Handbook of Modules
for the Degree Programme

Information Engineering and Computer Science, M.Sc.

Faculty of Communication and Environment

Version 1.5

27.1.2021

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	2021-1-27	MS	Bearbeitung zur Auflagenerfüllung

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). The Master’s degree program “Information Engineering and Computer Science” makes only use of graded examinations according to RPO §20. 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) in §§ 10 to 18 in accordance to the RPO.

Examinations (according RPO §14 and PO §§16,17,18): 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, PO §16), multiple choice examinations (RPO §17a), oral examinations (RPO §18, PO §17) or assignments, term papers or projects (RPO §19, PO §18). 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), PO §10(3)):

1 = Very Good	= Excellent
2 = Good	= Well above average
3 = Satisfactory	= Average
4 = Sufficient	= Meets all 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 Oral / Written examination	according to RPO §14 (3) and according PO §16 /17
Case study and presentation	according to PO §18

RPO Rahmenprüfungsordnung für die Studiengänge an der Hochschule Rhein-Waal.

PO Prüfungsordnung des Studiengangs Information Engineering & Computer Science.

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

Information Engineering and Computer Science, M.Sc.

Code No (Kennnummer)	Module	SW	Type (Veranstaltungsart)						TE	CP	Sum CP	SS 1	WS 2	SS 3
			L	SL	S	Ex	PT	Pro						
M-IE_1.01	**System Simulation**	5	2			2	1		E	5	**5**	5		M-IE_3.01 Master Thesis /Masterarbeit (27 CP) and Colloquium/Kolloquium (3 CP)
M-IE_1.02	**Data Analysis & Information Engineering**	4	2			2			E	5	**5**	4		
M-IE_1.03	**Scientific and Technical Communication**	3	3						E	5	**5**	3		
M-IE_1.04	**Applied Research Project A**	4					4		E	5	**5**	4		
M-IE_2.01	**Data Mining**	4	2			2			E	5	**5**		4	
M-IE_2.02	**Geoinformatics**	4	2			2			E	5	**5**		4	
M-IE_2.03	**Intercultural Management and Intercultural Competence**	4							E	5	**5**			
	Intercultural Management and Intercultural Competence		2			1							3	
	Localisation and Internationalisation						1						1	
M-IE_2.04	**Innovation Management**	3							E	5	**5**			
	User-Centred Innovation and Design Management		2										2	
	Digital Culture and New Markets		1										1	
M-IE_2.05	Applied Research Project B	4					4		E	5	**5**		4	
	Specialisation Track (1st semester)	8								10	**10**			
	Course 1		2			2			E			4		
	Course 2		2			2			E			4		
	Specialisation Track (2nd semester)	4								5	**5**			
	Course 3		2			2			E				4	
	Semester hours per week (Semesterwochenstunden)	**47**								**CP**	**60**	**24**	**23**	**30**

47 SW

90 CP

Specialisation Tracks

	Module	SW	CP
	Track Computer Science		
M-IE_CS.01	Advanced System Security	4	5
M-IE_CS.02	Mobile and Internet Computing	4	5
M-IE_CS.03	Advanced Software Engineering	4	5
	Track Environmental Analysis		
M-IE_EA.01	Environmental Analysis, Impact and Risk	4	5
M-IE_EA.02	Environmental Monitoring Research Project	4	5
M-IE_EA.03	Data Processing in Ecosystem Management	4	5
	Track Logistics		
M-IE_LG.01	Logistics Networks Modeling	4	5
M-IE_LG.02	Advanced Logistic Control	4	5
M-IE_LG.03	Advanced Logistics Concepts	4	5
	Track Cyber-Physical Systems		
M-IE_CP.01	Distributed Systems	4	5
M-IE_CP.02	Real-Time Embedded Systems	4	5
	Track Artificial Intelligence		
M-IE_AI.01	Artificial Intelligence and its Application	4	5
M-IE_AI.02	Machine Learning	4	5
M-IE_AI.03	Advanced Topics of Artificilal Intelligence	4	5

Abbreviations

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

M-IE_1.01 System Simulation

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_1.01	150 h	5 CP	1st semester	Summer semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Exercise: 22,5 h / 2 SWS	45 h / 4 SWS	105 h	Lecture: open Exercise: 25 students / working group

Learning outcomes / Competences and qualifications profile

This module enables students to create models of real systems, such as technical, natural or economical systems and to analyze them via simulations. It provides basic methods of modelling and simulation and their applications in different contexts. In detail, the students are able to apply modelling and simulation techniques to technical, natural and/or economic problems, i.e. they are able to describe the problems mathematically and to find solutions. They know the appropriate use of models and simulations as well as their limitations and understand the steps of the simulation process. Students are familiar with a range of modern modelling and simulation techniques as well as common tools and they can apply the learned methods to different problems in practice, for example to make predictions, to find general rules and to raise new questions. They are able to develop or apply their own ideas in this field. They understand modelling and simulation as a useful tool to analyze real systems, in particular technical systems, and they can apply them in different contexts.

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 Octave/Matlab, Scilab/Xcos, R, Python, Arena, or Dosimis (e.g. signal processing, queuing systems, optimization)
- Transfer of the learned methods 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. radioactive decay)

Modelling and simulations in **data science** and **machine learning.**

Modelling and Simulation in **3D-Tools**, such as **Houdini** etc.

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

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade

5,42%

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.* (2nd ed.). Berlin: Springer.

Chapra, S.C., & Canale, R.P. (2014). *Numerical Methods for Engineers* (7th ed.). Europe: McGraw-Hill Education.

Gilat, A., & Subramaniam, V. (2013). *Numerical Methods for Engineers and Scientists: An Introduction with Applications Using MATLAB* (3rd ed.). John Wiley & Sons Inc.

Hill, C. (2016). *Learning Scientific Programming with Python*. Cambridge University Press.

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

Kreyszig, E. (2015). *Advanced Engineering Mathematics* (10th ed.). John Wiley & Sons.

Quarteroni, A. M., Saleri, F., & Gervasio, P. (2014). *Scientific Computing with MATLAB and Octave* (4th ed.). Berlin: Springer.

Stroud, K.A., & Booth, D. J. (2011). *Advanced Engineering Mathematics* (5th ed.). Red Globe Press.

Stroud, K.A., & Booth, D. J. (2013). *Engineering Mathematics* (7th ed.). Red Globe Press.

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

Tyagi, A.K. (2011). *MATLAB and Simulink for Engineers.* Oxford University Press, Pap/Cdr.

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

M-IE_1.02 Data Analysis & Information Engineering

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_1.02	150 h	5 CP	1st semester	Summer semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Exercise: 22,5 h / 2 SWS	45 h / 4 SWS	105 h	Lecture: open Exercise: 25 students / working group

Learning outcomes / Competences and qualifications profile

Students have learned about the philosophical foundations of Information Theory based on Epistemology. They have also been introduced in the statistical basics of Information Theory (Shannon Entropy). They know about the relevance of Markov Chains for the modelling of stochastic processes for Information Processing. They have learned about the value-adding process of refining data into information and finally retrieving knowledge from the information (Pyramid of Knowledge).

On the practical side students learned which criteria and methods are suitable to collect proper quality data from the source as an input for the information gaining process based on classical statistical methods. Students are able to use R and Python programming tools to analyze and interpret statistical data through fundamental and selected advanced statistical data analysis methods. Students are able to understand the complexity of Information Engineering as a system science making use of the skills acquired in this course.

Prerequisites:

Good understanding of fundamental descriptive statistics, probability theory and inferential statistics, including Random Variables and Probability Distributions, Moments of One Random Variable, Parametric Distributions, Sampling Distributions.

Content

- Philosophical Foundations of Information Theory
- Basics of Information 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

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Michael Schwind

Additional information

Recommended readings:

Batini, C. et al. (2016). *Data and Information Quality*, Springer

Brookes C. B. (1980) *The foundations of information science. Part I. Philosophical aspects*. Journal of Information Science, 2 (3-4), 125-133. SAGE.

Fan , J. Li, R. Zhang C., Zou H. (2020) *Statistical Foundations of Data Science,* CRC Press

Field A., Miles J., & Field Z. (2012). *Discovering Statistics with R.* SAGE.

