MODULE HANDBOOK

Master of Science

Data Science (FI-MADS-60)

60 ECTS

Distance Learning

INTERNATIONAL
UNIVERSITY OF
APPLIED SCIENCES

Classification: Non-consecutive

Contents

2020-06-01

1. Semester

Advanced Statistics

Module Code: DLMDSAS

Module Type	Admission Requirements	Study Level	CP	Student Workload
see curriculum	None	MA	5	150 h

Semester / Term	Duration	Regularly offered in	Language of Instruction
see curriculum	Minimum 1 semester	WiSe/SoSe	English

Module Coordinator
N.N. (Advanced Statistics)

Contributing Courses to Module
▪ Advanced Statistics (DLMDSAS01)

Module Exam Type	
Module Exam Study Format: Distance Learning Workbook	**Split Exam**
Weight of Module see curriculum	

Module Contents

- Introduction to statistics
- Important probability distributions and their applications
- Bayesian statistics
- Descriptive statistics
- Data visualization
- Parameter estimation
- Hypothesis tests

Learning Outcomes	
Advanced Statistics On successful completion, students will be able to ▪ understand the fundamental building blocks of statistics. ▪ analyze stochastic data in terms of the underlying probability distributions. ▪ utilize Bayesian statistics techniques. ▪ summarize the properties of observed data using descriptive statistics. ▪ apply data visualization techniques to design graphics that illustrate the behavior of observed data. ▪ evaluate model parameters using parameter estimation techniques. ▪ create hypothesis tests to discriminate between several model classes.	
Links to other Modules within the Study Program This module is similar to other modules in the field of Methods.	**Links to other Study Programs of IUBH** All Master Programmes in the Business & Management field.

Advanced Statistics

Course Code: DLMDSAS01

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	DLMDSAM01

Course Description

Nearly all processes in nature and technical or scientific scenarios are not deterministic but stochastic. Therefore, these processes must be described in terms of probabilities and probability density distributions.After defining and introducing the fundamental concepts of statistics, the course will cover important probability distributions and their prevalence in application scenarios; discuss descriptive techniques to summarize and visualize data effectively; and discuss the Bayesian approach to statistics.Estimating parameters is a key ingredient in optimizing data models, and the course will give a thorough overview of the most important techniques.Hypothesis testing is a crucial aspect in establishing the observation of new effects and determination of the significance of statistical effects. Special focus will be given to the correct interpretation of p-Values and the correct procedure for multiple hypothesis tests.

Course Outcomes

On successful completion, students will be able to

- understand the fundamental building blocks of statistics.
- analyze stochastic data in terms of the underlying probability distributions.
- utilize Bayesian statistics techniques.
- summarize the properties of observed data using descriptive statistics.
- apply data visualization techniques to design graphics that illustrate the behavior of observed data.
- evaluate model parameters using parameter estimation techniques.
- create hypothesis tests to discriminate between several model classes.

Contents

6. Parameter Estimation
   - 6.1 Maximum Likelihood
   - 6.2 Ordinary Least Squares
   - 6.3 Expectation Maximization (EM)
   - 6.4 Lasso and Ridge Regularization
   - 6.5 Propagation of Uncertainties

7. Hypothesis Test
   - 7.1 Error of 1st and 2nd Kind
   - 7.2 Multiple Hypothesis Tests
   - 7.3 p-Value

Literature

Compulsory Reading

Further Reading

- Bishop, C. (2007). Pattern recognition and machine learning (2nd ed.). Singapore: Springer.
- Bruce, P., & Bruce, A. (2017). Statistics for data scientists: 50 essential concepts. Sebastopol, CA: O’Reilley Publishing.
- Downey, A. (2013). Think Bayes. Sebastopol, CA: O’Reilley Publishing.
- Downey, A. (2014). Think stats. Sebastopol, CA: O’Reilley Publishing.
- McKay, D. (2003). Information theory, inference and learning algorithms. Cambridge: Cambridge University Press.
- Reinhart, A. (2015). Statistics done wrong. San Francisco, CA: No Starch Press.

Study Format Distance Learning

Study Format	**Course Type**
Distance Learning	Online Lecture

Information about the examination	
Examination Admission Requirements	**BOLK:** yes **Course Evaluation:** no
Type of Exam	Workbook

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
110 h	0 h	20 h	20 h	0 h	150 h

Instructional Methods

- ☐ Learning Sprints®
- ☑ Course Book
- ☐ Vodcast
- ☑ Shortcast
- ☐ Audio
- ☐ Exam Template
- ☑ Review Book
- ☐ Creative Lab
- ☑ Guideline
- ☑ Live Tutorium/Course Feed

Use Case and Evaluation

Module Code: DLMDSUCE

Module Type	Admission Requirements	Study Level	CP	Student Workload
see curriculum	none	MA	5	150 h

Semester / Term	Duration	Regularly offered in	Language of Instruction
see curriculum	Minimum 1 semester	WiSe/SoSe	English

Module Coordinator

Prof. Dr. Ulrich Kerzel (Use Case and Evaluation)

Contributing Courses to Module

- Use Case and Evaluation (DLMDSUCE01)

Module Exam Type

Module Exam	Split Exam
Study Format: Fernstudium Oral Assignment	

Weight of Module

see curriculum

Module Contents

- Use case evaluation
- Model-centric evaluation
- Business-centric evaluation
- Monitoring
- Avoiding common fallacies
- Change management

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Learning Outcomes

Use Case and Evaluation

On successful completion, students will be able to

- analyze use cases and their requirements regarding the project objectives.
- apply common metrics to evaluate predictions.
- evaluate key performance indicators to asses projects from a business perspective.
- create monitoring tools that can be used to constantly evaluate the status quo of a project.
- understand common fallacies and how to avoid them.

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Links to other Modules within the Study Program

This module is similar to other modules in the fields of Data Science & Artificial Intelligence

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Links to other Study Programs of IUBH

All Master Programmes in the IT & Technology fields

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Use Case and Evaluation

Course Code: DLMDSUCE01

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	none

Course Description

The evaluation and definition of use cases is the fundamental groundwork from which the projects can be defined. This does not only include the scope and technical requirements of a project but also how value can be derived from the project. A crucial aspect is the definition of what makes a project successful, both in terms of a technical evaluation as well as a business centric perspective and how the status quo can be monitored effectively during the progress of a project. The course also discusses how to avoid common fallacies and understand the implications of introducing data-driven decisions into traditional management structures.

