyperparameters
- Market-oriented innovation management
- Economic foundations of innovation: the case of Schumpeter, Solow and Romer
- Strategic management and design management of innovation: innovation portfolio management
- Legal Background of innovation: patents, copyrights and intellectual property
- Risk of innovation: e.g., long-term impact of digital media on societal evolution.

- Financing innovative startups

Teaching methods

Tuition in seminars, lectures and practical trainings. Students work individually and in teams.

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Michael Schwind

Additional Information

Recommended readings:

Grassmann, O.; Bader, M.; Thompson, M. J. (2021): *Patent Management: Protecting Intellectual Property and Innovation*, ISBN 978-3662629970, Springer, 2021.

Tidd, J.; Bessant, J. (2018): *Managing Innovation: Integrating Technological, Market and Organizational Change*, ISBN 978-1119379454, Wiley, 6th ed., 2018.

Sledzik, K. (2013): *Schumpeter's View on Innovation and Entrepreneurship*, in: *Management Trends in Theory and Practice*, University of Zilina & Institute of Management by University of Zilina, 2013.

Romer, P. (1990): *Endogenous Technological Change*, The Journal of Political Economy, Vol. 98, No. 5, University of Chicago Press, 1990.

Solow, R. (1956): *A Contribution to the Theory of Economic Growth*, The Quarterly Journal of Economics, Vol. 70, No. 1, pp. 65–94, 1956.

Lasalla, C.; Ribeiro-Navarrete (Eds.) (2022): *Financing Startups: Understanding Strategic Risks, Funding Sources, and the Impact of Emerging Technologies*, ISBN 978-3030907709, Springer, 2022.

9526 Applied Research Project

Code	Workload	Credits	Level	Frequency
9526	150 h	5 CP	2nd semester	winter semester
Duration	**Courses**	**Teaching time**	**Self-study**	**Planned group size**
1 semester	Practical Training: 60 TU / 4 SWS	depending on individual needs	105 h	25 students / working group

Learning outcomes / Competences and qualification profile

In this module, students work in small groups to address complex, interdisciplinary research questions. They apply knowledge and skills from core and elective modules in Computer Science, Supply Chain, and Environmental Sciences to real-world problems. The course emphasizes collaborative project work, scientific methodology, and professional communication, fostering both technical and transferable competencies. After completing the module, students are able to:

- define and analyze complex problems within technical, natural, or economic systems and develop requirement-oriented solutions;
- plan, organize, and manage project work in teams, applying appropriate project management methods, tools, and procedures;
- conduct scientific research, including literature review, data collection, analysis, and interpretation of results;
- document research findings and write clear, structured, and convincing project reports;
- present and communicate project results effectively to target-specific audiences, using appropriate visualizations and presentation techniques;
- collaborate efficiently in distributed project teams, demonstrating teamwork, role coordination, and constructive conflict resolution;
- apply creativity and critical reflection to generate innovative and feasible solutions to current research questions;
- integrate methods and concepts from multiple disciplines to design and implement practical solutions in diverse industrial or research contexts.

Content

Students must plan, realize, document and present their own projects by applying the knowledge they have gained in accompanying courses. The projects should be related to current research topics of the core modules and electives or can be realized by doing practical work in cooperation with partners from the private or public sector. A focus on information modeling or computer science is mandatory.

Students have to analyze the topic of the project, propose applied research questions that feature a certain complexity, plan how to answer them, conduct applied research in teamwork, and communicate the results. Outcome of a project can be IT-artefacts, services, improvements of existing processes, artefacts or services or research studies.

In the first phase, project teams must prepare a project proposal for a sponsor. In regular status meetings project progress is discussed and preliminary findings are presented. The results are presented in a final meeting when also scientific posters are displayed. The project is documented in a report with mandatory sections such as related work", "data/information model", methodo-

logy", or "discussion of design decisions".

Teaching methhods

Project-related (regular) teaching sessions for project development and monitoring are held by the lecturers. In addition, in-depth subject-specific courses are held with the involvement of, for example, practitioners or experts, as well as regular meetings with the respective clients, customers, or partners. At the beginning of the semester, the different project ideas are developed by students and teams are set up. The lecturers act as facilitators and moderators during this initial process. Afterwards the teachers take the role of a project sponsor (approval of project proposals / design decisions, the steering of deviations from plan / schedule or modifications of the project scope). The projects conclude with a final presentation to an interested audience (university staff, students, clients, and/or partners) and the submission of a scientific project report.

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Timo Kahl

Additional Information

Literature depending on project

9527 Advanced Applications of Artificial Intelligence

Code 9527	**Workload** 150 h	**Credits** 5 CP	**Level of module** 2nd semester	**Frequency of offer** winter semester
Duration 1 semester	**Courses** Seminaristic Lecture: 60 TU / 4 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students / working group

Learning outcomes / Competences and qualification profile

This module prepares students to conduct advanced scientific research on specialized topics in artificial intelligence, including machine vision, large language models, autonomous driving, speech recognition, text mining, and retrieval-augmented generation.

- identify and critically evaluate current research topics, methods, and results in advanced AI applications;
- assess scientific literature and other sources to synthesize recent developments and trends in AI;
- extract, understand, and summarize the main ideas of scientific articles and research papers;
- structure, draft, and write scientific papers on specialized AI topics, following academic conventions and ensuring clarity, coherence, and integrity;
- design, implement, and test innovative AI applications, integrating concepts from machine learning, data science, and software engineering;
- develop AI-driven business concepts and translate them into practical implementation plans;
- present, discuss, and defend research findings in oral and written form to peers and instructors, demonstrating effective communication and argumentation skills.

Content

The content depends on the topics that students choose from a list presented by the lecturer. These topics can be in the field of the elective track selected by the students.

Teaching methods

Problem-based learning, lecture, student presentations, discussion, practical exercises

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points Passed assessment
Use of module (in other study programs) - -
Weight towards final grade 5,55%
Person in charge of module Prof. Dr. Patrick-Benjamin Bök
Additional Information Literature differs according to the selected topics of the seminar.

9528 Machine Learning

Code 9528	**Workload** 150 h	**Credits** 5 CP	**Level of module** 2nd semester	**Frequency of offer** winter semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 15 TU / 1 SWS Practical Training: 15 TU / 1 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module introduces students to the fundamental concepts, methods, and practical applications of machine learning. Students gain hands-on experience in designing, implementing, and evaluating models for a variety of tasks, while also developing the ability to critically reflect on model assumptions, data quality, and ethical implications of AI systems.

- explain the theoretical foundations and key concepts of machine learning, including learning paradigms, common challenges such as overfitting, and generalization;
- implement core machine learning algorithms using Python libraries (e.g., `scikit-learn`, `PyTorch`, `TensorFlow`);
- design and evaluate supervised and unsupervised models for classification, regression, and clustering tasks;
- perform model selection and hyperparameter tuning using validation techniques and cross-validation strategies;
- analyze model performance using appropriate evaluation metrics and diagnostic techniques;
- develop structured, data-driven workflows for training, validation, and testing of machine learning models;
- critically assess the quality, quantity, and suitability of data for machine learning tasks;
- reflect critically on the assumptions and limitations of models, and understand issues related to bias, fairness, and responsible AI practices.

Content

- Introduction to machine learning: overview
- Bias-variance trade-off, underfitting vs. overfitting.
- Multivariate linear regression: Feature scaling, gradient descent, learning rate, and hyperparameters
- Large-scale machine learning: Stochastic Gradient Descent (SGD)
- Classification based on logistic regression: hypothesis, cost function, multiclass classification
- Nonlinear hypotheses in classification problems
- Support vector machine as a kernel-based method
- Ensemble methods (e.g. random forests, boosting)
- Simple neural networks: model representation, cost function, backpropagation, gradient check
- Model selection, training, validation, and testing
- Hyperparameter optimization

- Multivariate Gaussian: anomaly detection and recommender systems
- Reinforcement Learning (RL): Q-learning, SARSA (introductory)

Teaching methods

Problem-based learning, lecture, student presentations, discussion, practical exercises

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Patrick-Benjamin Bök

Additional Information

Recommended readings:

Buduma, N. (2022): *Fundamentals of Deep Learning: Designing Next-Generation Machine Intelligence Algorithms*, ISBN 978-1491925617, O'Reilly UK Ltd., 2022.