Hastie T., Tibshirani R., & Friedman J. (2017). *The Elements of Statistical Learning: Data Mining, Inference, and Prediction.* Springer.

James G., Witten D., Hastie T., & Tibshirani R. (2017). *An Introduction to Statistical Learning with Applications in R.* Springer.

Mc Kinney, Wes (2017). *Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython.* (2nd ed.) O'Reilly.

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

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

M-IE_1.03 Scientific and Technical Communication

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_1.03	150 h	5 CP	1st semester	Summer semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 33,75 h / 3 semester hours per week (SWS)	33,75 h / 3 SWS	116,25 h	Lecture: open 25 students / working group

Learning outcomes / Competences and qualifications profile

Students have learned to communicate technical information in an easily understandable language. They have internalized the fundamentals of effective scientific writing. They have deepened their knowledge of how to write and revise (technical) reports and manuals and have practiced their skills by completing different hands-on assignments. Students have learned to plan and edit documentation materials and to estimate the effort needed to include illustrations, photographs, charts and diagrams. In addition to the ability to communicate technical knowledge. Students have learned how to document and present research in information engineering and computer science (especially complex systems) in adequate ways to a diverse audience. Students also know about risk of plagiarism and are aware how to cite appropriately in order to avoid any suspicious use sources. Students are also trained to do in depth literature research in library systems (journal catalogs) to procure input for PhD-appropriate procurement of scientific input literature.

Content

- Writing style
- Creative and technical writing
- Illustrations, charts and diagrams
- Presentation techniques
- Editing and publishing
- Experimental design, analysis and documentation
- Scientific use of sources and appropriate way of citing
- Avoiding plagiarism

Teaching methods

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

Entry requirements

None

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assesment

Use of module (in other study programs)

--

Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Michael Schwind

Additional information

Recommended readings:

Agarwal, B. L. (2010). *Theory & Analysis of Experimental Designs.* CBS Publishers & Distributors Private Limited.

Albers, M. J., & Mazur M. B. (2003). *Content and Complexity: The Role of Content in Information Design*. Routledge.

Alley, M. (1998). *The Craft of Scientific Writing* (3rd ed.). Springer.

Anderson, P. V. (1998). *Technical Communication: A Reader-centered Approach* (4th ed.). Heinle & Heinle Publishing.

Cargill, M., & O'Connor P. (2009). *Writing Scientific Research Articles: Strategy and Steps*. Wiley-Blackwell.

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

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

Meenakshi R., & Sharma S. (2012). *Technical Communication: Principles and Practice* (2nd ed.). OUP India.

Menager-Beeley, R., & Paulos L. (2010). *Quick Coach Guide to Avoiding Plagiarism: with 2009 MLA and APA Update.* Cengage Learning.

Miller, F. P., Vandome A. F., & McBrewster J. (2010). *Illustration: Information Drawing, Painting, Photograph, Art, Technical illustration.* Alphascript Publishing.

Surhone, L. M., Timpledon, M. T., & Marseken, S. F. (2010). *Technical Illustration: Technical Drawing, Diagram, Line Drawing, Exploded View Drawing, Cutaway Drawing, Clip-Art, Parallel Projection, Perspective Projection.* Betascript Publishing.

M-IE_1.04 Applied Research Project A

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_1.04	150 h	5 CP	1st semester	Summer semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Practical Training: 45h / 4 semester hours per week (SWS)	Depending on individual needs	105 h	25 students / group

Learning outcomes / Competences and qualifications profile

Students have worked in small groups on a specific topic in applied research from information engineering and computer science in depth. They have experience in finding interesting and realistically to answer research questions, in conducting research, in shaping a plan how to work on the topic in a team, and in how to present and document the results to an audience.

As such students have learned to apply the knowledge they have gained in other courses to their project work. They are able to write a convincing project report and to communicate project results in a professional way. They are used to project management and to procedures of scientific technical gatherings such as company presentations, conference talks, and poster sessions.

Due to this project experience students have improved also their soft skills and their ability to work in a team.

Students are able to apply information engineering and computer science methods in different self-chosen fields such as technical, natural or economical systems in different contexts. They are able to develop or apply their own ideas in this field in different contexts.

Students have learnt to work as a team reflecting all organizational and social hurdles, they now how to solve conflicts in teams and how to attribute the profit from collaboration to the team members including social responsibility.

Content

Students have to plan, realize, document and present their own projects by applying the knowledge they have gained in accompanying courses. The projects students choose should be related to current research projects of the faculty or can be realized by doing industrial internships.

A focus on information modeling aspects is mandatory.

Students have to analyze the project topic, propose applied research questions that feature a certain complexity, plan how to answer them, conduct applied research in team work, and communicate the results.

In order to communicate, project teams have to prepare a project proposal for a sponsor that has to be approved by the teacher, in regular status meetings project progress is discussed, preliminary findings are presented during a mid-term meeting, the final results are presented in a final meeting when also scientific posters are displayed. Finally the project is documented in a report. In the report there are mandatory sections such as "related work", "data/information model", "methodology", or "discussion of design decisions".

Teaching methods

At the beginning of the semester the different project ideas are developed by students and teams are built. The teacher acts as a facilitator and moderator during this process. Afterwards the teacher becomes project sponsor and needs to approve project proposals and design decisions. He or she also controls deviations from plan or schedule and modifications of the project scope. In the end of this course the teacher acts as external audience and offers constructive critique as well as feedback according to the process.

Entry requirements

None

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Timo Kahl

Additional information

Same as Applied Research Project B

Literature depending on project

M-IE_2.01 Data Mining

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_2.01	150 h	5 CP	2nd semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Exercise: 22,5 h / 2 SWS	45 h / 4 SWS	105 h	Lecture: open Exercise: 25 students / group

Learning outcomes / Competences and qualifications profile

Students have been introduced to typical tasks in which data mining techniques can be used effectively. They know about basic data types, the methods and the models for the data mining process. They are familiar with data mining projects and know how to use at least one software system in order to solve data mining tasks. Students have gained an in-depth understanding of concepts, methods, and limitations as well as practical experience in the area of scalable data analysis and data mining. Students are also able to organize data such that they can engineer big database models supporting high-performance data mining tasks.

Students are able to apply data mining methods in different fields such as technical, natural or economical systems in different contexts. They know the appropriate use of data mining methods as well as their limitations. Students are familiar with a range of modern data mining technologies as well as common tools. They are able to develop or apply their own ideas in this field in different contexts. Student have learnt to assess the risk of uncontrolled collection and use of data. They are able to make a trade-off between usefulness and harm of exploiting available data sources in the data mining context.

Content

Recent advances in technology have led to rapid growth of data. This resulted in a need for cost efficient and scalable techniques to analyze data.

A special focus is put on the impact of data models for data mining and accordingly on the extraction, transformation, and loading steps (ETL) in data mining processes.

- Data mining process (standards and typical tasks of data mining such as anomaly detection, association rule learning (dependency modeling), search for relationships between variables, clustering, classification, regression, summarization)
- Learning methods in data mining e.g. Statistical Learning, Random Forest, Support Vector Machines, Artificial Neural Networks
- Data mining and text mining, data mining and web mining, data mining and information retrieval
- Algorithms and tools (e.g. R, Weka)
- Data mining trends research frontiers and applications
- Data mining and society, big data and privacy
- Massive Parallel Data Mining Tasks using distributed computing such as “Hadoop” project allows for running on different Web Servers.
- Data mining in Knowledge Management and Semantic Web

- Data mining and Social Network Analysis
- Data mining and the responsible use of data

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

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

--

Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Michael Schwind

Additional information

Recommended readings:

Dunham, M. H. (2003). *Data Mining Introductory and Advanced Topics*. New Jersey: Prentice Hall.

Han, J., Kamber, M., & Pei, J. (2011). *Data Mining: Concepts and Techniques* (3rd revised ed.). Morgan Kaufmann.

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

Russel, M.A. (2013). *Mining the Social Web: Data Mining Facebook, Twitter, LinkedIn, Google+, GitHub, and More.* O'Reilly Media.