Course Outcomes

On successful completion, students will be able to

- analyze use cases and their requirements regarding the project objectives.
- apply common metrics to evaluate predictions.
- evaluate key performance indicators to asses projects from a business perspective.
- create monitoring tools that can be used to constantly evaluate the status quo of a project.
- understand common fallacies and how to avoid them.

Contents

1. Use Case Evaluation
   - 1.1 Identification of Use Cases
   - 1.2 Specifying Use Case Requirements
   - 1.3 Data Sources and Data Handling Classification

2. Model-centric Evaluation
   - 2.1 Common Metrics for Regression and Classification
   - 2.2 Visual Aides

3. Business-centric Evaluation
   - 3.1 Cost Function and Optimal Point Estimators
   - 3.2 Evaluation Using KPIs
   - 3.3 A/B Test

4. Monitoring
   4.1 Visual Monitoring Using Dashboards
   4.2 Automated Reporting and Alerting

5. Avoiding Common Fallacies
   5.1 Cognitive Biases
   5.2 Statistical Effects
   5.3 Change Management: Transformation to a Data-driven Company

Literature

Compulsory Reading

Further Reading

- Few, S. (2013). Information dashboard design: Displaying data for at-a-glance monitoring (2nd ed.). Burlingame, CA: Analytics Press.
- Gilliland, M., Tashman, L., & Sglavo, U. (2016). Business forecasting: Practical problems and solutions. Hoboken, NJ: John Wiley & Sons.
- Hyndman, R. (2018). Forecasting: Principles and practices (2nd ed.). OTexts.
- Kahneman, D. (2012). Thinking, fast and slow. London: Penguin.
- Parmenter, D. (2015). Key Performance Indicators (KPI): Developing, implementing, and using winning KPIs (3rd ed.). Hoboken, NJ: John Wiley & Sons.

Study Format Fernstudium

Study Format	Course Type
Fernstudium	Online Lecture

Information about the examination	
Examination Admission Requirements	**BOLK:** yes **Course Evaluation:** no
Type of Exam	Oral Assignment

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
110 h	0 h	20 h	20 h	0 h	150 h

Instructional Methods

- ☐ Learning Sprints®
- ☑ Course Book
- ☐ Vodcast
- ☑ Shortcast
- ☑ Audio
- ☐ Exam Template
- ☐ Review Book
- ☐ Creative Lab
- ☑ Guideline
- ☑ Live Tutorium/Course Feed

Seminar: Current Topics in Data Science

Module Code: DLMDSSCTDS

Module Type	Admission Requirements	Study Level	CP	Student Workload
see curriculum	none	MA	5	150 h

Semester / Term	Duration	Regularly offered in	Language of Instruction
see curriculum	Minimum 1 semester	WiSe/SoSe	English

Module Coordinator
Prof. Dr. Tim Schlippe (Seminar: Current Topics in Data Science)

Contributing Courses to Module
▪ Seminar: Current Topics in Data Science (DLMDSSCTDS01)

Module Exam Type	
Module Exam Study Format: Fernstudium Written Assessment: Research Essay	**Split Exam**
Weight of Module see curriculum	

Module Contents
In this module, students will reflect on current developments in data science. To this end, pertinent topics will be introduced via articles, that are then critically evaluated by the students in the form of a written essay.

Learning Outcomes	
Seminar: Current Topics in Data Science On successful completion, students will be able to ▪ identify current research trends and topics in data science. ▪ outline a selected topic in the form of a written essay. ▪ explain relevant assumptions and design choices pertaining to the topic of choice. ▪ relate the chosen topic to comparable approaches. ▪ name and describe potential applications for the chosen topic's concepts.	
Links to other Modules within the Study Program This module is similar to other modules in the fields of Data Science & Artificial Intelligence	**Links to other Study Programs of IUBH** All Master Programmes in the IT & Technology fields

Seminar: Current Topics in Data Science

Course Code: DLMDSSCTDS01

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	none

Course Description

The theory and applications of data science are constantly evolving, with new models and model variations being proposed at a steady rate. Innovative methodological approaches as well as fresh application possibilities are also being continuously developed. This course aims to familiarize the students with the current trends in this rapidly-changing environment. The students learn to independently analyze selected topics and case studies and link them with well-known concepts, as well as critically question and discuss them.

Course Outcomes

On successful completion, students will be able to

- identify current research trends and topics in data science.
- outline a selected topic in the form of a written essay.
- explain relevant assumptions and design choices pertaining to the topic of choice.
- relate the chosen topic to comparable approaches.
- name and describe potential applications for the chosen topic's concepts.

Contents

- The seminar covers current topics in data science. Each participant must write a seminar paper on a topic assigned to him/her.

Literature

Compulsory Reading

Further Reading

- Bishop, C. M. (2016). Pattern recognition and machine learning. New York, NY: Springer.
- James, G., Witten, D., Hastie, T., & Tibshirani, R. (2017). Introduction to statistical learning. New York, NY: Springer.
- Kirk, M. (2017). Thoughtful machine learning with Python. Sebastopol, CA: O'Reilly.
- Kleppmann, M. (2017). Designing data-intensive applications: The big ideas behind reliable, scalable, and maintainable systems. Sebastopol, CA: O'Reilly.

Study Format Fernstudium

Study Format	Course Type
Fernstudium	Seminar

Information about the examination	
Examination Admission Requirements	**BOLK:** no **Course Evaluation:** no
Type of Exam	Written Assessment: Research Essay

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
120 h	0 h	30 h	0 h	0 h	150 h

Instructional Methods

- ☐ Learning Sprints®
- ☐ Course Book
- ☐ Vodcast
- ☐ Shortcast
- ☐ Audio
- ☐ Exam Template
- ☐ Review Book
- ☐ Creative Lab
- ☑ Guideline
- ☐ Live Tutorium/Course Feed

Machine Learning

Module Code: DLMDSML

Module Type	Admission Requirements	Study Level	CP	Student Workload
see curriculum	DLMDSAM01, DLMDSPWP01	MA	5	150 h

Semester / Term	Duration	Regularly offered in	Language of Instruction
see curriculum	Minimum 1 semester	WiSe/SoSe	English

Module Coordinator

Prof. Dr. Thomas Zöller (Machine Learning)

Contributing Courses to Module

- Machine Learning (DLMDSML01)