Burger, S. (2018): *Introduction to Machine Learning with R: Rigorous Mathematical Analysis*, ISBN 978-1789957983, O'Reilly UK Ltd., 2018.

Chollet, F. (2025): *Deep Learning with Python*, ISBN 978-1617296864, Manning, 2nd ed., 2025.

Ganegedara, T. (2018): *Natural Language Processing with TensorFlow: Teach language to machines using Python's deep learning library*, ISBN 978-1788478311, Packt Publishing, 2018.

Géron, A. (2022): *Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems*, ISBN 978-1098125974, O'Reilly UK Ltd., 2nd ed., 2022.

Ghatak, A. (2017): *Machine Learning with R*, ISBN 978-1484227336, Springer Nature Singapore Pte Ltd., 2017.

Track Software and Systems

9531 Advanced System Security

Code 9531	**Workload** 150 h	**Credits** 5 CP	**Level of module** 1st semester	**Frequency of offer** Summer semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module provides students with an advanced understanding of system security, covering threats, vulnerabilities, and defense mechanisms in ICT systems. Students explore theoretical and practical aspects of communication and information security, including cryptographic protocols, security tools, and implementation challenges.

- analyze and evaluate the security of complex ICT systems, identifying potential vulnerabilities and threats;
- apply modern security methods, tools, and cryptographic protocols effectively in different contexts;
- design robust security solutions for traditional and emerging platforms, balancing functionality, usability, and security requirements;
- critically assess the limitations, costs, and societal impact of security measures, including privacy considerations;
- develop and articulate innovative ideas to address current and future security challenges.

Content

This course covers the core principles and advanced topics in system security, blending theoretical knowledge with practical application. The curriculum includes:

- Security Operations and Monitoring: Design of modern network defenses using firewalls and VPNs, coupled with advanced monitoring through SIEM/SOC infrastructures, AI-driven event analysis, intrusion detection, and incident handling.
- Offensive Security: Methodologies for penetration testing and vulnerability analysis.
- Advanced Risk Assessment
- Advanced Cryptography: In-depth study of protocols and their mathematical foundations.
- Trustworthy Computing: Formal methods for proving security and system certification standards.
- Specialized Topics: Security for IoT and Industrial Control Systems, advanced risk management. Information Security Management Systems (e. g. ISO 27001)
- Privacy and Society:: Technologies for privacy protection and the societal relevance of secure infrastructures.
- Research Frontiers: Discussion of current research trends in system security.

Teaching methods

Lectures, group discussions, presentations and practical classes

Entry requirements

None

Recommendation: Prior attendance of a foundational IT security course at the Bachelor's level is highly advised. A strong working knowledge of computer networks, operating systems (including CLI scripting), and proficiency in programming languages are considered essential for success in this module.

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr.-Ing. Ulrich Greveler

Additional Information

The books listed below are recommended for general preparation. Additional reading materials, including current e-books and online resources, will be provided during the course, tailored to the specific project topics undertaken by the students.

Ackerman, P. (2021): *Industrial Cybersecurity: Efficiently Monitor the Cybersecurity Posture of Your ICS Environment*, ISBN 978-1839216025, Packt Publishing, 2021.

Anderson, R. (2020): *Security Engineering: A Guide to Building Dependable Distributed Systems*, ISBN 978-1119642787, John Wiley & Sons, 3rd ed., 2020.

Maymi, F.; Harris, S. (2021): *CISSP All-in-One Exam Guide*, ISBN 978-1260467373, McGraw-Hill Education, 9th ed., 2021.

Mahmood, Z. (2019): *Security, Privacy and Trust in the IoT Environment*, ISBN 978-3030183541, Springer, 2019.

Muniz, J.; McIntyre, G.; AlFardan, N. (2023): *Security Operations Center: Building, Operating, and Maintaining Your SOC*, ISBN 978-0137475797, Cisco Press, 2023.

Paar, C.; Pelzl, J.; Güneysu, T. (2024): *Understanding Cryptography: From Established Symmetric and Asymmetric Ciphers to Post-Quantum Algorithms*, ISBN 978-3031375365, Springer, 2nd ed., 2024.

Schneier, B. (2015): *Applied Cryptography: Protocols, Algorithms, and Source Code in C*, ISBN 978-1119096726, John Wiley & Sons, 20th Anniversary Edition / 2nd ed., 2015.

Stavroulakis, P.; Stamp, M. (Eds.) (n.d.): *Handbook of Information and Communication Security*, Springer, latest edition.

Weidman, G. (2024). *Penetration Testing: A Hands-On Introduction to Hacking* (3rd ed.). No Starch Press.

9532 Mobile & Internet Computing

Code	Workload	Credits	Level of module	Frequency of offer
9532	150 h	5 CP	2nd semester	Winter semester
Duration	**Courses**	**Teaching time**	**Self-study**	**Planned group size**
1 semester	Lecture: 30 TU / 2 SWS Lab Exercise: 15 TU / 1 SWS Project supervision: 15 TU / 1 SWS	60 TU / 4 SWS	105 h	25 students

Learning outcomes / Competences and qualification profile

This module provides students with advanced knowledge of architectures, frameworks, and software engineering principles for developing integrated mobile and internet-based applications. Students gain hands-on experience in designing, implementing, and testing multi-tiered information systems, including mobile apps, server-based backends, communication protocols, and persistence layers. The course emphasizes practical skills, systematic design, and critical reflection on architectural choices, component limitations, and software development best practices.

- explain the architectures and software engineering concepts necessary for developing integrated mobile and internet-based applications;
- design and implement multi-tiered information systems, including mobile apps, server-based backends, communication protocols, and data persistence layers;
- apply appropriate design patterns, frameworks, and development tools in various contexts, while critically evaluating their limitations and trade-offs;
- use modern development and testing methodologies;
- develop, adapt, and implement their own innovative ideas and solutions within mobile and web application contexts;
- reflect critically on software design decisions, considering technical, practical, and user-centered aspects of application development.

Content

The coverage included deployment processes, API aging aspects, and best practices for handling short release cycles in production environments.

- General concepts of and best practices for mobile applications
- User interface concepts for mobile applications (native and web interfaces)
- Programming languages and development environments for mobile applications
- Testing mobile applications
- Multi-tier architectures for mobile business information systems
- Design patterns for mobile business information systems
- Backend integration of mobile applications including cloud technologies and communication strategies
- Web applications as backend technology
- Societal Impact of Internet Computing

- Individual risk of mobile media addiction

Teaching methods

Problem-based learning, lecture, student presentations, discussion, practical exercises

Entry requirements

None

Recommendation:
It is strongly recommended to have attended a bachelor module covering the basics of software development and methodologies first. It is also recommended that students have fluent knowledge of a programming language and of the fundamentals of operating systems.

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Patrick-Benjamin Bök

Additional Information

Recommended readings:

- `https://developer.apple.com`
- `https://www.swift.org`
- `https://developer.android.com`
- `https://kotlinlang.org`
- `https://code.visualstudio.com`

Additional readings:

Humphrey, W. S. (2011): *Leadership, Teamwork, and Trust: Building a Competitive Software Capability*, ISBN 978-0321711539, Addison-Wesley, 2011.

IEEE Computer Society (2013): *Software Engineering Body of Knowledge (SWEBOK V3)*, ISBN 978-0769551661, IEEE Computer Society, 2013.

INCOSE (2013): *Guide to the Systems Engineering Body of Knowledge (SEBoK, V. 1.2)*, INCOSE, 2013.

ISO/IEC 12207:2008: *Systems and Software Engineering – Software Life Cycle Processes*, International Organization for Standardization (ISO), 2008.

ISO/IEC/IEEE 42010:2011: *Systems and Software Engineering – Architecture Description*, ISO/IEC/IEEE, 2011.

Marco, T. (2009): *Software Engineering: An Idea Whose Time Has Come and Gone?*, IEEE Software, 26(6), 96–96, 2009.

Office of Government Commerce (2009): *Managing Successful Projects with PRINCE2™*, ISBN 978-0113310593, The Stationery Office, 2009 ed., 2009.

Project Management Institute (2012): *A Guide to the Project Management Body of Knowledge (PMBOK Guide)*, ISBN 978-1935589679, Project Management Institute, 5th ed., 2012.