Tan, P.-N., Steinbach, M., & Kumar, V. (2006*). Introduction to Data Mining*. Boston: Addison Wesley.

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

Wickham, H., & Grolemund, G. (2017). *R for Data Science: Import, Tidy, Transform, Visualize, and Model Data*. O'Reilly Media.

Witten, I.H., Frank, E., & Hall, M.A. (2011). *Data Mining: Practical Machine Learning Tools and Techniques* (3rd ed.). Morgan Kaufmann.

M-IE_2.02 Geoinformatics

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_2.02	150 h	5 CP	2nd semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Exercise: 22,5 h / 2 SWS	45 h / 4 SWS	105 h	Lecture: open Exercise: 25 students / group

Learning outcomes / Competences and qualifications profile

Students have expanded the ability to understand and apply basic and advanced concepts and techniques in geo-informatics and geographical information systems (GIS). With respect to their fields of application students have developed skills to recognize the assumptions, implications, values and limitations of different methods in spatial analysis. They have learned to deploy existing skills in modeling and programming for implementing spatial algorithms and extending existing GIS software.

They are able to oversee the impacts of information modelling decisions on GIS feasibility and performance of GIS systems.

Students are able to apply GIS methods in different fields such as technical, natural or economical systems in different contexts. They know the appropriate use of GIS as well as their limitations. Students are familiar with a range of modern GIS technologies as well as common tools. They are able to develop or apply their own ideas in this field in different contexts.

Content

- Basic concepts and usage of Geographical Information Systems (GIS)
- Open Source Geospatial Foundation (OSGeo)
- Spatial data types
- Simple Feature Model of the Open Geospatial Consortium (OGC)
- Standardized web services (WMS, etc.)
- Coordinate reference system, ellipsoid and map projection
- Global navigation satellite system
- Airborne laser scanning, digital surface and terrain and models
- Geodata handling in Python
- Retrieval and usage of open online geodata
- Remote sensing
- Cartography
- Spatial database management systems
- Geostatistics

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

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

--

Weight towards final grade

5,42%

Person in charge of module

Prof. Dr.-Ing. Rolf Becker

Additional information

Recommended readings:

Acevedo, M. F. (2013). *Data Analysis and Statistics for Geography, Environmental Science and Engineering*. CRC Press.

de Smith, M. J., Goodchild M. F., & Longley, P.A. (2009). *Geospatial Analysis: A Comprehensive Guide to Principles, Techniques and Software Tools (*3rd ed.).

Kemp, K.K. (2008). *Encyclopedia of Geographic Information Science* (ed. 2008). Sage Publications.

O'Sullivan, D. & Unwin, D. J. (2010). *Geographic Information Analysis* (2nd ed.). John Wiley & Sons.

M-IE_2.03 Intercultural Management and Intercultural Competence

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_2.03	150 h	5 CP	2nd semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Exercise: 11,25 h / 1 SWS Practical Training: 11,25 h / 1 SWS	45 h / 4 SWS	105 h	Lecture: open Exercise: 25 students / group

Learning outcomes / Competences and qualifications profile

Students have gained a good understanding of the basic concepts in the field of cross-cultural differences in business settings. They know the main cultural dimensions developed by different scholars and are familiar with strong and weak points of these approaches. Students are able to conduct a cross-cultural analysis of a case study or a business situation, evaluating potential threats and risks arising from a culture clash. These analytical skills form the basis of their core competences in issues related to intercultural management. Students coming from different cultural regions have also learned to use their capability to communicate in research and business context using role-games and other situation dependent teaching methods to improve their interactivity and compatibility.

Content

- Definition of culture. The Iceberg Model of Culture
- Sources of cultural diversity
- Culture as mental programming
- G. Hofstede's cultural dimensions
- Power distance (G. Hofstede). Ascribed vs. achieved status (F. Trompenaars)
- Individualism and collectivism as a cultural dimension. Views of Globe study project on this dimension
- Masculinity vs. femininity. Critique of this dimension by other scholars
- Uncertainty avoidance and its importance for crisis management
- Attitude to time (approaches by R. Lewis and F. Trompenaars)
- Culture shock. Stages of a culture shock. Cultural stereotypes
- The role of culture in organizations
- Decision making across cultures
- Negotiating in cross-cultural settings
- Communication patterns and socializing in intercultural management

Teaching methods

The course is held in form of a seminar: lectures are accompanied by various practical activities, discussions and exercises.

Entry requirements

None

Types of assessment

Graded examination

Requirements for the award of credit points

Passed examination

Use of module (in other study programs)

--

Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Michael Schwind

Additional information

Recommended readings:

Comfort, J., & Franklin P. (2011). *The mindful manager: how to work effectively across cultures*. London: Kogan Page.

Hofstede, G. H., & Hofstede, G. J. (2005). *Cultures and Organizations: Software of the Mind*. New York: McGraw-Hill.

House, R.J., Hanges, P. L., Javidan, M., Dorfmann, P. W., & Gupta, V. (2004). *Culture, leadership, and organizations: The GLOBE study of 62 societies.* London: Sage Publications.

Kublin, M. (1995). *International negotiating: a primer for American business professionals*. New York: The Haworth Press, Inc.

Lewis, R. D. (2001). *When cultures collide: managing successfully across cultures.* London: Nicholas Brealey Publishing.

Lustig M., Koester J., & Halualani R. (2017). *Intercultural Competence: Interpersonal Communication Across Cultures* (8th ed.). Pearson.

Spencer-Oatey H., & Franklin P. (2009). *Intercultural Interaction: A Multidisciplinary Approach to Intercultural Communication.* Basingstoke: Palgrave Macmillan.

Storti, C. (1994). *Cross-cultural dialogues. 74 brief encounters with cultural difference.* Boston: Intercultural Press, Inc.

M-IE_2.04 Innovation Management

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_2.04	150 h	5 CP	2nd semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Practical Training: 12,25 h / 1 SWS	33,75 h / 3 SWS	116,25 h	Lecture: open Practical training: 25 students / group

Learning outcomes / Competences and qualifications profile

Students have learned about the various approaches to innovation focusing on customer-driven and user-driven methodology. They are able to identify opportunities and to transform these opportunities into requirements and concepts for future products that aim to achieve an optimum balance between all functional and non-functional requirements from all stakeholders' perspectives. Students have gained knowledge of various concepts of design, including design activities such as analysis and synthesis. They understand design thinking as a human-centered process of innovation. Students can apply techniques from design thinking and synthesis, are able to balance different design alternatives and can communicate the design rationales appropriately. Students are familiar with the strategy, process and implementation of design thinking and design management. They have gained knowledge of the breadth of principles, methods and practices that shape design management across the different design disciplines. Students know about the balance between a fruitful innovation progress and a disruptive innovation process. They elaborate concepts to curb negative impact of uncontrolled innovation.

Content

- Strategic management and design management
- Economic foundations of innovation: the case of Schumpeter
- Design thinking and creativity methods
- Open innovation and user-centered innovation
- Innovative business models for new markets and digital culture
- Types of Innovation: Incremental / Disruptive
- Innovation as a product of collaborative social networks
- Risk of innovation: e.g. long-term impact of digital media on societal evolution.

Teaching methods

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

Entry requirements

None

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

--

Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Michael Schwind

Additional information

Recommended readings:

Ambrose, P. H. G. (2010). *Design Thinking: Fragestellung, Recherche, Ideenfindung, Prototyping, Auswahl, Ausführung, Feedback.* Stiebner Verlag Gmbh.

Brown, T. (2009). *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation*. Harper Business.

Cooper, R., Junginger S., & Lockwood, T. (2011). *The Handbook of Design Management*. Berg Publishers.

Gray, D., Brown S., & Macanufo J. (2010). *Gamestorming: A Playbook for Innovators, Rulebreakers, and Changemakers.* O'Reilly Media.

Greene, J. (2010). *Design Is How It Works: How the Smartest Companies Turn Products into Icons*. Portfolio Hardcover.

Johnson, S. (2011). *Where Good Ideas Come From: The Natural History of Innovation*. Riverhead Trade.

Kelley, T. (2008*). The Ten Faces of Innovation: Strategies for Heightening Creativity*. Profile Books Ltd.