Module Exam Type

Module Exam	Split Exam
Study Format: Distance Learning Exam	

Weight of Module

see curriculum

Module Contents

- Supervised, unsupervised, and reinforcement learning approaches
- Regression and classification learning problems
- Estimation of functional dependencies via regression techniques
- Data clustering
- Support vector machines, large margin classification
- Decision tree learning

Learning Outcomes	
Machine Learning On successful completion, students will be able to ▪ know different machine learning model classes. ▪ comprehend the difference between supervised, unsupervised, and reinforcement learning methods. ▪ understand common machine learning models. ▪ analyze trade-offs in the application of different models. ▪ appropriately choose machine learning models according to a given task.	
Links to other Modules within the Study Program This module is similar to other modules in the fields of Data Science & Artificial Intelligence	**Links to other Study Programs of IUBH** All Master Programmes in the IT & Technology fields

Machine Learning

Course Code: DLMDSML01

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	DLMDSAM01, DLMDSPWP01

Course Description

Machine learning is a field of scientific study concerned with algorithmic techniques that enable machines to learn performance on a given task via the discovery of patterns or regularities in exemplary data. Consequently, its methods commonly draw upon a statistical basis in conjunction with the computational capabilities of modern computing hardware. This course aims to acquaint the student with the main branches of machine learning and provide a thorough introduction to the most widely used approaches and methods in this field.

Course Outcomes

On successful completion, students will be able to

- know different machine learning model classes.
- comprehend the difference between supervised, unsupervised, and reinforcement learning methods.
- understand common machine learning models.
- analyze trade-offs in the application of different models.
- appropriately choose machine learning models according to a given task.

Contents

1. Introduction to Machine Learning
   - 1.1 Regression & Classification
   - 1.2 Supervised & Unsupervised Learning
   - 1.3 Reinforcement Learning
2. Clustering
   - 2.1 Introduction to clustering
   - 2.2 K-Means
   - 2.3 Expectation Maximization
   - 2.4 DBScan
   - 2.5 Hierarchical Clustering

3. Regression
   - 3.1 Linear & Non-linear Regression
   - 3.2 Logistic Regression
   - 3.3 Quantile Regression
   - 3.4 Multivariate Regression
   - 3.5 Lasso & Ridge Regression

4. Support Vector Machines
   - 4.1 Introduction to Support Vector Machines
   - 4.2 SVM for Classification
   - 4.3 SVM for Regression

5. Decision Trees
   - 5.1 Introduction to Decision Trees
   - 5.2 Decision Trees for Classification
   - 5.3 Decision Trees for Regression

6. Genetic Algorithms
   - 6.1 Introduction to Genetic Algorithms
   - 6.2 Applications of Genetic Algorithms

Literature

Compulsory Reading

Further Reading

- Bishop, C. M. (2011). Pattern recognition and machine learning. New York, NY: Springer.
- Efron, B., & Hastie, T. (2016). Computer age statistical inference. Cambridge: Cambridge University Press.
- Muller, A. C., & Guido, S. (2016). Introduction to machine learning with Python. Sebastopol, CA: O’Reilly.
- VanderPlas, J. (2017). Python data science handbook. Sebastopol, CA: O’Reilly Publishing.

Study Format Distance Learning

Study Format Distance Learning	**Course Type** Online Lecture

Information about the examination	
Examination Admission Requirements	**BOLK:** yes **Course Evaluation:** no
Type of Exam	Exam

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
90 h	0 h	30 h	30 h	0 h	150 h

Instructional Methods

- ☐ Learning Sprints®
- ☑ Course Book
- ☐ Vodcast
- ☑ Shortcast
- ☑ Audio
- ☑ Exam Template
- ☐ Review Book
- ☐ Creative Lab
- ☐ Guideline
- ☑ Live Tutorium/Course Feed

Deep Learning

Module Code: DLMDSDL

Module Type	Admission Requirements	Study Level	CP	Student Workload
see curriculum	DLMDSAM01, DLMDSPWP01, DLMDSML01	MA	5	150 h

Semester / Term	Duration	Regularly offered in	Language of Instruction
see curriculum	Minimum 1 semester	WiSe/SoSe	English

Module Coordinator
Prof. Dr. Thomas Zöller (Deep Learning)

Contributing Courses to Module
▪ Deep Learning (DLMDSDL01)

Module Exam Type	
Module Exam Study Format: Distance Learning Oral Assignment	**Split Exam**
Weight of Module see curriculum	

Module Contents

- Introduction to neural networks and deep earning
- Network architectures
- Neural network training
- Alternative training methods
- Further network architectures

Learning Outcomes

Deep Learning

On successful completion, students will be able to

- comprehend the fundamental building blocks of neural networks.
- understand concepts in deep learning.
- analyze the relevant deep learning architecture in a wide range of application scenarios.
- create deep learning models.
- utilize alternative methods to train deep learning models.

Links to other Modules within the Study Program	**Links to other Study Programs of IUBH**
This module is similar to other modules in the fields of Data Science & Artificial Intelligence	All Master Programmes in the IT & Technology fields

Deep Learning

Course Code: DLMDSDL01

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	DLMDSAM01, DLMDSPWP01, DLMDSML01

Course Description

Neural networks and deep learning approaches have revolutionized the fields of data science and artificial intelligence in recent years, and applications built on these techniques have reached or surpassed human performance in many specialized applications.After a short review of the origins of neural networks and deep learning, this course will cover the most common neural network architectures and discuss in detail how neural networks are trained using dedicated data samples, avoiding common pitfalls such as overtraining.The course includes a detailed overview of alternative methods to train neural networks and further network architectures which are relevant in a wide range of specialized application scenarios.

Course Outcomes

On successful completion, students will be able to

- comprehend the fundamental building blocks of neural networks.
- understand concepts in deep learning.
- analyze the relevant deep learning architecture in a wide range of application scenarios.
- create deep learning models.
- utilize alternative methods to train deep learning models.