9534 Privacy in Distributed Systems

Code 9534	**Workload** 150 h	**Credits** 5 CP	**Level of module** 1st semester	**Frequency of offer** Summer semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 semester hours per week (SWS) Practical Training: 15 TU / 1 SWS Seminar: 15 TU / 1 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module introduces students to distributed systems, their architectures, protocols, and frameworks, with a focus on privacy and data protection. Students gain theoretical and practical knowledge to design and implement complex distributed systems, apply privacy-enhancing techniques, and critically evaluate the impact of design decisions on privacy, feasibility, and performance. The course spans multiple application domains, including ambient intelligence environments, Internet-of-Things, logistics control, geo-/environmental monitoring, mobile computing, and distributed databases.

- explain core concepts of distributed systems, including operating systems, networked systems, architectures, protocols, and frameworks;
- analyze application problems in distributed environments, deduce requirements, and evaluate architectural approaches;
- design and implement privacy-preserving solutions using appropriate techniques, patterns, and tools (e.g., k-anonymity, differential privacy, OpenWPM);
- apply knowledge of privacy regulations and laws, such as GDPR and CCPA, to the design and evaluation of distributed systems;
- develop information models and analyze the effects of design decisions on privacy, feasibility, and system performance;
- select and apply suitable design patterns and components while understanding their limitations in different contexts;
- implement and adapt distributed system solutions for various application domains, including IoT, smart environments, logistics, mobile computing, and distributed databases;
- work independently and collaboratively to generate, apply, and communicate original ideas and solutions to research and practical problems.

Content

- Architectures and types of Distributed Systems: Grid, Cloud, Virtualization, Containers, K8s etc.
- Technologies (theory, methodology, design patterns, capabilities, performance):
- Privacy Enhancing Technologies and Methods (k-anonymity, differential privacy . . .)
- Model-based systems engineering of distributed applications using Architecture Frameworks
- Measurement architectures such as OpenWPM

- Process Management in Distributed Systems
- Communication in Distributed Systems
- Semantic sensor networks (knowledge representation, ontologies, inference, RDF, OWL, SPARQL)
- Application domains (specific protocols, frameworks, and tools)
  - The Internet of services and things
  - Smart Cities/ Smart Home / Connected Living
  - Smart Logistics /Autonomous Driving

Teaching methods

Tuition in seminars, lectures and (partially self-organized) practical trainings. Students work individually and in teams.

Entry requirements

Recommendation: Practice in programming (e.g. Go, Kotlin, Java, Python, C++, C#), knowledge of UML, knowledge of SQL and NoSQL databases, as well as basic knowledge of software engineering (processes, disciplines) are assumed and needed.

Types of assessment

Graded split exam according to examination rules: Certificate (project work) and graded examination, usually a written exam, details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Matteo Große-Kampmann

Additional Information

Recommended readings:

Van Steen, M.; Tanenbaum, A. S. (2025): *Distributed Systems*, ISBN 978-1712391625, 4th ed., 2025.

Demir, N.; Große-Kampmann, M.; Urban, T.; Wressnegger, C.; Holz, T.; Pohlmann, N. (2022): *Reproducibility and Replicability of Web Measurement Studies*, In Proceedings of the ACM Web Conference 2022, pp. 533–544, April 2022.

Demir, N.; Hörnemann, J.; Große-Kampmann, M.; Urban, T.; Pohlmann, N.; Holz, T.; Wressnegger, C. (2023): *On the Similarity of Web Measurements Under Different Experimental Setups*, In Proceedings of the 2023 ACM on Internet Measurement Conference, pp. 356–369, October 2023.

Klarreich, E. (2012): *Privacy by the Numbers: A New Approach to Safeguarding Data*, retrieved May 8, 2017, `https://www.simonsfoundation.org/2012/09/17/privacy-by-the-numbers`.

Piotrowska, A. M.; Hayes, J.; Elahi, T.; Meiser, S.; Danezis, G. (2017): *The Loopix Anonymity System*, In 26th USENIX Security Symposium (USENIX Security 17), pp. 1199–1216, 2017.

Nuñez von Voigt, S.; Mehner, L.; Tschorsch, F. (2024): *From Theory to Comprehension: A Comparative Study of Differential Privacy and k-Anonymity*, In Proceedings of the Fourteenth ACM Conference on Data and Application Security and Privacy, pp. 221–232, June 2024.

9535 Innovative Approaches in Applied Computer Science I

Code 9535	**Workload** 150 h	**Credits** 5 CP	**Level of module** 2nd semester	**Frequency of offer** Winter semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module provides students with comprehensive knowledge of current trends, emerging technologies, and innovative methodologies in applied computer science, covering areas such as media informatics, administrative informatics, software development, IT security, artificial intelligence, computer networks, and cloud computing. Students gain the ability to critically analyze, evaluate, and compare novel technological concepts, and to design and implement practical solutions tailored to specific professional contexts. The course also fosters lifelong learning, adaptability, and responsible professional practice in a rapidly evolving technological landscape.

- explain and evaluate current trends, emerging technologies, and innovative methodologies across applied computer science domains;
- critically analyze, compare, and assess novel technological concepts and approaches for their applicability and potential impact;
- design, implement, and optimize innovative solutions using modern frameworks, methodologies, and best practices in applied computer science;
- independently assess the feasibility, benefits, and limitations of emerging technologies in professional and real-world contexts;
- demonstrate adaptability, lifelong learning, and self-directed acquisition of knowledge to keep pace with technological advancements.

Content

Examples of possible topics in this module:

- Recent approaches to mobile and web application development
- Modern frameworks and methods for developing interactive and responsive systems
- Software development methodologies for Industry 4.0 and cyber-physical systems (CPS).
- Development and integration of virtual reality (VR) and augmented reality (AR) applications
- Current trends in cloud computing platforms and cloud-native application development
- Artificial Intelligence (AI) and machine learning approaches in software development
- Data-driven and intelligent applications
- Recent innovations in IT security and digital forensics
- Modern software architecture principles, including microservices and containerisation
- Emerging technologies in computer networks and distributed systems

Teaching methods

Problem-based learning, lecture, student presentations, discussion, practical exercises

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Patrick-Benjamin Bök

Additional Information

Recommended readings: depending on the specific topic

9536 Innovative Approaches in Applied Computer Science II

Code 9536	**Workload** 150 h	**Credits** 5 CP	**Level of module** 2nd semester	**Frequency of offer** Winter semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module provides students with comprehensive knowledge of current trends, emerging technologies, and innovative methodologies in applied computer science, covering areas such as media informatics, administrative informatics, software development, IT security, artificial intelligence, computer networks, and cloud computing. Students gain the ability to critically analyze, evaluate, and compare novel technological concepts, and to design and implement practical solutions tailored to specific professional contexts. The course also fosters lifelong learning, adaptability, and responsible professional practice in a rapidly evolving technological landscape.

- explain and evaluate current trends, emerging technologies, and innovative methodologies across applied computer science domains;
- critically analyze, compare, and assess novel technological concepts and approaches for their applicability and potential impact;
- design, implement, and optimize innovative solutions using modern frameworks, methodologies, and best practices in applied computer science;
- independently assess the feasibility, benefits, and limitations of emerging technologies in professional and real-world contexts;
- demonstrate adaptability, lifelong learning, and self-directed acquisition of knowledge to keep pace with technological advancements.

Content

Examples of possible topics in this module:

- Recent approaches to mobile and web application development
- Modern frameworks and methods for developing interactive and responsive systems
- Software development methodologies for Industry 4.0 and cyber-physical systems (CPS).
- Development and integration of virtual reality (VR) and augmented reality (AR) applications
- Current trends in cloud computing platforms and cloud-native application development
- Artificial Intelligence (AI) and machine learning approaches in software development
- Data-driven and intelligent applications
- Recent innovations in IT security and digital forensics
- Modern software architecture principles, including microservices and containerisation
- Emerging technologies in computer networks and distributed systems

Teaching methods

Problem-based learning, lecture, student presentations, discussion, practical exercises

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Patrick-Benjamin Bök

Additional Information

Recommended readings: depending on the specific topic

9537 Innovative Approaches in Applied Computer Science III

Code 9537	**Workload** 150 h	**Credits** 5 CP	**Level of module** 2nd semester	**Frequency of offer** Winter semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module provides students with comprehensive knowledge of current trends, emerging technologies, and innovative methodologies in applied computer science, covering areas such as media informatics, administrative informatics, software development, IT security, artificial intelligence, computer networks, and cloud computing. Students gain the ability to critically analyze, evaluate, and compare novel technological concepts, and to design and implement practical solutions tailored to specific professional contexts. The course also fosters lifelong learning, adaptability, and responsible professional practice in a rapidly evolving technological landscape.