Merholz, P., Wilkens T., Schauer B., & Verba D. (2008). *Subject To Change: Creating Great Products & Services for an Uncertain World.* O'Reilly Media.

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers.* John Wiley & Sons.

Project Management Institute (2004). *A Guide to the Project Management Body of Knowledge*. Project Management Institute.

Schilling, M. (2010). *A strategic management of technological innovation* (3rd ed.). New York: McGraw-Hill/Irwin.

Tidd, J. (2009). *Managing innovation* (4th ed.). Hoboken, NJ: Wiley.

Verganti, R. (2009). *Design Driven Innovation: Changing the Rules of Competition by Radically Innovating What Things Mean*. Harvard Business Press.

von Hippel, E. (1995). *The Sources of Innovation*. OUP USA.

M-IE_2.05 Applied Research Project B

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_2.05	150 h	5 CP	2nd semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Practical Training: 45h / 4 semester hours per week (SWS)	Depending on individual needs	105 h	25 students /group

Learning outcomes / Competences and qualifications profile

Students have worked in small groups on a specific topic in applied research from information engineering and computer science in depth. They have experience in finding interesting and realistically to answer research questions, in conducting research, in shaping a plan how to work on the topic in a team, and in how to present and document the results to an audience.

As such students have learned to apply the knowledge they have gained in other courses to their project work. They are able to write a convincing project report and to communicate project results in a professional way. They are used to project management and to procedures of scientific technical gatherings such as company presentations, conference talks, and poster sessions.

Due to this project experience students have improved also their soft skills and their ability to work in a team.

Students are able to apply information engineering and computer science methods in different self-chosen fields such as technical, natural or economical systems in different contexts. They are able to develop or apply their own ideas in this field in different contexts.

Students have learnt to work as a team reflecting all organizational and social hurdles. They now how to solve conflicts in teams and how to attribute the profit from collaboration to the team members including social responsibility.

Content

Students have to plan, realize, document and present their own projects by applying the knowledge they have gained in accompanying courses. The projects students choose should be related to current research projects of the faculty or can be realized by doing industrial internships.

A focus on information modeling aspects is mandatory.

Students have to analyze the project topic, propose applied research questions that feature a certain complexity, plan how to answer them, conduct applied research in team work, and communicate the results.

In order to communicate, project teams have to prepare a project proposal for a sponsor that has to be approved by the teacher, in regular status meetings project progress is discussed, preliminary findings are presented during a mid-term meeting, the final results are presented in a final meeting when also scientific posters are displayed. Finally, the project is documented in a report. In the report there are mandatory sections such as "related work", "data/information model", "methodology", or "discussion of design decisions".

Teaching methods

At the beginning of the semester the different projects are presented and teams are built. Project kickoffs and regular meetings will be initiated by the professors in charge who will also support the projects and will be available in case of problems and questions.
Entry requirements None
Types of assessment Graded examination
Requirements for the award of credit points Passed assessment
Use of module (in other study programs) --
Weight towards final grade 5,42%
Person in charge of module Prof. Dr. Timo Kahl
Additional information Same as Applied Research Project A Literature depending on project

M-IE_3.01 Master Thesis and Colloquium

Code	Workload	Credits	Level of module	Frequency of offer	Duration
UE_3.01	810 h	30 CP (27 + 3 CP)	3rd semester	Winter semester	20 weeks

Courses	Teaching time	Self-study	Planned group size
Master Thesis: 27 CP Colloqium: 3 CP	Depending on individual needs		

Learning outcomes / Competences and qualifications profile

Students have worked on a research topic of their interest in the scientific field of Information Engineering and Computer Science. They have conducted intensive studies on literature and developed their research question. Students have developed appropriate methodological strategies concerning that question. They have conducted the approach focusing on specific details of the question, have analyzed the results and transferred their findings to the broader perspective of the field. They have reflected their work and findings critically and have come up with some further research questions. Students have proven that they are able to analyze a complex field of work, find specific new research questions and have been able to answer them.

During the colloquium students have presented their work and have proven their expertise in the field of work. They have been able to defend the topic and to reflect on its impact on real-life problems in a professional way.

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 35%
Person in charge of module All professors of the faculty
Additional information

Track Computer Science

M-IE_CS.01 Advanced System Security

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_CS.01	150 h	5 CP	1st semester	Summer semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Lab exercise: 11,25 h / 1 SWS Project supervision: 11,25 h / 1 SWS	45 h / 4 SWS	105 h	Lecture: open Lab exercise: 20 students

Learning outcomes / Competences and qualifications profile

Students have gained advanced knowledge of security concepts, such as threats, vulnerabilities, protection and incident handling. They have been provided with a deep understanding of the field of communication / information security and respective implementation issues for communication systems. Students have been exposed to the spectrum of security activities, its methods, methodologies and mechanisms.

Students are able to apply security related methods in different fields of ICT in different contexts. They know the appropriate use of security related activities and components as well as their limitations. Students are familiar with a range of modern ICT security related technologies as well as common tools and processes. They are able to develop or apply their own ideas in this field in different contexts. Students know about the societal relevance of secure IT infrastructure. They are able assess cost and utility of system security measures in the context of consumer protection and the holistic societal system.

Content

Coverage has included advanced cryptographic functions, detection of and reaction to threats to communication systems, and trustworthy computing. Another focus has been set on security related organizational structures and product / system certification with respect to standardized security evaluation criteria.

- Advanced cryptographic protocols
- Mathematical foundations for security
- Communication security concepts:
- Methods
- Methodologies
- Mechanisms
- Perimeters, firewalls and (virtual) private networks
- Penetration testing
- Approaches to intrusion detection
- Privacy and metrics to quantify privacy
- Proving security, logical reasoning models
- Advanced information security and risk management, IoT security, industrial control system security
- Research topics regarding system security
- Societal relevance of IT System Security

Teaching methods

Lectures and practical classes

Entry requirements

None

Recommendation: It is strongly recommended to have attended a bachelor module covering the basics of IT security concepts and methodologies first. It is expected that students have fluent knowledge of a programming language, computer networks and of the fundamentals of operating systems.

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

--

Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Ulrich Greveler

Additional information

Recommended readings:

Anderson, R. (2008). *Security Engineering: A Guide to Building Dependable Distributed Systems* (2nd ed.). New York: John Wiley & Sons.

Harris, S. (2018). *CISSP All-in-One Exam Guide* (8th ed.). McGraw-Hill Education Ltd.

Mahmood, Z. (2019). *Security, Privacy and Trust in the IoT Environment* (1st ed.). Springer.

Paar, C. et al. (2011). *Understanding Cryptography: A Textbook for Students and Practitioners* (1st ed.). Heidelberg: Springer.

Schneier, B. (2011). *Applied Cryptography: Protocols, Algorithms and Source Code in C* (3rd ed.). New York: John Wiley & Sons.

Stavroulakis, P et al. (2010). *Handbook of Information and Communication Security* (1st ed.). Heidelberg: Springer.

M-IE_CS.02 Mobile and Internet Computing

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_CS.02	150 h	5 CP	2nd semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Lab Exercise: 11,25 h / 1 SWS Project supervision: 11,25 h / 1 SWS	45 h / 4 SWS	105 h	Lecture: open Lab exercise: 20 students

Learning outcomes / Competences and qualifications profile

Students have gained advanced knowledge of architectures and software engineering concepts for developing integrated mobile applications with distributed, internet-based backend systems. Furthermore, after practical work they are able to plan and implement multi-tiered information systems consisting of mobile app(s), server-based back-ends, modern communication protocols, and advanced persistency layers. They have been provided with a deep understanding of mobile and web-based architectures, accompanying frameworks, and the appropriate development and testing techniques. Students have been exposed to the spectrum of development activities, its methods, methodologies and mechanisms.

Students are able to apply appropriate design patterns in different contexts. They know the appropriate use of components as well as their limitations. Students are familiar with a range of modern frameworks as well as common tools and processes. They are able to develop or apply their own ideas in this field in different contexts.

Content

Coverage has included deployment processes, aspects of API-ageing, as well as best practices to handle short release cycles in production environments.