Contents

1. Introduction to Neural Network and Deep Learning
   - 1.1 The Biological Brain
   - 1.2 Perceptron and Multi-Layer Perceptrons
2. Network Architectures
   - 2.1 Feed-Forward Networks
   - 2.2 Convolutional Networks
   - 2.3 Recurrent Networks, Memory Cells and LSTMs
3. Neural Network Training
   - 3.1 Weight Initialization and Transfer Function
   - 3.2 Backpropagation and Gradient Descent
   - 3.3 Regularization and Overtraining

4. Alternative Training Methods
    4.1 Attention
    4.2 Feedback Alignment
    4.3 Synthetic Gradients
    4.4 Decoupled Network Interfaces

5. Further Network Architectures
    5.1 Generative Adversarial Networks
    5.2 Autoencoders
    5.3 Restricted Boltzmann Machines
    5.4 Capsule Networks
    5.5 Spiking Networks

Literature

Compulsory Reading

Further Reading

- Chollet, F. (2017). Deep learning with Python. Shelter Island, NY: Manning.
- Efron, B., & Hastie, T. (2016). Computer age statistical inference. Cambridge: Cambridge University Press.
- Geron, A. (2017). Hands-on machine learning with Scikit-Learn and TensorFlow. Boston, MA: O’Reilly Publishing.
- Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep learning. Boston, MA: MIT Press.
- Russel, S., & Norvig, P. (2010). Artificial intelligence – A modern approach (3rd ed.). Essex: Pearson.

Study Format Distance Learning

Study Format	Course Type
Distance Learning	Online Lecture

Information about the examination	
Examination Admission Requirements	**BOLK:** yes **Course Evaluation:** no
Type of Exam	Oral Assignment

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
110 h	0 h	20 h	20 h	0 h	150 h

Instructional Methods

- ☐ Learning Sprints®
- ☑ Course Book
- ☐ Vodcast
- ☑ Shortcast
- ☑ Audio
- ☐ Exam Template
- ☐ Review Book
- ☐ Creative Lab
- ☑ Guideline
- ☑ Live Tutorium/Course Feed

Case Study: Model Engineering

Module Code: DLMDSME

Module Type	Admission Requirements	Study Level	CP	Student Workload
see curriculum	DLMDSAM, DLMDSAS, DLMDSPWP, DLMDSML, DLMDSDL	MA	5	150 h

Semester / Term	Duration	Regularly offered in	Language of Instruction
see curriculum	Minimum 1 semester	WiSe/SoSe	English

Module Coordinator

Dr. Markus Pak (Case Study: Model Engineering)

Contributing Courses to Module

- Case Study: Model Engineering (DLMDSME01)

Module Exam Type	
Module Exam Study Format: Distance Learning Written Assessment: Case Study	**Split Exam**
Weight of Module see curriculum	

Module Contents

- Data science methodologies
- Data quality
- Feature engineering
- Feature selection
- Building a predictive model
- Avoiding common fallacies

Learning Outcomes	
Case Study: Model Engineering On successful completion, students will be able to ▪ understand current data science methodologies. ▪ devaluate the quality of the data used in data science projects. ▪ create new features from raw data. ▪ apply feature selection techniques. ▪ make predictive models using data science techniques. ▪ identify common fallacies and know how to avoid them.	
Links to other Modules within the Study Program This module is similar to other modules in the fields of Data Science & Artificial Intelligence	**Links to other Study Programs of IUBH** All Master Programmes in the IT & Technology fields

Case Study: Model Engineering

Course Code: DLMDSME01

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	DLMDSAM, DLMDSAS, DLMDSPWP, DLMDSML, DLMDSDL

Course Description

The construction of data science models and applying the techniques to real-world problems requires a deep understanding of data science processes and techniques beyond the application of relevant algorithms.This course starts by introducing two commonly used data science methodologies: CRISP-DM and MS Team Data Science. Any data taken from real machines, systems, or processes will include some errors to varying degrees. This course discusses in detail how to detect and correct data quality issues, including the importance of domain knowledge in the determination of the veracity of the data.Many machine learning approaches require the creation and subsequent selection of model features which determine which part of the data are used in which way in the later modelling step. This course discusses methods to engineer and build new features from raw data and outlines statistical methods to identify the most relevant features for the given task.Finally, this course outlines strategies to avoid common fallacies when building data science models, as well as approaches to automate workflows.

Course Outcomes

On successful completion, students will be able to

- understand current data science methodologies.
- devaluate the quality of the data used in data science projects.
- create new features from raw data.
- apply feature selection techniques.
- make predictive models using data science techniques.
- identify common fallacies and know how to avoid them.

Contents

1. Data Science Methodologies
   - 1.1 CRISP-DM
   - 1.2 MS Team Data Science
2. Data Quality
   - 2.1 Evaluating data quality
   - 2.2 Using low quality data
   - 2.3 Data duality and domain knowledge

3. Feature Engineering
   - 3.1 Building new features
   - 3.2 Splitting variables
   - 3.3 Feature engineering exploiting domain knowledge

4. Feature Selection
   - 4.1 Univariate feature selection
   - 4.2 Model based feature selection

5. Building a Predictive Model
   - 5.1 Establishing a benchmark model
   - 5.2 Prediction as probabilities
   - 5.3 Interpretable machine learning and results

6. Avoiding Common Fallacies
   - 6.1 Overtraining & generalization
   - 6.2 Overfitting & Occam's Razor
   - 6.3 Workflow automation and model persistence

Literature
Compulsory Reading
Further Reading ▪ Chapman, P. (n.d.). CRISP-DM user guide [PDF document]. Retrieved from https://s2.smu.edu/~mhd/8331f03/crisp.pdf ▪ Geron, A. (2017). Hands-on machine learning with Scikit-Learn and TensorFlow. Boston, MA: O'Reilly Publishing. ▪ Kuhn, M., & Johnson, K. (2013). Applied predictive modeling. New York, NY: Springer. ▪ Maydanchik, A. (2007). Data quality assessment. New Jersey: Technics Publications. ▪ Microsoft. (2017). Team Data Science Process Documentation. Retrieved from https://docs.microsoft.com/en-us/azure/machine-learning/team-data-science-process/overview ▪ Müller, A., & Guido, S. (2016). Introduction to machine learning with Python: A guide for data scientists. Boston, MA: O'Reilly. ▪ Olson, J. (2003). Data quality – The accuracy dimension. San Francisco, CA: Morgan Kaufmann.