- explain and evaluate current trends, emerging technologies, and innovative methodologies across applied computer science domains;
- critically analyze, compare, and assess novel technological concepts and approaches for their applicability and potential impact;
- design, implement, and optimize innovative solutions using modern frameworks, methodologies, and best practices in applied computer science;
- independently assess the feasibility, benefits, and limitations of emerging technologies in professional and real-world contexts;
- demonstrate adaptability, lifelong learning, and self-directed acquisition of knowledge to keep pace with technological advancements.

Content

Examples of possible topics in this module:

- Recent approaches to mobile and web application development
- Modern frameworks and methods for developing interactive and responsive systems
- Software development methodologies for Industry 4.0 and cyber-physical systems (CPS).
- Development and integration of virtual reality (VR) and augmented reality (AR) applications
- Current trends in cloud computing platforms and cloud-native application development
- Artificial Intelligence (AI) and machine learning approaches in software development
- Data-driven and intelligent applications
- Recent innovations in IT security and digital forensics
- Modern software architecture principles, including microservices and containerisation
- Emerging technologies in computer networks and distributed systems

Teaching methods

Problem-based learning, lecture, student presentations, discussion, practical exercises

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Patrick-Benjamin Bök

Additional Information

Recommended readings: depending on the specific topic

Track Environmental Sciences

9541 Environmental Analysis, Impact and Risk

Code 9541	**Workload** 150 h	**Credits** 5 CP	**Level of module** 1st semester	**Frequency of offer** summer semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students / working group

Learning outcomes / Competences and qualification profile

This module provides students with an in-depth understanding of environmental analysis, impact, and risk assessment related to anthropogenic activities such as industrial production, mining, traffic, and agriculture. Students gain insight into analytical methods for investigating environmental systems and learn to evaluate environmental impacts on ecosystems and abiotic components. In addition to technical and scientific competencies, the module emphasizes critical reflection, the societal relevance of environmental analysis, and the responsible communication of scientific results in decision-making contexts.

- explain the environmental impacts of anthropogenic activities on ecosystems and abiotic system components;
- describe and evaluate analytical techniques and methods used for environmental analysis, such as chemical fingerprinting, ion-sensitive electrodes, bioassays, and biomonitoring approaches;
- interpret environmental data derived from different analytical methods and assess their relevance for impact and risk assessment;
- explain key technical and scientific concepts applied in environmental impact and environmental risk assessment;
- identify and describe the roles of relevant actors and stakeholders involved in environmental assessment and decision-making processes;
- assess the significance of environmental impact and risk analysis for planning and policy-related decision-making;
- evaluate and critically discuss environmental impacts on ecosystems, considering interactions between organisms (e.g. vegetation, soil fauna, microorganisms) and abiotic factors;
- apply selected environmental risk assessment procedures to real-world environmental problems;
- critically reflect on the societal relevance of environmental analysis and communicate analytical results in a clear, responsible, and audience-appropriate manner.

Content

With the help of case studies the following topics will be covered

- Environmental Impact of selected anthropogenic activities
- Environmental Impact Assessment and Strategic Environmental Assessment, rationale, legal frameworks
- Technological hazards, protection, mitigation, adaptation

- Managing real and perceived risks, involvement of actors
- Field and or laboratory practicals on environmental analytics and environmental assessment like:
- Methods of environmental sampling, ecosystem assessment, assessment of spatial patterns (e.g. regarding soil and vegetation)
- Species sensitivity, indicator and sensitive species, bioassays in assessing ecosystem status
- Methods of impact assessment

Teaching methods

Lectures and practical training

Entry requirements

None

Types of assessment

Graded split exam according to examination rules: Certificate (practical protocols) and graded examination, details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed Certificate for the Practical

Use of module (in other study programs)

–

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Daniela Lud

Additional Information

Recommended readings:

Barbooti, M. M. (2015): *Environmental Applications of Instrumental Chemical Analysis*, ISBN 978-1771883059, Apple Academic Press, 1st ed., 2015.

Duinker, P. N. (2018): *The Application of Science in Environmental Impact Assessment*, ISBN 978-1138391703, Routledge, 1st ed., 2018.

Govorushko, S. (2016): *Human Impact on the Environment: An Illustrated World Atlas*, ISBN 978-3319259918, Springer International Publishing, 1st ed., 2016.

Hundloe, T. (2021): *Environmental Impact Assessment: Incorporating Sustainability Principles*, ISBN 978-9811639993, Springer International Publishing, Palgrave Macmillan, 1st ed., 2021.

Reed, B. (2020): *Communicating Social and Environmental Issues Effectively*, ISBN 978-1838674796, Emerald Publishing Limited, 1st ed., 2020.

Therivel, R.; Wood, G. (2018): *Methods of Environmental and Social Impact Assessment*, ISBN 978-1138647640, Routledge, 4th ed., 2018.

9543 Data Processing in Ecosystems Management

Code	Workload	Credits	Level of module	Frequency of offer
9543	150 h	5 CP	2nd semester	summer semester
Duration	**Courses**	**Teaching time**	**Self-study**	**Planned group size**
1 semester	Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	60 TU / 4 SWS	105 h	25 students

Learning outcomes / Competences and qualification profile

Upon completion of this course, students will know why monitoring data on ecosystems and technical ecosystem management are collected, who is responsible for monitoring programs, how data are processed, aggregated and stored in databases, to which organizations data are reported and why they have to be available to the public. As a result of their work on case studies

- students will have gained a broad understanding of the basics of Biogeochemistry relevant for drinking water production, waste water treatment and air quality management;
- they will further have gained insight into the evaluation of the status of groundwater and surface water bodies according to the European Union Water Framework Directive and several aspects of disaster risk management;
- students will have gained the competence to analyze, present and discuss knowledge transfer and data visualization strategies.

Content

Data Management in Environmental Sciences (seminaristic lecture):

- Data procurement and data processing as a basis for the development of policy on ecosystem management, the control of policy implementation, policy impact assessment, forecasting and scenario development
- Data procurement and data processing as the basis for meteorology, global change research and the determination of chemical, physical and biotic environmental factors
- Data procurement and data processing as the basis for controlling technical processes and installations with relevance to the management of ecosystems (e.g. controlling waste water treatment and industrial pollutant emissions and supporting disaster management)
- Concepts of data collection, data logging, data analysis, exploration of information, field data acquisition in limnic ecosystems, data procurement in environmental engineering and controlling of technical processes, visits to professionals in procurement and processing of data and monitoring air quality, noise, water quality etc.
- Evaluation of data provided by organizations at the regional level (e.g.LANUV), at national scale, European data and data published at the international level by, for example, UN and WHO
- Interpretation, visualization and communication of research outcomes, critical discussion of concepts, giving presentations and writing reports.

Teaching methods

Lecture, seminar, practical training and excursions

Entry requirements

None

Types of assessment

Graded split exam according to examination rules: Certificate (Testat) and graded examination, usually a term paper, details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Testate for participation in the seminaristic lectures and passed graded examination of the module

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Ute Hansen

Additional Information

Recommended readings:

Pyrcz, M. J.; Deutsch, C. V. (2014): *Geostatistical Reservoir Modeling*, ISBN 978-0199731442, Oxford University Press, New York, NY, USA; Oxford, UK, 2nd ed., 2014.

Artiola, J. F.; Pepper, I. L.; Brusseau, M. (2004): *Environmental Monitoring and Characterization*, ISBN 978-0120644772, Elsevier Academic Press, 2004.

Gray, N. F. (2010): *Water Technology: An Introduction for Environmental Scientists and Engineers*, ISBN 978-1856175149, Elsevier, 3rd ed., 2010.

Schlesinger, W. H.; Bernhardt, E. S. (2013): *Biogeochemistry*, ISBN 978-0123858749, Elsevier Academic Press, 3rd ed., 2013.

Wildi, O. (2010): *Data Analysis in Vegetation Ecology*, ISBN 978-0470664493, Wiley, 2nd ed., 2010.