- General concepts of mobile applications
- Software engineering 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
- Cloud technologies
- Communication strategies
- Web applications as backend technology
- Persistence layers
- Client/Server-stacks for developing web applications
- Cross-platform approaches
- Societal impact of Internet Computing
- Individual risk of mobile media addiction

Teaching methods

Lectures and practical classes

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

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

--

Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Thomas Richter

Additional information

Recommended readings:

http://developer.android.com

http://developer.windowsphone.com

https://developer.apple.com/

Additional readings:

Han, Choi, & Song (eds.): *High Performance Cloud Auditing and Applications.*

Kumar: *Fundamentals of Pervasive Information Management Systems.*

Matera, & Rossi (eds.): Mobile Web Information Systems: MobiWIS 2013, International Workshops, Paphos, Cyprus, August 26-28, Revised Selected Papers (Communications in Computer and Information Science)

Steinbock, & Noam (eds.): *Competition for the Mobile Internet.*

Upadhyaya, Chaudhury, Kwiat, & Weiser (eds.): *Mobile Computing: Implementing Pervasive Information and Communications Technologies (*Operations Research/Computer Science Interfaces Series)

M-IE_CS.03 Advanced Software Engineering

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_CS.03	150 h	5 CP	2nd semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Seminar: 11,25 h / 1 SWS Practical training: 11,25 h / 1 SWS	45 h / 4 SWS	105 h	Lecture: open Seminar and practical training: 25 students

Learning outcomes / Competences and qualifications profile

In 1968 the term "software engineering" was introduced at a NATO conference on tackling the "software crisis". Since then numerous methodologies for improving the development and implementation of complex software products have been presented.

In that context students have gained an overview of the ten knowledge areas of software engineering as defined by the ACM/IEEE Computer Society Software Engineering Body of Knowledge (IEEE 2013) and have been introduced to selected methods in each knowledge area. Students are able to decide which software engineering methods should be applied in different situations. Students are able to evaluate the appropriateness of specific methods in the context of specific organizational setting and software product requirements. They also have developed the skills to use tools that help introducing specific methods in software development organizations.

Students are able to apply appropriate software engineering methods in different contexts. They know the appropriate use of them as well as their limitations. Students are familiar with a range of common tools and processes. They are able to develop or apply their own ideas in this field in different contexts. Besides they have discussed and understood the direct and indirect responsibility that comes with the leap of faith provided by society to engineers, computer scientists and technical development.

Content

- Management of software development projects
  - Project management: PRINCE2 or PMI model
  - Model based systems engineering and traceability of system elements
  - Quality management in software context: e.g. Maturity Models like CMMI or SPICE
  - Typical organizational structures for software production
  - Development Processes (document-centric: e.g. V-Modell XT or openUP, agile: e.g. SCRUM or Crystal)

- Software engineering knowledge areas (software requirements, software design, software construction, software testing, software maintenance, software configuration management, software engineering management (engineering management), software engineering process, software engineering tools and methods, software quality), special focus on:
  - Software architecture (e.g. quality aspects, description, viewpoints, assessment)
  - Requirements engineering (e.g. user/system requirements)

- Test (e.g. white-box/black box, system/component/unit test, test coverage, test documentation), TDD Test-Driven Development
- Integration (e.g. continuous integration, software factories)

- Safety critical software intensive systems: DO-178B/C, software engineering for embedded systems IEC 61508, MISRA-Rule Sets
- Software tools e.g. Eclipse Process Framework Composer
- Implementation of software engineering disciplines in development organizations
- Ethical aspects of software engineering, software engineering as a professional discipline and the influence on society

Teaching methods

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

During the course an electronic information system describing software engineering methodologies is built using Eclipse Process Framework Composer. This repository is then used to specify different software engineering practices for case study development organizations.

Entry requirements

None

Recommendation: Practice in object-oriented programming (e.g. Java, Python, C++, C#), knowledge of UML are expected and needed.

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

--

Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Michael Schwind

Additional information

Recommended readings:

Brooks, F. (1995). *The Mythical Man-Month*. Addison-Wesley.

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

IEEE Computer Society (2013). *Software Engineering Body of Knowledge (SWEBOK V3).*

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

ISO/IEC 12207:2008: *Systems and software engineering - Software life cycle processes.*

ISO/IEC/IEEE 42010:2011: *Systems and software engineering - Architecture description.*

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

Office of Government Commerce (2009). *Managing Successful Projects with PRINCE2™* (2009 ed.).

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

Track Environmental Analysis

M-IE_EA.01 Environmental Analysis, Impact and Risk

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_EA.01	150 h	5 CP	1st semester	Summer semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Practical training: 22,5 h / 2 SWS	45 h / 4 SWS	105 h	Lecture: open Practical training: 15 students

Learning outcomes / Competences and qualifications profile

Upon completion of this course, students are able to explain the significance of sampling methods and sample preparation for the quality of analytical data. Students have learned to outline and apply an analytical approach for environmental problems, exhaust streams and process evaluation. They can explain and value the application of advanced analytical techniques and methods such as for example natural radioactivity, chemical fingerprints, ion sensitive electrodes and bioassays for the analysis of environmental samples. Students have got the skills to explain the significance of technical and scientific concepts used in environmental impact and risk assessment. They are able to describe the significance of risk and impact analysis in planning and decision-making processes and they can evaluate and critically discuss environmental impacts on ecosystems regarding interactions of organisms (e.g. vegetation, soil fauna, microorganisms) and abiotic system components. Students are skilled to value and apply selected environmental risk assessment procedures. Students know about the societal relevance of environmental analysis.

Content

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

- Analytical techniques for environmental sampling in e.g. in ecosystems, exhaust streams or flue gas or biogas plants with special focus on on-site measurement techniques
- Design of sampling/monitoring plan, choice of analytical technique and data evaluation
- Overview advanced topics of environmental analytics
- Environmental Impact Assessment and Strategic Environmental Assessment, rationale, legal frameworks
- Technological hazards, protection, mitigation, adaptation
- Managing real and perceived risks
- Field and 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, exhaust streams, biogas plants)
- Species sensitivity, indicator and sensitive species, bioassays in assessing ecosystem status
- Methods of impact assessment

Teaching methods

Lecture and practical training
Entry requirements None
Types of assessment Graded examination
Requirements for the award of credit points Passed assessment
Use of module (in other study programs) --
Weight towards final grade 5,42%
Person in charge of module Prof. Dr. Irmgard Buder, Prof. Dr. Daniela Lud
Additional information Recommended readings: Bizer, K. (2010). *The European Impact Assessment and the Environment*. Berlin Heidelberg: Springer. Glasson, J., Therivel, R., & Chadwick, A. (2012). *Introduction to environmental impact assessment.* London: Routledge. Jørgensen, S. E. (2010). *Handbook of ecological indicators for assessment of ecosystem health*. Boca Raton: CRC Press. Kellner, R., Mermet, J.-M., Otto, M., Valcarcel, M., & Widmer, H. M. (2004). *Analytical Chemistry: A Modern Approach to Analytical Science.* Weinheim: Viley VCH GmbH & Co. KGaA. Patt, A. G. et al. (2011). *Assessing vulnerability to global environmental change. Making research useful for adaptation decision making and policy*. London: Earthscan. Ricci, P. F. (2006). *Environmental and health risk assessment and management principles and practices.* Dordrecht: Springer. Skoog, D. A., Holler, F. J., & Crouch, S. R. (2006). *Instrumental Analysis Principles*. Belmont: Thomson Brooks/Cole.

M-IE_EA.02 Environmental Monitoring Research Project

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_EA.02	150 h	5 CP	1st semester	Summer semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Seminar-like lecture and practical exercises	45 h / 4 SWS	105 h	15 students

Learning outcomes / Competences and qualifications profile

Having passed the course students are familiar with the whole processing chain of environmental monitoring, from wireless sensors networks via geospatial databases to online presentation of data. They are able to analyze environmental monitoring problems and propose technical solutions. In practical exercises and projects they have built individual components of a whole distributed monitoring system. They have utilized components and methods from the domain of "Internet of Things (IoT)". The students have followed a problem-based approach. They set up and conducted a project of practical relevance for an (envisaged) customer.