Study Format Distance Learning

Study Format	**Course Type**
Distance Learning	Case Study

Information about the examination	
Examination Admission Requirements	**BOLK:** yes **Course Evaluation:** no
Type of Exam	Written Assessment: Case Study

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
110 h	0 h	20 h	20 h	0 h	150 h

Instructional Methods

- ☐ Learning Sprints®
- ☑ Course Book
- ☐ Vodcast
- ☑ Shortcast
- ☑ Audio
- ☐ Exam Template
- ☐ Review Book
- ☐ Creative Lab
- ☑ Guideline
- ☑ Live Tutorium/Course Feed

2. Semester

Big Data and Software Engineering

Module Code: DLMDSEBDSE

Module Type	Admission Requirements	Study Level	CP	Student Workload
see curriculum	▪ none ▪ DLMDSPWP	MA	10	300 h

Semester / Term	Duration	Regularly offered in	Language of Instruction
see curriculum	Minimum 1 semester	WiSe/SoSe	English

Module Coordinator
Prof. Dr. Thomas Zöller (Big Data Technologies) / Prof. Dr. Max Pumperla (Software Engineering for Data Intensive Sciences)

Contributing Courses to Module
▪ Big Data Technologies (DLMDSBDT01) ▪ Software Engineering for Data Intensive Sciences (DLMDSSEDIS01)

Module Exam Type	
Module Exam	**Split Exam** Big Data Technologies • Study Format "Distance Learning": Oral Assignment Software Engineering for Data Intensive Sciences • Study Format "Distance Learning": Oral Assignment
Weight of Module see curriculum	

Module Contents

Big Data Technologies

- Data types and data sources
- Databases
- Modern storage frameworks
- Data formats
- Distributed computing

Software Engineering for Data Intensive Sciences

- Agile project management
- DevOps
- Software development
- API
- From model to production

Learning Outcomes

Big Data Technologies

On successful completion, students will be able to

- identify the different types and sources of data.
- understand different database concepts.
- build new database structures.
- evaluate various data storage frameworks w.r.t. project requirements.
- analyze which data format to use for a given project.
- create a distributed computing environment for a given project.

Software Engineering for Data Intensive Sciences

On successful completion, students will be able to

- understand the agile approaches Scrum and Kanban.
- explain how DevOps brings software development and operations together into one team.
- write high-quality code using relevant software development techniques.
- evaluate the requirements for APIs.
- create APIs for software applications.
- identify the challenges of bringing a model into production.

Links to other Modules within the Study Program	**Links to other Study Programs of IUBH**
This module is similar to other modules in the fields of Data Science & Artificial Intelligence	All Master Programmes in the IT & Technology fields

Big Data Technologies

Course Code: DLMDSBDT01

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	none

Course Description

Data are often considered the “new oil”, the raw material from which value is created. To harness the power of data, the data need to be stored and processed on a technical level. This course introduces the four “Vs” of data, as well as typical data sources and types. This course then discusses how data are stored in databases. Particular focus is given to database structures and different types of databases, e.g., relational, noSQL, NewSQL, and time-series.Beyond classical and modern databases, this course covers a wide range of storage frameworks such as distributed filesystems, streaming, and query frameworks. This is complemented by a detailed discussion of data storage formats ranging from classical approaches such as CSV and HDF5 to more modern approaches like Apache Arrow and Parquet.Finally, this course gives an overview of distributed computing environments based on local clusters, cloud computing facilities, and container-based approaches.

Course Outcomes

On successful completion, students will be able to

- identify the different types and sources of data.
- understand different database concepts.
- build new database structures.
- evaluate various data storage frameworks w.r.t. project requirements.
- analyze which data format to use for a given project.
- create a distributed computing environment for a given project.

Contents

1. Data Types and Data Sources
   - 1.1 The 4Vs of data: volume, velocity, variety, veracity
   - 1.2 Data sources
   - 1.3 Data types

2. Databases
   - 2.1 Database structures
   - 2.2 Introduction to SQL
   - 2.3 Relational databases
   - 2.4 nonSQL, NewSQL databases
   - 2.5 Timeseries DB

3. Modern data storage frameworks
   - 3.1 Distributed Filesystems
   - 3.2 Streaming frameworks
   - 3.3 Query frameworks

4. Data formats
   - 4.1 Traditional data exchange formats
   - 4.2 Apache Arrow
   - 4.3 Apache Parquet

5. Distributed Computing
   - 5.1 Cluster-based approaches
   - 5.2 Containers
   - 5.3 Cloud-based approaches

Literature

Compulsory Reading

Further Reading

- Date, C. J. (2012). Database design and relational theory: Normal forms and all that jazz. Sebastopol, CA: O'Reilly Publishing.
- Karau, H., Konwinski, A., Wendell, A., & Zaharia, M. (2015). Learning spark: Lightning-fast data analysis. Sebastopol, CA: O'Reilly Publishing.
- Narkhede, N., Shapira, G., & Palino, T. (2017). Kafka: The definitive guide: Real-time data and stream processing at scale. Sebastopo, CA: O'Reilly Publishing.
- Poulton, N. (2017). Docker deep dive. Nigel Poulton.
- Psaltis, A. (2017). Streaming data: Understanding the real-time pipeline. Shelter Island, NY: Manning Publications.
- Redmond, E., & Wilson, J. R. (2012). Seven databases in seven weeks: A guide to modern databases and the noSQL movement. Dallas, TX: Pragmatic Bookshelf.
- Sadalage, P., & Fowler, M. (2012). NoSQL distilled: A brief guide to the emerging world of polyglot persistence. Ann Arbor, MI: Addison-Wesley.
- Viescas, J., & Hernandez, M. (2014). SQL queries for mere mortals: A hands-on guide to data manipulation in SQL, (3rd ed.). Ann Arbor, MI: Addison-Wesley.
- White, T. (2015). Hadoop: The definitive guide: Storage and analysis at Internet scale. Sebastopol, CA: O'Reilly Publishing.

Study Format Distance Learning

Study Format	Course Type
Distance Learning	Online Lecture

Information about the examination	
Examination Admission Requirements	**BOLK:** yes **Course Evaluation:** yes
Type of Exam	Oral Assignment

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
110 h	0 h	20 h	20 h	0 h	150 h

Instructional Methods	
☐ Learning Sprints®	☐ Review Book
☑ Course Book	☐ Creative Lab
☐ Vodcast	☑ Guideline
☑ Shortcast	☑ Live Tutorium/Course Feed
☑ Audio	
☐ Exam Template	

Software Engineering for Data Intensive Sciences

Course Code: DLMDSSEDIS01

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	DLMDSPWP

Course Description
Building a successful data-based product requires a significant amount of high-quality code which needs to run in a professional production environment. This course starts by introducing the agile approaches Scrum and Kanban and then discusses the shift from more traditional software development approaches to the DevOps culture.Special focus is given to the discussion and understanding of techniques and approaches for producing high-quality code such as unit and integration testing, test-driven development, pair programing, and continuous delivery and integration.Since many software artefacts are accessed via APIs, this course introduces concepts of API design and paradigms.Finally, this course addresses the challenges of bringing code into a production environment, building a scalable environment, and using cloud-cased approaches.