9544 Applied Geoinformatics

Code	Workload	Credits	Level of module	Frequency of offer
9544	150 h	5 CP	2nd semester	winter semester
Duration	**Courses**	**Teaching time**	**Self-study**	**Planned group size**
1 semester	Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	60 TU / 4 SWS	105 h	25 students

Learning outcomes / Competences and qualification profile

This module equips students with advanced skills in applied geoinformatics to analyze and interpret spatial and temporal environmental data, addressing challenges posed by climate change. Students work with open-source tools, including Python, QGIS, and PostgreSQL/PostGIS, and apply geospatial workflows to real-world environmental problems, integrating remote sensing, data analysis, and visualization.

- explain core geoinformatics concepts and the space-time dynamics of environmental data, with a focus on climate change;
- acquire, manage, and analyze open geospatial datasets from German and international sources, applying data engineering techniques for cleaning and transformation;
- design and execute integrated geospatial workflows, including data acquisition, processing, analysis, and visualization, using open-source tools;
- create remote sensing products from satellite and drone imagery, including land use classifications and environmental monitoring using machine learning techniques;
- critically assess the assumptions, limitations, and implications of spatial analysis methods in environmental and climate data contexts;
- apply problem-solving and analytical skills to address complex environmental and geospatial challenges in collaborative and interactive project settings;
- communicate geospatial findings effectively to technical and non-technical audiences.

Graduates of this module are well-prepared for careers in environmental consulting and management, climate and environmental policy, urban and regional planning, geospatial data science, surveying, meteorological and hydrological services, agriculture, land management, and geospatial software development.

Content

- Fundamentals of geoinformatics and environmental data
- Free and Open Source Software (FOSS) in geoinformatics
- Open Geospatial Consortium (OGC) standards and interoperability
- Characteristics of spatio-temporal environmental datasets
- Online open data retrieval, data engineering, and geospatial analysis with Python
- QGIS Geographical Information System (GIS): principles and hands-on practice
- Coordinate Reference Systems (CRS) and spatial transformations
- Global Navigation Satellite Systems (GNSS)
- Airborne Laser Scanning (ALS) and Digital Terrain Models (DTM)
- OGC Web Services (WMS, WFS, WCS)
- Cartography and map creation principles

- Georeferencing and georectification
- Remote sensing (RS) with satellites and drones
- Drone image processing with Web OpenDroneMap (WebODM)
- Machine learning for image analysis (e.g. land use classification)
- Object-Relational Database Management with PostgreSQL/PostGIS
- Spatial data storage, management, and querying with PostGIS
- Animating time-dependent spatial data by linking PostGIS and QGIS
- Case studies: climate change effects on temperature, drought risk, groundwater quality, etc.

Teaching methods

Instruction includes seminars, lectures, and (partially self-organized) practical sessions, plus potential excursions. Students work both independently and in teams, using their own devices (BYOD). The HSRW Earth Observation Lab's on-premises cloud provides computing resources.

Entry requirements

No formal prerequisites; however, prior programming experience (Python) is beneficial and will support engagement with the course. Support is available for those building their programming skills during the course.

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module

The integration of the elective module "9542 Hands-On IoT Systems for Environmental Monitoringäs a data source for this course provides practical experience in gathering real-time environmental measurements with custom-built IoT devices, which are subsequently analyzed using geoinformatics methods. The module's alignment with all other data science related courses of the master's program further ensures a coherent learning progression.

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr.-Ing. Rolf Becker

Course Information

The course page on the website of the HSRW Earth Observation Lab:
https://courses.eolab.de/geoinfo

Online Courses and Tutorials

QGIS Training Manual: Comprehensive, official guide for mastering QGIS from basics to advanced workflows. https://docs.qgis.org/latest/en/docs/training_manual/index.html

QGIS Tutorials by Hans van der Kwast: Practical video tutorials focusing on environmental applications using QGIS. https://www.youtube.com/c/HansvanderKwast

QGIS Tutorials by Klas Karlsson: Concise video guides covering GIS techniques, QGIS plugins, and troubleshooting. https://www.youtube.com/@KlasKarlsson

Geo-Python course by University of Helsinki: Step-by-step introduction to Python for geospatial data analysis, ideal for beginners and those building programming confidence. https://geo-python.github.io/site/

GIS OpenCourseWare: Free university-level lectures and materials on core GIS topics for supplementary study. https://courses.gisopencourseware.org/

OSGeo (n.d.): FOSS4G Academy curriculum [Open educational resource]. Modular, open curriculum offering hands-on labs and tutorials on GIS fundamentals, spatial analysis, data management, cartography, and remote sensing using only free and open source geospatial software (mainly QGIS); suitable for university courses and self-paced study. https://github.com/FOSS4GAcademy

Books

de Smith, M. J., Goodchild M. F., & Longley, P.A. (2024). *Geospatial Analysis: A Comprehensive Guide to Principles, Techniques and Software Tools* (7th ed.). Comprehensive open-access reference covering spatial analysis concepts and practical GIS methods. https://www.spatialanalysisonline.com/extractv7.pdf

Acevedo, M. F. (2013). *Data Analysis and Statistics for Geography, Environmental Science and Engineering*. CRC Press. Textbook covering essential statistics and data analysis for environmental and geospatial applications. Full text available through the HSRW library.

Sagar, B. S. D., Cheng, Q., McKinley, J., & Agterberg, F. (Eds.). (2023). *Encyclopedia of Mathematical Geosciences*. Springer. Reference work providing comprehensive entries on mathematical methods and modeling in geosciences. Full text available through the HSRW library.

Natural Resources Canada. (2008). *Fundamentals of remote sensing* (3rd ed.). Canada Centre for Remote Sensing. Introductory and in-depth open-access textbook on remote sensing principles and applications. https://natural-resources.canada.ca/sites/nrcan/files/earthsciences/pdf/resource/tutor/fundam/pdf/fundamentals_e.pdf

Hengl, T., & Contributors. (2022). *Open geospatial data science* (Version 1.0). OpenGeoHub Foundation. Open textbook focused on open-source tools, workflows and packages in R for geospatial data processing, analysis, and visualization. https://opengeohub.github.io/opendatascience-book/

9545 Hands-On IoT Systems for Environmental Monitoring

Code 9545	**Workload** 150 h	**Credits** 5 CP	**Level of module** 1st semester	**Frequency of offer** summer semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module provides a hands-on introduction to the design and implementation of Internet of Things (IoT) systems for environmental monitoring. Students learn how distributed sensor-based systems can be used to collect, transmit, store, and visualize environmental data in real time, addressing challenges arising from climate change, urbanization, and sustainable resource management. By developing complete monitoring solutions in project-based settings, students acquire practical skills in embedded systems, wireless communication, and data handling, while also reflecting on the societal relevance and responsible use of environmental data.

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

- explain the core components and architecture of distributed wireless sensor networks, from sensing and data acquisition to online storage and visualization;
- apply Internet of Things (IoT) technologies for environmental data collection, transmission, and presentation;
- analyze interoperability requirements and integrate heterogeneous devices and data sources in distributed systems;
- use standardized communication protocols and services to unify and manage heterogeneous sensor data;
- store and manage sensor data in spatial databases and time-series databases;
- design and implement online dashboards for the visualization and interpretation of environmental data;
- assess the technical challenges of battery-powered and low-energy embedded sensor systems;
- develop and deploy their own embedded sensor-based monitoring systems in realistic application scenarios;
- beyond technical skills, demonstrate critical thinking, problem-solving abilities, and collaborative competencies essential for innovation in environmental monitoring.

Content

- Real-world environmental monitoring applications and problem identification
- Distributed architecture of environmental monitoring systems
- Building blocks of weather station networks and environmental sensor networks
- Embedded systems, smart sensors, and low-power design principles
- Wireless data transmission technologies such as WiFi, LoRa, and BLE
- Principles of the Internet of Things (IoT)
- IoT communication protocols, platforms, and dashboards
- The MQTT protocol with its publisher-subscriber design pattern
- Node-RED to wire together hardware devices, APIs, and online services

- Integration of geospatial databases and dedicated time series databases
- Online data presentation and real-time plotting with Grafana and similar platforms
- Computer vision techniques for environmental monitoring and precision agriculture
- Selected advanced topics including security and data privacy, standards and regulations, and data quality and calibration

Teaching methods

Interactive, seminar-style discussions introducing relevant theory, current research, system architectures, and state-of-the-art technologies for IoT-based environmental monitoring.