Content

- Real world applications and problem identification
- Distributed architecture of environmental monitoring systems
- Smart sensors, embedded systems and low power design
- Wireless data transmission technologies such as Wifi, LoRa, or BLE
- Principles of Internet of Things (IoT)
- IoT communication protocols, platforms and dashboards
- Geodatabases
- Online data presentation and real-time plotting

Teaching methods

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

Entry requirements

None

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade 5,42%
Person in charge of module Prof. Dr.-Ing. Rolf Becker
Additional information Recommended readings: Kitanidis, P. K. (2008). *Introduction to geostatistics, applications in hydrogeology*. Cambridge University Press. Skøien, J. O., & Blöschl, G. (2006). *Sampling Scale Effects in Random Fields and Implications for Environmental Monitoring. Environmental Monitoring and Assessment*, Volume 114, Issue 1-3, pp 521-552. Tso, B., & Mather, P. M. (2009). *Classification methods for remotely sensed data (*2nd ed.). CRC Press. Zehe, E., Becker, R., Bardossy, A., & Plate, E. (2005). *Uncertainty of simulated catchment scale runoff response in the presence of threshold processes: role of initial soil moisture and precipitation.* Journal of Hydrology, 315 (1-4), 183 – 202.

M-IE_EA.03 Data Processing in Ecosystem Management

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_EA.03	150 h	5 CP	2nd semester	Summer semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: Data Management in Environmental Sciences 22,5 h / 2 semester hours per week (SWS) Practical training and excursions 22,5 h / 2 SWS	45 h / 4 SWS	105 h	25 students

Learning outcomes / Competences and qualifications 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. The students will have gained the competence to analyze, present and discuss knowledge transfer and data visualization strategies.

Content

1. Data Management in Environmental Sciences (lecture 2 SWS)
   - 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)

2. Practical training and excursions (2 SWS)
   - 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, giving presentations and writing reports.

Teaching methods

Lecture, seminar, practical training and excursions

Entry requirements

None

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Ute Hansen

Additional information

Recommended readings:

Artiola, J.F., Pepper, I.L. & Brusseau, M. (2004). *Environmental Monitoring and Characterization*. Elsevier Academic Press.

Gray, N.F. (2010). *Water Technology*. Elsevier.

Schlesinger, W.H., & Bernhardt, E.S. (2013). *Biogeochemistry.* Elsevier Academic Press.

Wildi, O. (2010). *Data Analysis in Vegetation Ecology*. Wiley.

Track Logistics

M-IE_LG.01 Logistics Networks Modelling

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_LG.01	150 h	5 CP	1st semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Exercise: 22,5 h / 2 SWS	45 h / 4 SWS	105 h	Lecture: open Exercise: 25 students

Learning outcomes / Competences and qualifications profile

This module covers the model-based description (modelling), the analysis and optimization of large, external logistic networks like worldwide supply-networks, traffic-nets or distribution- and procurement networks.

Having passed this module, students have gained a sound understanding of model based analyzing and optimization of logistic networks.

They are able to describe and analyze the main structures, processes as well as the management and control of large external networks.

They are also able to analyze the main objectives and to define Key Performance Indicators (KPI) to measure and evaluate the cost, service and performance of logistic networks.

Students can acquire the skills they need to optimize and stabilize logistic processes to create optimal and robust external networks.

Students are able to apply 4-step travel demand modelling to model the travel demand and transport supply of a given region.

Students can acquire the basis of discrete choice modelling and decision modelling.

The successful student can apply his knowledge of analysis, modelling and optimization of logistic networks and transport demand and supply of a given region in the above-mentioned areas 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.
- Travel demand modelling (Passenger) (4-Step modelling)
- Travel demand modelling (Freight)
- Travel demand forecasts
- Data collection and survey methodologies
- In hand travel demand modelling with PTV Visum.

Teaching methods

Lectures and exercise classes

Entry requirements

None

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. – Ing. Dirk Bruckmann

Additional information

Recommended readings:

Ben-Akiva, M. E., & Lerman, S. R. (post 2006, cop. 1985). *Discrete choice analysis. Theory and application to travel demand*. Cambridge, Mass, London: The MIT Press.

Ben-Akiva, M. E., & Lerman, S. R. (1987). *Discrete Choice Analysis: Theory and Application to Travel Demand.* Cambridge Massachusets: The MIT Press.

Cormen, T., Leiserson, C., Rivest, R., & Stein, C. (2009). *Introduction to Algorithms* (3rd ed.). MIT Press.

Diestel, R. (2016/17). *Graph Theory* (5th ed.). Springer.

Hensher, D. A., & Button, K. J. (2008). *Handbook of transport modelling* (2nd ed.). Amsterdam, London: Elsevier.

Klincewicz, J. G. (1996*). A dual algorithm for the uncapacitated hub location problem*. In Location Science 4 (3), pp.173184. DOI: 10.1016/S0966-8349(96)00010-1.

Ortúzar, S., de Dios, J., & Willumsen, L. G. (2011). *Modelling Transport. Fourth edition.* Chichester, West Sussex, United Kingdom: John Wiley et Sons.

Thie, P. R., & Keough, G. E. (2008). *An introduction to linear programming and game theory* (3rd ed.). Hoboken, N.J.: Wiley.

M-IE_LG.02 Advanced Logistic Control

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_LG.02	150 h	5 CP	1st semester	Summer semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Exercise: 22,5 h / 2 SWS)	45 h / 4 SWS	105 h	Lecture: open Exercise: 25 students

Learning outcomes / Competences and qualifications profile

Students having attended this module are able to model, analyze, optimize and control logistics processes by using IT-based methods. The capability to implement and manage electronic control systems for logistic processes (centralized as well as decentralized) in existing logistics networks (such as supply, production and procurement networks) has been in the focus of this learning unit.

In addition to this, students have gained knowledge about information technologies, optimization methods, and control approaches, that provide the basis for fifth party logistics concepts guaranteeing a real-time fully integrated procurement, production and distribution process in industry environments.

Successful students also acquired knowledge and experiences in:

- information technology for decentralized logistics systems such as location-based and ICT-supported online systems and multi-agent systems.
- on and off-line optimization methods for logistics and production processes (based on classical operations research as well as exact and heuristic problem solution methods).
- ability to model and solve a real-world logistics problem by using the concepts described above.
- developing own approaches of IT-based logistics applications by studying and using domain-specific scientific literature.
- implementing and evaluating the advanced logistics control concepts using Intelligent Multi-Agent and Web-based Technologies.

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)
- 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 CO_2 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

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Michael Schwind

Additional information

Recommended readings:

Belfimine, G., Caire, G., & Greenwood, D. (2007). *Developing Multi-Agent Systems with JADE*. Wiley.

Bordini, R., Hübner, J., & Wooldrige, M. (2007). *Programming Multi-Agents Systems with AgentSpeak Using Jason.*

Cachon, G., & Terwiesch, C. (2009). *Matching Supply with Demand: An Introduction to Operations Management.* NY: McGraw-Hill.

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

Jacobs, F. R., & Chase, R. B. (2008). *Operations and Supply Chain Management: The Core*. NY: McGraw-Hill.

Rothlauf, F. *Design of Modern Heuristics: Principles and Application* (Natural Computing Series*).* Springer.

Russel, & Norvig, *Artificial Intelligence: A Modern Approach* (3rd ed.). New Jersey: Prentice Hall.

Stevenson (2009). *Operations Management.* NY: McGraw-Hill.

M-IE_LG.03 Advanced Logistics Concepts

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_LG.03	150 h	5 CP	2nd semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Seminar 45 h / 4 semester hours per week (SWS)	45 h / 4 SWS	105 h	25 students

Learning outcomes / Competences and qualifications profile

Students having attended this module are able to identify, to describe and to present new logistic concepts for production processes, supply chain management (SCM) and transportation of freight and passengers. They know about present and future challenges and opportunities of new, innovative solutions for the design of logistics process, infrastructures and moveable equipment.