Course Outcomes

On successful completion, students will be able to

- understand the agile approaches Scrum and Kanban.
- explain how DevOps brings software development and operations together into one team.
- write high-quality code using relevant software development techniques.
- evaluate the requirements for APIs.
- create APIs for software applications.
- identify the challenges of bringing a model into production.

Contents

1. Agile Project Management
   - 1.1 Introduction to SCRUM
   - 1.2 Introduction to Kanban

2. DevOps
   - 2.1 Traditional lifecycle management
   - 2.2 Bringing development and operations together
   - 2.3 Impact of team structure
   - 2.4 Building a DevOps infrastructure

3. Software Development
    - 3.1 Unit & integration test, performance monitoring
    - 3.2 Test-driven development & pair programing
    - 3.3 Continuous delivery & integration
    - 3.4 Overview of relevant tools

4. API
    - 4.1 API design
    - 4.2 API paradigms

5. From Model to Production
    - 5.1 Building a scalable environment
    - 5.2 Model versioning and persistence
    - 5.3 Cloud-based approaches

Literature

Compulsory Reading

Further Reading

- Farcic, V. (2016). The DevOps 2.0 toolkit: Automating the continuous deployment pipeline with containerized microservices. Scotts Valley, CA: CreateSpace Independent Publishing Platform.
- Humble, J., & Farley, D. (2010). Continuous delivery: Reliable software releases through build, test, and deployment automation. Boston, MA: Addison-Wesley Professional.
- Humble, J., Molesky, J., & O'Reilly, B. (2015). Lean enterprise. Sebastopol, CA: O'Reilley Publishing.
- Hunt, A., & Thomas, D. (1999). The pragmatic programmer. From journeyman to master. Reading, MA: Addison-Wesley.
- Martin, R. C. (2008). Clean code. Boston, MA: Prentice Hall.
- Morris, K. (2016). Infrastructure as code. Sebastopol, CA: O'Reilley Publishing.
- Richardson, L., & Ruby, S. (2007). RESTful web services. Sebastopol, CA: O'Reilley Publishing.
- Senge, P. (1990). The fifth discipline: The art and practice of the learning organization. New York, NY: Broadway Business.

Study Format Distance Learning

Study Format	Course Type
Distance Learning	Online Lecture

Information about the examination	
Examination Admission Requirements	**BOLK:** yes **Course Evaluation:** no
Type of Exam	Oral Assignment

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
110 h	0 h	20 h	20 h	0 h	150 h

Instructional Methods	
☐ Learning Sprints® ☑ Course Book ☑ Vodcast ☑ Shortcast ☐ Audio ☐ Exam Template	☐ Review Book ☐ Creative Lab ☑ Guideline ☐ Live Tutorium/Course Feed

Smart Manufacturing Methods and Industrial Automation

Module Code: DLMDSESMMI

Module Type	Admission Requirements	Study Level	CP	Student Workload
see curriculum	none	MA	10	300 h

Semester / Term	Duration	Regularly offered in	Language of Instruction
see curriculum	Minimum 1 semester	WiSe/SoSe	English

Module Coordinator

Prof. Dr. Leonardo Riccardi (Manufacturing Methods Industry 4.0) / Prof. Dr. Leonardo Riccardi (Industrial Automation)

Contributing Courses to Module

- Manufacturing Methods Industry 4.0 (DLMBMMIIT02)
- Industrial Automation (DLMDSINDA01)

Module Exam Type

Module Exam	Split Exam
	<u>Manufacturing Methods Industry 4.0</u> • Study Format "Distance Learning": Exam, 90 Minutes <u>Industrial Automation</u> • Study Format "Distance Learning": Module Exam

Weight of Module

see curriculum

Module Contents

Manufacturing Methods Industry 4.0

- Forming
- Cutting
- Rapid prototyping
- Rapid tooling
- Direct manufacturing

Industrial Automation

- Mathematical frameworks for the formal description of discrete event systems
- Analysis and evaluation methods
- Simulation of discrete event systems
- Supervisory control
- Advanced issues (fault diagnosis, adaptive supervision, optimization)

Learning Outcomes

Manufacturing Methods Industry 4.0

On successful completion, students will be able to

- evaluate different manufacturing methods against given product and process requirements.
- define and design modern additive techniques in contrast to traditional manufacturing.
- assess and estimate the impact of current trends on manufacturing like cyber-physical systems to given manufacturing challenges and practical problems.
- apply modern processes like rapid prototyping, rapid tooling, and direct manufacturing.

Industrial Automation

On successful completion, students will be able to

- identify the main issues related to industrial automation and Industry 4.0 automation in particular.
- describe a discrete event system in a formal way by means of different mathematical models.
- analyze the performance of a system using formalisms and numerical simulation approaches.
- choose the best formalism for a given design scenario and formulate requirements.
- design and implement a supervisory controller to fulfill requirements.
- understand advanced topics related to Industry 4.0 industrial automation.

Links to other Modules within the Study Program	Links to other Study Programs of IUBH
This module is similar to other modules in the fields of Computer Science & Software Development and Engineering	All Master Programmes in the IT & Technology fields

Manufacturing Methods Industry 4.0

Course Code: DLMBMMIIT02

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	none

Course Description

The aim of the course is to enable students to evaluate and identify appropriate manufacturing methods in the context of Industry 4.0. For that purpose, the course provides a comprehensive introduction of such processes based on traditional, standardized manufacturing techniques that have influenced and are still influencing production processes through technological developments under the generic term Industry 4.0. These include technological advances in additive manufacturing processes that enable applications such as rapid prototyping, rapid tooling, and direct manufacturing. Finally, the course deals with the consequences of the digitization and networking of production facilities and their elements in terms of a cyber-physical system.

Course Outcomes

On successful completion, students will be able to

- evaluate different manufacturing methods against given product and process requirements.
- define and design modern additive techniques in contrast to traditional manufacturing.
- assess and estimate the impact of current trends on manufacturing like cyber-physical systems to given manufacturing challenges and practical problems.
- apply modern processes like rapid prototyping, rapid tooling, and direct manufacturing.