Students build their own measuring systems which can be based on any sensors including cameras.

Students work individually and in teams in guided laboratory sessions and workshops focusing on real-world hardware and software integration (microcontrollers, sensors, wireless communication, data platforms).

Students are provided with equipment that they may take home for the duration of the course and must return at the end. Preferably students use their own laptops.

In addition to scheduled class meetings, students can come to the HSRW IoT Lab as well as the two HSRW Fab Labs, where they can independently work on their projects.

Presentation and reflection: Teams present their results in technical demonstrations and reports, reflecting on design choices, technical obstacles, and the overall system solution.

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module

The elective module 9542 Hands-On IoT Systems for Environmental Monitoring provides practical experience in building and deploying IoT-based sensor networks for real-time environmental data collection. This hands-on knowledge complements 9544 Applied Geoinformatics by supplying authentic data sources for spatial analysis, modeling, and visualization. Integrating 9542 ensures a seamless learning progression, linking hardware-level sensing with advanced geospatial data management and analytics. The skills gained in embedded systems, wireless communication,

and IoT platforms also prepare students for diverse applications beyond geoinformatics, such as smart cities, agriculture, home automation, and logistics.

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr.-Ing. Rolf Becker

Additional Information

Course Information
The course page on the website of the HSRW Earth Observation Lab:
`https://courses.eolab.de/envmon`

Online Courses and Tutorials

Brian W. Evans. *Arduino Programming Notebook* (1st ed., 2007). A concise, compact, and beginner-friendly programming guide with practical code examples. The appendix illustrates hardware-software interaction. `https://archive.org/details/arduino_notebook` (accessed July 27, 2025)

Arduino. *Official Arduino Tutorials*. Step-by-step beginner guides, examples, and project ideas for learning Arduino hardware and software. `https://www.arduino.cc/en/Tutorial/HomePage` (accessed July 27, 2025)

Arduino. *Getting Started with Arduino*. Covers hardware, software setup, and programming basics for novices. `https://www.arduino.cc/en/Guide/` (accessed July 27, 2025)

Tutorialspoint. *Arduino Tutorial - Learn Arduino Programming*. An online tutorial offering Arduino basics, hardware overview, and sensor interfacing. `https://www.tutorialspoint.com/arduino/index.htm` (accessed July 27, 2025)

Espressif Systems. *Get Started - ESP32 — ESP-IDF Programming Guide*. Covers setting up the environment and running projects with ESP32. `https://docs.espressif.com/projects/esp-idf/en/stable/esp32/get-started/index.html` (accessed July 27, 2025)

Random Nerd Tutorials. *Getting Started with the ESP32 Dev Board*. Beginner-friendly guide to ESP32 programming and Wi-Fi projects. `https://randomnerdtutorials.com/getting-started-with-esp32/` (accessed July 27, 2025)

The Things Network Foundation. *LoRaWAN Basics*. Vendor-neutral intro to LoRaWAN architecture, components, and applications. `https://www.thethingsnetwork.org/docs/lorawan/` (accessed July 27, 2025)

Semtech Corporation. *Introduction to LoRa and LoRaWAN*. Primer on LoRa physical layer, networking, and key features. `https://lora-developers.semtech.com/library/tech-papers-and-guides/introduction-to-lora-and-lorawan/` (accessed July 27, 2025)

LoRa Alliance. *The Complete LoRaWAN Guide for Beginners*. Covers LoRaWAN design, node deployment, and sample IoT projects. `https://learn.lora-alliance.org/en/` (accessed July 27, 2025)

9546 Environmental Analysis of Energy Production

Code 9546	**Workload** 150 h	**Credits** 5 CP	**Level of module** 1st semester	**Frequency of offer** summer semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module introduces students to environmental analysis, impact assessment, and risk evaluation in the context of energy production. Students acquire theoretical and practical competencies to assess the availability, efficiency, and environmental and health impacts of different energy sources. The module emphasizes evidence-based analysis, critical reflection, and the societal relevance of sustainable energy systems in supporting informed decision-making and energy planning.

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

- explain the importance of access to affordable and clean energy and discuss its societal and environmental implications;
- describe different methods of energy production and evaluate their availability, efficiency, and potential health and environmental impacts;
- apply analytical approaches to assess environmental impacts and waste gas flows, and critically balance these impacts against the benefits of clean energy production;
- analyze and compare process performance indicators for different types of energy production;
- conduct environmental impact assessments, energy efficiency analyses, and risk assessments to support informed planning and decision-making;
- apply selected methods of environmental risk assessment to real-world energy production scenarios;
- critically reflect on the social, environmental relevance of environmental analyses of energy generation facilities and communicate findings in a structured and professional manner.

Content

With the help of case studies the following topics will be covered:

- Basic understanding of thermodynamics and other physical principles of energy transformation
- Technology of energy conversion for renewable and non-renewable energy carriers.
- Environmental impacts of different energy conversion technologies.
- Analysis of abstract concepts (e.g. sustainability, carbon or ecological footprint)
- Methods of Environmental Impact Assessment and Strategic Environmental Assessment, rationale, legal frameworks
- Technological hazards, protection, mitigation, adaptation
- Managing real and perceived risks

Teaching methods

Lectures, trainings, excursions, and exercises

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Irmgard Buder

Additional information

Recommended readings:

Quaschning, V. (2016): *Understanding Renewable Energy Systems*, ISBN 978-1138781627, Earthscan, London; Washington DC, 2nd ed., 2016.

Hundloe, T. (2021): *Environmental Impact Assessment: Incorporating Sustainability Principles*, ISBN 978-3030809423, Palgrave Studies in Environmental Policy and Regulation, Springer Nature Switzerland AG, 2021. Verfügbar unter: https://doi.org/10.1007/978-3-030-80942-3

Gellings, C. W. (2020): *Saving Energy and Reducing* CO_2 *Emissions with Electricity*, ISBN 978-8770223809, River Publishers, Gistrup, 1st ed., 2020. Verfügbar unter: https://doi.org/10.1201/9781003151647

Holloway, M. D.; Rudd, O. (2013): *Fracking: The Operations and Environmental Consequences of Hydraulic Fracturing*, ISBN 978-1118304334, Wiley; Scrivener Publishing, Hoboken, NJ; Salem, MA, 1st ed., 2013.

RSC Publishing (2011): *Nuclear Power and the Environment*, ISBN 978-1849731942, RSC Publishing, Cambridge, 1st ed., 2011.

Tipler, P. A.; Mosca, G. (2007): *Physics for Scientists and Engineers*, ISBN 978-1429201247, W.H. Freeman, enlarged 6th ed., 2007.

9547 Applied Sustainability Research Project

Code 9547	**Workload** 150 h	**Credits** 5 CP	**Level of module** 1nd semester	**Frequency of offer** summer semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module provides students with the opportunity to conduct an applied research project addressing a real-world sustainability challenge.

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

- design, plan, and implement an independent applied research project addressing a real-world sustainability issue and integrating environmental, social, and economic dimensions;
- select, justify, and apply appropriate qualitative and/or quantitative research methods, including data collection, analysis, and interpretation;
- critically evaluate, synthesize, and contextualize scholarly literature relevant to applied sustainability research;
- communicate research objectives, methods, and findings effectively through written reports and oral presentations to both expert and non-expert audiences;
- demonstrate ethical awareness, professional responsibility, and compliance with standards such as data protection and research integrity throughout the research process.

Content

- Project Development: Identification and formulation of a research question or problem in applied sustainability; project planning and timeline creation.
- Methodological Approaches: Overview and application of qualitative and quantitative research methods relevant to sustainability, including data collection techniques, digital manufacturing and indicator assessment.
- Data Analysis: Use of analytical tools and sustainability metrics (e.g., ESG, life cycle assessment) to interpret research data.
- Collaboration and Communication: Group work, peer feedback, and professional presentation of research outcomes.
- Ethics and Impact: Discussion of ethical issues, stakeholder engagement, and the societal relevance of sustainability research.
- Reporting: Preparation of a comprehensive research report and formal presentation of results.

Teaching methods

Problem-based learning, seminaristic lecture, student presentations, discussion, practical training and exercises.