Successful students also have got knowledge and experiences in:

- assessing literature and other sources presenting recent research results for their specific topic.
- finding/understanding and summarizing main ideas of scientific articles
- structuring and writing a scientific paper about a logistics topic.
- integrating their argumentation in the broader context of their specific topic.
- presenting their findings to a larger group of audients.
- discussing and defending the results of their research papers to the teacher and other students.

Content

The content depends of the topics the students choose from the list of topics presented by the teacher. The topics can be in the field of production logistics, transportation logistics, supply chain management and information logistics.

Teaching methods

Tuition in seminars and presentations

Entry requirements

None

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade 5,42%
Person in charge of module Prof. Dr.-Ing. Dirk Bruckmann
Additional information Literature differs between courses and depends on the selected topics of the seminar.

Track Cyber-Physical Systems

M-IE_CP.01 Distributed Systems

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_CP.01	150 h	5 CP	1st semester	Summer semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Practical training: 11,25 h / 1 SWS Seminar: 11,25 h / 1 SWS	45 h / 4 SWS	105 h	Lecture: open Practical Training, Seminar: 25 students

Learning outcomes / Competences and qualifications profile

This module starts with an overview on distributed systems in general on the base of operating-systems knowledge. The general knowledge is then applied to different specializations in domains, such as Ambient Intelligence Environments, Internet-of-Things, Logistics Control, Geo- / Environmental monitoring, Mobile Computing as well as Distributed Databases.

Having completed this module students know a variety of different approaches for designing and implementing complex distributed systems. They are able to analyze application problems in this context, deduce requirements and evaluate architectural approaches. They have gained experience and in-depth knowledge in selected architectures, protocols, frameworks, and tools.

One core outcome of this course is thus experience in designing information models as well as in analyzing effects of design decisions of the information model to feasibility and performance of communication in distributed systems.

Students are able to apply appropriate design patterns in different contexts. They know the appropriate use of components as well as their limitations. Students are familiar with the OMG Data Distribution Service architecture and common tools such as Enterprise Architect for information modeling in depth. They are able to develop or apply their own ideas in this field in different contexts.

Content

- Architectures and types of Distributed Systems: Grid, Cloud, P2P-Systems, Virtualization, etc.
- Technologies (theory, methodology, design patterns, capabilities, performance):
- Enterprise architecture design patterns
- Distributed object models
- Near real time publish-subscribe: OMG Data Distribution Service
- Model-based systems engineering of distributed applications: Enterprise Architecture Frameworks
- 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

None

Recommendation: Practice in object-oriented programming (e.g. 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 examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Michael Schwind

Additional information

Recommended readings:

Andreev (2012). *Internet of Things, Smart Spaces, and Next Generation Networking.*

Chakravarthy, & Jiang (2010). *Stream Data Processing: A Quality of Service Perspective: Modeling, Scheduling, Load Shedding, and Complex Event Processing.*

Daigneau (2011). *Service Design Patterns: Fundamental Design Solutions for SOAP/WSDL and RESTful Web Services.*

Denecke (2012). *Event-Driven Surveillance: Possibilities and Challenges.*

Etzion, & Niblett (2010). *Event Processing in Action.*

Fowler (2002). *Patterns of Enterprise Application Architecture.*

Hersent et al. (2012). *The Internet of Things: Key Applications and Protocols*.

Hohpe, & Woolf (2003). *Enterprise Integration Patterns: Designing, Building, and Deploying Messaging Solutions.*

Hossain, & Poor (2012). *Smart Grid Communications and Networking.*

Lankhorst (2012). *Enterprise Architecture at Work: Modelling, Communication and Analysis.*

Luckham (2002). *The Power of Events: An Introduction to Complex Event Processing in Distributed Enterprise Systems.*

Luckham (2011). *Event Processing for Business: Organizing the Real-Time Enterprise.*

Van Steen, M & Tanenbaum, A. S. (2017). *Distributed Systems* (Third edition), 2017

Pfister (2011). *Getting Started with the Internet of Things: Connecting Sensors and Microcontrollers to the Cloud.*

Ranadive (2013). *Enterprise Application Integration: Enabling the Event-Driven Enterprise with CDROM.*

Taylor et al. (2009). *Event-Driven Architecture: How SOA Enables the Real-Time Enterprise*.

Uckelmann et al. (2011). *Architecting the Internet of Things.*

Wang et al. (2009). *Quantitative Quality of Service for Grid Computing: Applications for Heterogeneity, Large-Scale Distribution, and Dynamic Environments.*

Weber (2012). *Complex Event Processing – Unabridged Guide*

Wyszkowski (2012). *ESB in effective synchronization of large volume measurements data: Exploiting ESB facilities to build effective and scalable, service-oriented data distribution application.*

Zhou (2012). *The Internet of Things in the Cloud: A Middleware Perspective.*

M-IE_CP.02 Real-Time Embedded Systems

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_CP.03	150 h	5 CP	2nd semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Seminar-like lecture and practical exercises	45 h / 4 SWS	105 h	15 students

Learning outcomes / Competences and qualifications profile

The term embedded system specifies a computing unit which is in general not directly visible as a computer. Typical examples for embedded systems are mobile phones, washing machine controllers, pace makers or smart watches. The core of such systems are chips with a lot of internal peripherals integrated. Sensors and actuators can be connected easily to interact with users and/or environment.

Embedded systems development has become very popular which is significantly driven by the maker community. Systems like Arduino, ESP32, or Raspberry PI are examples of widely used embedded systems for everybody with a broad spectrum of integrated development environments and example projects making firsts steps easy. Nevertheless, the professional development of embedded systems needs some special engineering abilities including basic knowledge in processing and sensor hardware as well as software development. In this course special emphasis is put on real-time principles, such as fast response on external events with interrupts and real-time scheduling.

Having passed this module, students are able to specify and implement simple embedded systems based on the needs and specifications of the customer's application. Moreover, they know details related to the implementation of embedded systems. Students are able to develop or apply their own ideas in different contexts of the embedded systems domain.

Content

- Architecture of microcontrollers and the main peripherals
- Fundamentals of digital and analog input and output
- Serial bus systems for integrated circuit interconnection
- Different sensor types and their interfacing
- Real-time requirements
- Interrupt handling
- Principles of embedded real-time operating systems
- Wireless data-transmission
- Low-power design

Teaching methods

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

Entry requirements

None

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade

5,42%

Person in charge of module

Prof. Dr.-Ing. Rolf Becker

Additional information

Recommended readings:

Ashenden, P. (2008). *The Designer's Guide to VHDL* (Morgan Kaufmann Series in Systems on Silicon). Morgan Kaufmann.

Borre, K. et al. (2007). *A Software-Defined GPS and Galileo receiver: A Single Frequency Approach (Applied and Numerical Harmonic Analysis).* Boston: Birkhäuser.

Hamacher, C., et al. (2012). *Computer Organization and Embedded Systems* (6th ed.). McGraw Hill.

Kaplan, E.D., & Hegarty, C.J. (2006). *Understanding GPS: Principles and Applications* (2nd ed.). Boston: Artech House.

Marwedel, P. (2010). *Embedded System Design: Embedded System Foundations of Cyber-Physical Systems* (2nd ed.). Springer.

Misra, P., & Enge, P. (2006). *Global Positioning System: Signals, Measurements, and Performance* (2nd ed.). Licoln: Ganga-Jamuna Press.

Parkinson, B., & Spilker, J.J. (1996). *Global Positioning System: Theory and Application Vol. I and Vol II.* Washington: American Institute of Aeronautics and Astronautics, Inc.

Press, W.H. et al. (1992). *Numerical Recipies: The Art of Scientific Computing* (3rd ed.). Cambridge University Press.

van Diggelen, F. (2009). *A-GPS: Assisted GPS, GNSS, and SBAS (GNSS Technology and Applications*). Boston: Artech House.

Track Artificial Intelligence

M-IE_AI.01 Artificial Intelligence and its Application

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_AI.01	150 h	5 CP	1st semester	Summer semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Lecture: 22,5 h / 2 semester hours per week (SWS) Exercise: 22,5 h / 2 SWS	45 h / 4 SWS	105 h	Lecture: open 25 students

Learning outcomes / Competences and qualifications profile

This course introduces students to the fundamentals of artificial intelligence. After a small introductory part to the different aspects of AI, it focuses on the knowledge representation, inference / reasoning and autonomous planning perspectives of AI systems. The topics are motivated by examples out of the domains of smart environments, assistive systems and industry 4.0.