Contents

1. Introduction to Manufacturing Methods
   - 1.1 Basic Concepts
   - 1.2 Historical Development of Manufacturing
   - 1.3 About the Long Tail

2. Manufacturing Methods
   - 2.1 Casting and Molding
   - 2.2 Shaping
   - 2.3 Machining
   - 2.4 Joining
   - 2.5 Coating

3. Additive Manufacturing and 3D printing
   - 3.1 Basics and Legal Aspects
   - 3.2 Material Extrusion
   - 3.3 Vat Polymerization
   - 3.4 Powder Bed Fusion
   - 3.5 Material Jetting
   - 3.6 Binder Jetting
   - 3.7 Direct Energy Deposition
   - 3.8 Sheet Lamination

4. Rapid Prototyping
   - 4.1 Definitions
   - 4.2 Strategical and Operative Aspects
   - 4.3 Application Scenarios

5. Rapid Tooling
   - 5.1 Definitions
   - 5.2 Direct and Indirect Methods
   - 5.3 Application Scenarios

6. Direct/Rapid Manufacturing
   - 6.1 Potentials and Requirements
   - 6.2 Implementation Examples

7. Cyber-Physical Production Systems
   - 7.1 Introduction
   - 7.2 Cyber-Physical Production Systems
   - 7.3 Impact on Design and Maintenance of Plants
   - 7.4 Dynamic Reconfiguration of Plants
   - 7.5 Application Examples

Literature
Compulsory Reading
Further Reading ▪ Anderson, C. (2012). Makers. The new industrial revolution. New York, NY: Crown Business. ▪ Gebhardt, A. (2012). Understanding additive manufacturing. Rapid prototyping – Rapid tooling – Rapid manufacturing. Munich: Hanser. ▪ Groover, Mikell P. (2012). Fundamentals of modern manufacturing: Materials, processes, and systems. Hoboken, NJ: John Wiley & Sons Inc.

Study Format Distance Learning

Study Format	Course Type
Distance Learning	Online Lecture

Information about the examination	
Examination Admission Requirements	**BOLK:** yes **Course Evaluation:** no
Type of Exam	Exam, 90 Minutes

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
90 h	0 h	30 h	30 h	0 h	150 h

Instructional Methods

☐ Learning Sprints®	☐ Review Book
☑ Course Book	☐ Creative Lab
☐ Vodcast	☐ Guideline
☑ Shortcast	☐ Live Tutorium/Course Feed
☑ Audio	
☑ Exam Template	

Industrial Automation

Course Code: DLMDSINDA01

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	none

Course Description

Production systems can be described as discrete event systems where the evolution is characterized by the occurrence of events. In the era of Industry 4.0 and highly-flexible manufacturing, there is the need to provide adequate means for the modeling, analysis, design, and control of flexible production environments.This course introduces several modeling approaches for the mathematical description of discrete event systems, such as Automata, Petri Nets, and Markov processes. Each approach is presented in both theory and practice with examples taken from the industry. The approaches are grouped into logic—where only the logic sequence of events determines the evolution—and timed, where the time schedule of the events also plays an important role. Although simple discrete event systems can be analyzed mathematically, complex systems need the support of computer simulation. The main issues concerning the simulation of discrete event systems are addressed.The final part of this course introduces the concept of supervisory control, which aims at changing the properties of a given system to improve specified behaviors and fulfill defined design specifications. Supervisory control is addressed both from the theoretical practical sides, describing how it can be implemented in a modern industrial environment.The course wraps up with discussion of interesting applications for modeling and design approaches, e.g., in the modeling and analysis of an industrial production unit. Additional conversation on topics like fault-diagnosis, decentralized and distributed supervision, optimization, and adaptive supervision provide a contingent connection between classical industrial automation and the recent, (big) data-driven, flexible, Industry 4.0 advanced industrial automation.

Course Outcomes

On successful completion, students will be able to

- identify the main issues related to industrial automation and Industry 4.0 automation in particular.
- describe a discrete event system in a formal way by means of different mathematical models.
- analyze the performance of a system using formalisms and numerical simulation approaches.
- choose the best formalism for a given design scenario and formulate requirements.
- design and implement a supervisory controller to fulfill requirements.
- understand advanced topics related to Industry 4.0 industrial automation.

Contents

7. Applications
   7.1 Production system supervision
   7.2 Monitoring and diagnosis of faults
   7.3 Distributed and de-centralized supervision
   7.4 Model-based optimization of production systems
   7.5 Adaptive supervisory control

Literature

Compulsory Reading

Further Reading

- Cassandras, C. G./Lafortune, S. (Eds.). (2008): Introduction to discrete event systems. Springer, Boston, MA.
- Choi, B. K./Kang, D. (2013): Modeling and simulation of discrete-event systems. Wiley, Hoboken, NJ.
- Ding, D./Wang, Z./Wei, G. (2018): Performance analysis and synthesis for discrete-time stochastic systems with network-enhanced complexities. CRC Press, Boca Raton, FL.
- Hrúz, B./MengChu, Z. (2007): Modeling and control of discrete-event dynamic systems. Springer, London.
- Seatzu, C./Silva, M./van Schuppen, J. H. (Eds.). (2013): Control of discrete-event systems. Springer, London.
- Wonham, W. M./Cai, K. (2019): Supervisory control of discrete-event systems. Springer, Cham.
- Zimmermann, A. (2008): Stochastic discrete event systems. Springer, Berlin/Heidelberg.

Study Format Distance Learning

Study Format	Course Type
Distance Learning	Online Lecture

Information about the examination	
Examination Admission Requirements	**BOLK:** yes **Course Evaluation:** no
Type of Exam	Module Exam

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
90 h	0 h	30 h	30 h	0 h	150 h

Instructional Methods	
☐ Learning Sprints® ☑ Course Book ☐ Vodcast ☑ Shortcast ☑ Audio ☑ Exam Template	☐ Review Book ☐ Creative Lab ☐ Guideline ☐ Live Tutorium/Course Feed

Applied Autonomous Driving

Module Code: DLMDSEAAD

Module Type	Admission Requirements	Study Level	CP	Student Workload
see curriculum	none	MA	10	300 h

Semester / Term	Duration	Regularly offered in	Language of Instruction
see curriculum	Minimum 1 semester	WiSe/SoSe	English

Module Coordinator

Dr. Benjamin Lehmann (Architectures of Self-Driving Vehicles) / Dr. Benjamin Lehmann (Case Study: Localization, Motion Planning and Sensor Fusion)

Contributing Courses to Module

- Architectures of Self-Driving Vehicles (DLMDSEAAD01)
- Case Study: Localization, Motion Planning and Sensor Fusion (DLMDSEAAD02)