Entry requirements

None

Types of assessment

Graded Examination Usually an examination with several components (project work incl. documentation 60%, assignments 20% incl. mid-term presentation 20%), details to be announced at the beginning of the semester by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Kai J. Tiedemann

Additional Information

Recommended readings:

Everard, M. (2022): *Ecosystem Services, Key Issues*, ISBN 978-0367770025, Routledge, New York, 2nd ed., 2022.

König, A.; Ravetz, J. (Eds.) (2018): *Sustainability Science, Key Issues*, ISBN 978-1138782952, Routledge, London; New York, 2018.

Kopnina, H.; Padfield, R.; Mylan, J. (2023): *Sustainable Business, Key Issues*, ISBN 978-0367634242, Routledge, London, 3rd ed., 2023.

Further literature tba corresponding to the semester-specific topic.

Track Supply Chain

9551 Logistics Networks Modelling

Code 9551	**Workload** 150 h	**Credits** 5 CP	**Level of module** 1st semester	**Frequency of offer** winter semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module introduces students to the modelling, analysis, and optimization of internal and external logistics networks, including transport, supply, distribution, and procurement networks. Students learn to apply mathematical and computational methods, particularly graph theory, to describe and evaluate logistics systems. The module emphasizes data-driven decision-making, performance measurement, and the design of robust and efficient logistics processes, while fostering critical reflection, problem-solving, and professional responsibility in applied logistics contexts.

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

- model internal and external logistics networks using mathematical approaches, including graph theory, and represent logistics problems such as transport, hub location, shortest path, and travelling salesman problems;
- apply basic heuristics and optimization methods to solve standard logistics problems and analyze network performance;
- identify, collect, and process the necessary data for logistics modelling, using appropriate data sources and survey methods;
- apply travel demand modelling methods to describe transport supply and demand for a given region, including both freight and passenger networks;
- define and evaluate Key Performance Indicators (KPIs) to measure cost, service quality, and performance of logistics networks;
- optimize and stabilize logistic processes to design efficient, robust, and resilient networks;
- acquire foundational knowledge of discrete choice modelling and decision modelling for logistics applications;
- apply analytical, modelling, and optimization methods to real-world logistics and transport network problems in a professional context.

Content

- Mathematical basics (Graph Theory)
- Strategies and algorithms for solving complex external network problems like flexible resource allocations, rich vehicle routing or p-hub problems
- Discrete choice modelling
- Data collection and survey methodologies for transport models.
- Travel demand modelling (Passenger and Freight)
- Modelling internal transport networks

- Travel demand forecasts
- Analysis of the results of transport models

Teaching methods

Lectures and exercise classes

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr.-Ing. Dirk Bruckmann

Additional Information

Recommended readings:

Ben-Akiva, M. E.; Lerman, S. R. (1985): *Discrete Choice Analysis: Theory and Application to Travel Demand*, ISBN 978-0262022176, The MIT Press, Cambridge, MA; London, reprint post-2006, originally published 1985.

Cormen, T.; Leiserson, C.; Rivest, R.; Stein, C. (2009): *Introduction to Algorithms*, ISBN 978-0262033844, MIT Press, 3rd ed., 2009.

Diestel, R. (2017): *Graph Theory*, ISBN 978-3662536216, Springer, 5th ed., 2016/17.

Hensher, D. A.; Button, K. J. (2008): *Handbook of Transport Modelling*, ISBN 978-0080453767, Elsevier, Amsterdam; London, 2nd ed., 2008.

Klincewicz, J. G. (1996): *A Dual Algorithm for the Uncapacitated Hub Location Problem*, in Location Science, Vol. 4(3), pp. 173–184, DOI: 10.1016/S0966-8349(96)00010-1.

Ortúzar, J. de D.; Willumsen, L. G. (2011): *Modelling Transport*, ISBN 978-0470760393, John Wiley & Sons, Chichester, West Sussex, UK, 4th ed., 2011.

Thie, P. R.; Keough, G. E. (2008): *An Introduction to Linear Programming and Game Theory*, ISBN 978-0470232869, Wiley, Hoboken, NJ, 3rd ed., 2008.

9552 Advanced Logistics Control

Code 9552	**Workload** 150 h	**Credits** 5 CP	**Level of module** 1st semester	**Frequency of offer** summer semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module equips students with advanced skills in modeling, analyzing, optimizing, and controlling logistics processes using IT-based methods. The focus is on implementing and managing electronic control systems for centralized and decentralized logistics networks, including supply, production, and procurement systems. Students gain practical knowledge of information technologies, optimization techniques, and control approaches that underpin modern logistics concepts, including fifth-party logistics and real-time integrated production and distribution processes. The module also fosters critical reflection, problem-solving, and professional responsibility in applying IT solutions to complex logistics challenges.

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

- apply information technologies to decentralized logistics systems, including location-based ICT systems and intelligent multi-agent systems;
- utilize on-line and off-line optimization methods for logistics and production processes, based on operations research techniques as well as exact and heuristic solution methods;
- model, analyze, and solve real-world logistics problems using advanced IT-based control concepts;
- develop innovative approaches for IT-based logistics applications by critically reviewing and applying domain-specific scientific literature;
- implement and evaluate advanced logistics control solutions using intelligent multi-agent and web-based technologies;
- collaborate effectively in multidisciplinary teams to design, implement, and assess logistics control solutions.

Content

The content will be extended according to current developments:

- Multi-agent systems and distributed intelligent problem solving (theory and implementation using JADE and Jason (Java-based) or MESA (Python-based)
- Information and communication technology in advanced logistics systems
- Exact methods and heuristic algorithms for problem solving in logistics
- Technologies for geographical information systems
- ITC-based tracking and tracing methods
- Fundamental modeling of advanced logistics processes with operations management methods
- Important scheduling, routing and location planning algorithms
- Application domain example: An auction-based exchange of transportation services
- Big data and data mining for logistics control applications

- Responsible data and information treatment in supply chains
- Contribution of Advanced Logistics Control to CO2 footprint reduction
- Using ICT for sustainable Supply Chain Management

Teaching methods

Lecture, exercises (including programming solutions), case studies.

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Michael Schwind

Additional Information

Recommended readings:

Belfemine, G.; Caire, G.; Greenwood, D. (2007): *Developing Multi-Agent Systems with JADE*, ISBN 978-0470058407, Wiley, 2007.

Bordini, R.; Hübner, J.; Wooldridge, M. (2007): *Programming Multi-Agent Systems with AgentSpeak Using Jason*, ISBN 978-0470029001, Wiley, 2007.

Cachon, G.; Terwiesch, C. (2009): *Matching Supply with Demand: An Introduction to Operations Management*, ISBN 978-0073525167, McGraw-Hill, New York, 2009.

Fasli, M. (2007): *Agent Technology for e-Commerce*, ISBN 978-0470027113, Wiley, Chichester, Sussex, 2007.

Jacobs, F. R.; Chase, R. B. (2008): *Operations and Supply Chain Management: The Core*, ISBN 978-0073403281, McGraw-Hill, New York, 2008.

Rothlauf, F. (2011): *Design of Modern Heuristics: Principles and Application*, ISBN 978-3642245208, Springer (Natural Computing Series), 2011.

Russell, S.; Norvig, P. (2010): *Artificial Intelligence: A Modern Approach*, ISBN 978-0136042594, Prentice Hall, New Jersey, 3rd ed., 2010.

Stevenson, W. J. (2009): *Operations Management*, ISBN 978-0073377841, McGraw-Hill, New York, 10th ed., 2009.

9554 Supply Chain Planning & Optimization

Code 9554	**Workload** 150 h	**Credits** 5 CP	**Level of module** 2nd semester	**Frequency of offer** winter semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

Students will gain theoretical understanding and hands-on experience in applying predictive analytics and optimization techniques to supply chain problems. Key topics include demand forecasting, safety stock and reorder point planning, multi-echelon inventory optimization, and the role of digital technologies in planning processes. The module also strengthens key professional competencies such as teamwork, scientific judgment, critical reflection, and the ability to clearly communicate analytical results.

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

- analyze and model supply chain planning problems using quantitative approaches;
- apply statistical techniques for demand forecasting;
- design and implement inventory control policies under uncertainty;
- optimize inventory levels across multi-stage supply chains using relevant models and software tools;
- evaluate the impact of forecast accuracy and lead times on service levels and working capital;
- document and present results of application of supply chain planning and optimization methods and tools.