Having passed this module, students have acquired an understanding of AI-technologies: its history, functionality and potential, as well as its limitations. They are able to design systems that includes knowledge representation as well as elements to infer knowledge and perform planning based on given information and conceptional knowledge. However, students gained the fundamentals to develop these systems for fully observable, deterministic environments as well as for partial observable and nondeterministic environments with uncertain knowledge. Furthermore, the module enables students to develop or apply their own ideas in this field in different contexts. Students also know about the societal context of AI. The learn to assess the ethical and social impact of AI applications.

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 or C++ based. The ability to use higher mathematical concepts is expected. Furthermore, students attending this course should have an elementary knowledge in algorithms and are roughly familiar with fundamental search strategies and Boolean algebra.

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Christian Ressel

Additional information

Recommended readings:

Corchado, J. M. et al. (2010*). Ambient Intelligence and Future Trends -International Symposium on Ambient Intelligence.* Berlin: Springer.

Omatu, S. et al. (2009). *Distributed Computing, Artificial Intelligence, Bioinformatics, Soft Computing, and Ambient Assisted Living: 10th International Work-Conference*. Berlin: Springer.

Russel, S.; & Norvig, P. (2010). *Artificial Intelligence - A modern approach*. Pearson, Prentice Hall.

M-IE_AI.02 Machine Learning

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_AI.02	150 h	5 CP	2nd semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Seminar-like lecture and practical exercises	45 h / 4 SWS	105 h	15 students

Learning outcomes / Competences and qualifications profile

The term “Machine Learning” subsumes a set of algorithms which enable computers to perform tasks without having been programmed specifically to solve these. The actions taken or conclusions drawn (inference) are based on patterns identified in the available real-world data of the specific domain. Algorithmic models with free parameters are used as procedural skeleton for problem solving. These free parameters are tuned based on data an optimized with respect to a chosen performance score, e.g. a parametric curve is fitted to observed data such that the distance between model (predicted data) and real data is minimal, multidimensional data is clustered in a way that the inner class similarity is small and interclass dissimilarity is large, weights of convolutional neural networks are optimized such that most cats in a set of images are found and the false detection rate is low. The phase of parameter optimization is referred to as learning.

Professional application of ML is art. It is not enough to know how to call random algorithms from available libraries. A true machine learning expert has been gaining deep understanding of all underlying principles as well as a wide variety of practical experience including critical reflection. This enables her and him to perform reasonable model selection, feature engineering, hyperparameter optimization and performance analysis.

Having passed this module students are aware of the challenges of machine learning. They have gained basic understanding not just of algorithms but also critical reflection, which allows them to perform problem-oriented feature engineering, to find appropriate models and hyperparameter configurations. They have learned to step back and look at the data analysis problem from a distance. They are aware of the importance of critical questions such as: “Is the information content of my data principally enough to fulfill the task at all? Do I have enough data to train, test and validate my method? Is the model I have chosen the right one? Does it make sense to apply additional data transformation on the available features to achieve better model performance? What is the effect of a particular model hyperparameter? How do I assess the model performance and how to I assess the method of determining the model performance?”

Part of this course is inspired by “Machine Learning” (cs229), Stanford Univ. (Andrew Ng et al., 2018)

Content

- Introduction to Machine Learning: Overview
- Multivariate linear regression: feature scaling, gradient descent, learning rate and hyperparameters
- Large scale machine learning: stochastic gradient descent
- Classification based on Logistic regression: Hypothesis, cost function, multiclass classification
- Nonlinear hypotheses in classification problems
- Simple neural networks: model representation, cost function, back propagation, gradient check
- Model selection, training, validation, testing
- High bias (underfit) vs. high variance (overfit), regularization
- Support vector machine as kernel-based method
- Cluster analysis: k-means

- Multivariate Gaussian: anomaly detection, recommender system
- Reinforcement Learning: Q-learning, SARSA

Teaching methods

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

Entry requirements

None

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade

5,42%

Person in charge of module

Prof. Dr. Frank Zimmer

Additional information

Part of this course is inspired by “Machine Learning” (cs229), Stanford Univ. (Andrew Ng et al., 2018)

The 2018 version of Andrew Ng’s lecture is still available on Coursera. The Exercises of 2018 are based on Matlab.

The cs229 course as of 2019 is organized differently. Exercises are based on Python.

Further reading:

Buduma, N. (2017). *Fundamentals of Deep Learning: Designing Next-Generation Machine Intelligence Algorithms.* O’Reilly UK Ltd.

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

Chollet, F. (2017). *Deep Learning with Python*. Manning.

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

Géron, A. (2019). *Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems* (2nd ed.). O’Reilly UK Ltd.

Ghatak, A. (2017). *Machine Learning with R.* Springer Nature Singapore Pte Ltd.

Goodfellow, I., Bengiom, Y., & Courville, A. (2017). *Deep Learning.* Cambridge, MA, London: The MIT Press.

Goyal, P., Pandey, S., & Jain, K. (2018). *Deep Learning for Natural Language Processing: Creating Neural Networks with Python* (1st ed.). Apress.

Lapan, M. (2018). *Deep Reinforcement Learning Hands-On: Apply modern RL methods, with deep Q-networks, value iteration, policy gradients, TRPO, AlphaGo Zero and more*. Packt Publishing.

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

Raschka, S., & Mirjalili, V. (2017). *Python Machine Learning - Second Edition: Machine Learning and Deep Learning with Python, scikit-learn, and TensorFlow* (2nd revised ed.). Packt Publishing.

Sutton, R., S.; & Barto, A. G. (2018). *Reinforcement Learning: An Introduction* (2nd ed.). Cambridge, MA: The MIT Press.

Vasilev, I., Slater, D., Sopacagna, G., Roelants, P., & Zocca, V. (2019). *Python Deep Learning: Exploring deep learning techniques and neural network architectures with PyTorch, Keras, and TensorFlow* (2nd revised ed.). Packt Publishing.

Witten, I., H., Frank, E., & Hall, M., A. (2016). *Data Mining: Practical Machine Learning Tools and Techniques* (4th ed.). Cambridge, MA: Morgan Kaufmann, Elsevier.

Zafar, I., Tzanidou, G., Burton, R., Patel, N., & Araujo, L. (2018). *Hands-On Convolutional Neural Networks with TensorFlow: Solve computer vision problems with modeling in TensorFlow and Python*. Packt Publishing.

M-IE_AI.03 Advanced AI Application

Code	Workload	Credits	Level of module	Frequency of offer	Duration
M-IE_AI.03	150 h	5 CP	2nd semester	Winter semester	1 semester

Courses	Teaching time	Self-study	Planned group size
Seminar 45 h / 4 semester hours per week (SWS)	45 h / 4 SWS	105 h	25 students

Learning outcomes / Competences and qualifications profile

Students having attended this module are able to work scientifically on specific topics of Artificial Intelligence, such as Machine Vision, Autonomous Driving, Speech Recognition or Text Mining. They know about the present chances and risks, as well as challenges and opportunities of AI applications. They are able to design concepts for innovative AI applications including implementation concepts and related research and business plans.

Successful students also have got knowledge and experiences in:

- assessing literature and other sources presenting recent research results for their specific topic.
- finding/understanding and summarizing main ideas of scientific articles
- structuring and writing a scientific paper about a logistics topic.
- integrating their argumentation in the broader context of their specific topic.
- presenting their findings to a larger group of audients.
- discussing and defending the results of their research papers to the teacher and other students.

Content

The content depends of the topics the students choose from the list of topics presented by the teacher. The topics can be in the field of production logistics, transportation logistics, supply chain management and information logistics.

Teaching methods

Tuition in seminars and presentations

Entry requirements

None

Types of assessment

Graded examination

Requirements for the award of credit points

Passed assessment

Use of module (in other study programs)

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Weight towards final grade 5,42%
Person in charge of module Prof. Dr. Michael Schwind
Additional information Literature differs according to the selected topics of the seminar.