Content

- Forecasting methods (e.g., time series models, causal models)
- Forecast error measurement and forecast-value-added analysis
- Inventory control models (e.g., EOQ, safety stock, reorder point, periodic review)
- Multi-echelon inventory optimization
- Planning under uncertainty and stochastic modeling

Teaching methods

Lectures, readings, exercises and case analyses, application of analytical tools (e.g., Python)

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Mona Wappler

Additional Information

Readings will be announced during lecture.

Recommended readings:

Ivanov, D.; Tsipoulanidis, A.; Schönberger, J. (2021): *Global Supply Chain and Operations Management: A Decision-Oriented Introduction to the Creation of Value* [online], ISBN 978-3030723316, Springer International Publishing, Imprint: Springer, Cham, 3rd ed., 2021, verfügbar unter: `https://doi.org/10.1007/978-3-030-72331-6`.

Ivanov, D. (2024): *Introduction to Supply Chain Analytics: With Examples in AnyLogic and anyLogistix Software* [online], ISBN 978-3031512414, Springer Nature Switzerland, Imprint: Springer, Cham, 1st ed., 2024, verfügbar unter: `https://doi.org/10.1007/978-3-031-51241-4`.

Liu, K. Y. (2022): *Supply Chain Analytics: Concepts, Techniques and Applications* [online], ISBN 978-3030922245, Springer International Publishing, Imprint: Palgrave Macmillan, Cham, 1st ed., 2022, verfügbar unter: `https://doi.org/10.1007/978-3-030-92224-5`.

Vandeput, N. (2020): *Inventory Optimization: Models and Simulations*, ISBN 978-3110673944, De Gruyter, Berlin; Boston, 2020.

Vandeput, N.; Makridakis, S.; Ndiaye, A. B. (2021): *Data Science for Supply Chain Forecasting*, ISBN 978-3110671124, De Gruyter, Berlin; Boston, 2nd ed., 2021.

9555 Innovative Approaches in Supply Chains I

Code 9555	**Workload** 150 h	**Credits** 5 CP	**Level of module** 2nd semester	**Frequency of offer** winter semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module provides students with an in-depth understanding of current trends, emerging technologies, and innovative methodologies in supply chain management. Students explore advanced approaches to logistics, digital integration, and supply chain control, and analyze contemporary challenges in designing, coordinating, and steering complex multi-tiered supply chains in dynamic and volatile environments. The module emphasizes problem-solving, critical reflection, and the professional application of modern tools such as AI-based analysis and system design in supply chain contexts.

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

- analyze current challenges and emerging solutions in supply chain and logistics management for complex, multi-tiered networks;
- apply contemporary tools and methodologies, including AI-based analysis and system design, to identify, model, and solve supply chain problems;
- design, coordinate, and control innovative supply chain solutions in dynamic and volatile environments;
- critically evaluate the impact of technological and methodological innovations on supply chain efficiency, resilience, and sustainability.

Content

Examples of possible topics in this module:

- Supply Chain Network Design and Innovation, f.e.:
  - decentralized vs centralized supply chain structures,
  - global versus regional sourcing strategies in uncertain times
- Supply Chain Risk Management and Resilience: f.e.
  - geopolitical risk and trade disruptions,
  - supply chain resilience
- Innovative Mobility and Transportation Concepts: f.e.
  - urban logistics and last-mile innovation,
  - multi-modal transport integration and optimization,
  - autonomous transport
- Supply Chain Control and Visibility: f.e.
  - digital twins in supply chain management,
  - predictive analytics and forecasting,
  - exception management and decision support systems
- Technical Enablers of supply chain Innovation: f.e.

- Internet of things for asset tracking and condition monitoring,
- Digital Platforms and Supply Chain-as-a-Service Models

Teaching methods

Problem-based learning, lecture, student presentations, discussion, practical exercises

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Michael Schwind

Additional Information

Recommended readings: depending on the specific topic

9556 Innovative Approaches in Supply Chains II

Code 9556	**Workload** 150 h	**Credits** 5 CP	**Level of module** 2nd semester	**Frequency of offer** winter semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Planned group size** 25 students

Learning outcomes / Competences and qualification profile

This module provides students with an in-depth understanding of current trends, emerging technologies, and innovative methodologies in supply chain management. Students explore advanced approaches to logistics, digital integration, and supply chain control, and analyze contemporary challenges in designing, coordinating, and steering complex multi-tiered supply chains in dynamic and volatile environments. The module emphasizes problem-solving, critical reflection, and the professional application of modern tools such as AI-based analysis and system design in supply chain contexts.

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

- analyze current challenges and emerging solutions in supply chain and logistics management for complex, multi-tiered networks;
- apply contemporary tools and methodologies, including AI-based analysis and system design, to identify, model, and solve supply chain problems;
- design, coordinate, and control innovative supply chain solutions in dynamic and volatile environments;
- critically evaluate the impact of technological and methodological innovations on supply chain efficiency, resilience, and sustainability.

Content

Examples of possible topics in this module:

- Supply Chain Network Design and Innovation, f.e.:
  - decentralized vs centralized supply chain structures,
  - global versus regional sourcing strategies in uncertain times
- Supply Chain Risk Management and Resilience: f.e.
  - geopolitical risk and trade disruptions,
  - supply chain resilience
- Innovative Mobility and Transportation Concepts: f.e.
  - urban logistics and last-mile innovation,
  - multi-modal transport integration and optimization,
  - autonomous transport
- Supply Chain Control and Visibility: f.e.
  - digital twins in supply chain management,
  - predictive analytics and forecasting,
  - exception management and decision support systems
- Technical Enablers of supply chain Innovation: f.e.

- Internet of things for asset tracking and condition monitoring,
- Digital Platforms and Supply Chain-as-a-Service Models

Teaching methods

Problem-based learning, lecture, student presentations, discussion, practical exercises

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Michael Schwind

Additional Information

Recommended readings: depending on the specific topic

9557 Innovative Approaches in Supply Chains III

Code 9557	**Workload** 150 h	**Credits** 5 CP	**Level** 2nd semester	**Frequency** winter semester
Duration 1 semester	**Courses** Lecture: 30 TU / 2 SWS Exercise: 30 TU / 2 SWS	**Teaching time** 60 TU / 4 SWS	**Self-study** 105 h	**Group size** 25 students

Learning outcomes / Competences and qualification profile

This module provides students with an in-depth understanding of current trends, emerging technologies, and innovative methodologies in supply chain management. Students explore advanced approaches to logistics, digital integration, and supply chain control, and analyze contemporary challenges in designing, coordinating, and steering complex multi-tiered supply chains in dynamic and volatile environments. The module emphasizes problem-solving, critical reflection, and the professional application of modern tools such as AI-based analysis and system design in supply chain contexts.

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

- analyze current challenges and emerging solutions in supply chain and logistics management for complex, multi-tiered networks;
- apply contemporary tools and methodologies, including AI-based analysis and system design, to identify, model, and solve supply chain problems;
- design, coordinate, and control innovative supply chain solutions in dynamic and volatile environments;
- critically evaluate the impact of technological and methodological innovations on supply chain efficiency, resilience, and sustainability.

Content

Examples of possible topics in this module:

- Supply Chain Network Design and Innovation, f.e.:
  - decentralized vs centralized supply chain structures,
  - global versus regional sourcing strategies in uncertain times
- Supply Chain Risk Management and Resilience: f.e.
  - geopolitical risk and trade disruptions,
  - supply chain resilience
- Innovative Mobility and Transportation Concepts: f.e.
  - urban logistics and last-mile innovation,
  - multi-modal transport integration and optimization,
  - autonomous transport
- Supply Chain Control and Visibility: f.e.
  - digital twins in supply chain management,
  - predictive analytics and forecasting,
  - exception management and decision support systems
- Technical Enablers of supply chain Innovation: f.e.

- Internet of things for asset tracking and condition monitoring,
- Digital Platforms and Supply Chain-as-a-Service Models

Teaching methods

Problem-based learning, lecture, student presentations, discussion, practical exercises

Entry requirements

None

Types of assessment

Graded examination (Project with presentation and technical discussion). Details to be announced at the beginning of the lectures by the Examination Board.

Requirements for the award of credit points

Passed assessment

Use of moodule (in other study programs)

- -

Weight towards final grade

5,55%

Person in charge of module

Prof. Dr. Michael Schwind

Additional information

Recommended readings: depending on the specific topic