Module Exam Type

Module Exam	Split Exam
	<u>Architectures of Self-Driving Vehicles</u> • Study Format "Distance Learning": Exam, 90 Minutes <u>Case Study: Localization, Motion Planning and Sensor Fusion</u> • Study Format "Distance Learning": Written Assessment: Case Study

Weight of Module

see curriculum

Module Contents

Architectures of Self-Driving Vehicles

- Architectural patterns of a self-driving car
- Perception and motion control
- Social impact of autonomous vehicles

Case Study: Localization, Motion Planning and Sensor Fusion

- Algorithms for localization and navigation
- Sensor fusion methods for localization and objects tracking
- Motion planning algorithms

Learning Outcomes

Architectures of Self-Driving Vehicles

On successful completion, students will be able to

- explain and recognize the main components of a self-driving car.
- distinguish the sensor solutions for a self-driving car and adopt the best one for a given scenario.
- model and implement a simple motion control system.
- manage the main communication protocols to retrieve valuable information.
- reflect on the social impact of self-driving cars.

Case Study: Localization, Motion Planning and Sensor Fusion

On successful completion, students will be able to

- distinguish the methods used for localization, motion planning, and sensor fusion.
- apply the methods to autonomous vehicles.
- understand the main issues related to the adoption of autonomous vehicles in real-world scenarios.

Links to other Modules within the Study Program	Links to other Study Programs of IUBH
This module is similar to other modules in the field of Engineering	All Master Programmes in the IT & Technology fields

Architectures of Self-Driving Vehicles

Course Code: DLMDSEAAD01

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	none

Course Description

This course gives an overview of the main architectural aspects of a self-driving car. After introducing the hardware and software platforms, the course presents the sensor solutions necessary to provide environment perception for autonomous vehicles. Such perception yields the information used for motion control, including braking and steering. The fundamental concepts for the realization and implementation of motion control are presented, together with related safety issues (e.g., motion control under false information). The way in which a self-driving car exchanges information with the outside world is also discussed, and the main technologies and protocols are introduced. The last part of the course elaborates on the social impact of self-driving cars: ethics, mobility, and design.

Course Outcomes

On successful completion, students will be able to

- explain and recognize the main components of a self-driving car.
- distinguish the sensor solutions for a self-driving car and adopt the best one for a given scenario.
- model and implement a simple motion control system.
- manage the main communication protocols to retrieve valuable information.
- reflect on the social impact of self-driving cars.

Contents

1. Introduction
   - 1.1 Basic concepts and key technologies
   - 1.2 Hardware overview
   - 1.3 Software overview
   - 1.4 State of the art and open challenges
   - 1.5 Trends

2. Environment Perception
   - 2.1 Basic concepts
   - 2.2 GPS
   - 2.3 Inertial sensors
   - 2.4 Lidar and Radar
   - 2.5 Cameras

3. Moving, Braking, Steering
   - 3.1 Fundamentals
   - 3.2 Dynamics of a mobile vehicle
   - 3.3 Braking technologies
   - 3.4 Lateral and longitudinal control
   - 3.5 Safety issues

4. Communication
   - 4.1 Car2X communication
   - 4.2 Protocols
   - 4.3 Safety issues

5. Social Impact
   - 5.1 Ethics for autonomous vehicles
   - 5.2 New mobility
   - 5.3 Autonomous vehicles and design

Literature
Compulsory Reading
Further Reading ▪ Ben-Ari, M., & Mondada, F. (2018). *Elements of robotics*. Cham: Springer. ▪ Cheng, H. (2011). *Autonomous intelligent vehicles*. London: Springer. ▪ Fazlollahtabar, H., & Saidi-Mehrabad, M. (2015). *Autonomous guided vehicles*. Cham: Springer. ▪ Maurer, M., Gerdes, J. C., Lenz, B., & Winner, H. (Eds.). (2016). *Autonomous driving*. Berlin, Heidelberg: Springer. ▪ Miucic, R. (Ed.). (2019). *Connected vehicles*. Cham: Springer. ▪ Yu, H., Li, X., Murray, R. M., Ramesh, S., & Tomlin, C. J. (Eds.). (2019). *Safe, autonomous and intelligent vehicles*. Cham: Springer.

Study Format Distance Learning

Study Format	Course Type
Distance Learning	Online Lecture

Information about the examination	
Examination Admission Requirements	**BOLK:** yes **Course Evaluation:** no
Type of Exam	Exam, 90 Minutes

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
90 h	0 h	30 h	30 h	0 h	150 h

Instructional Methods

- ☐ Learning Sprints®
- ☑ Course Book
- ☐ Vodcast
- ☑ Shortcast
- ☑ Audio
- ☑ Exam Template
- ☐ Review Book
- ☐ Creative Lab
- ☐ Guideline
- ☑ Live Tutorium/Course Feed

Case Study: Localization, Motion Planning and Sensor Fusion

Course Code: DLMDSEAAD02

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		5	none

Course Description

This course provides the fundamental concepts and methods of localization, motion planning, and sensor fusion for mobile robotics and self-driving cars. Mobile robots and autonomous vehicles rely on the ability to perceive the environment and react to its dynamic changes.The first part of the course focuses on the representation of motion and navigation based on odometry, which is affected by errors due to information uncertainty. A possible solution is offered by localization methods which use odometry and complementary information, such as a GPS signal, to improve the estimation of the position of the autonomous vehicles within a reference frame. In this way, the vehicle is able to move towards a goal.The problems with detecting dynamic change in the environment is addressed in the last part of the course, where the methods of sensor fusion are introduced. Thanks to the fusion of multiple data sources, information can be extracted, e.g., an approaching object or a change in a situation can be revealed. The autonomous vehicle must be able to track the object and react to its movement to avoid human hazard and damage. The determination of the best trajectory to follow is addressed in the final part of the course.The course gives a hands-on overview of the main methods for localization, motion planning, and sensor fusion. The students must apply the concepts and methods to case studies involving a self-driving vehicle in two main scenarios: “on the road” and in a manufacturing facility.

Course Outcomes

On successful completion, students will be able to

- distinguish the methods used for localization, motion planning, and sensor fusion.
- apply the methods to autonomous vehicles.
- understand the main issues related to the adoption of autonomous vehicles in real-world scenarios.

Contents

1. Motion and Odometry
   - 1.1 Basic principles
   - 1.2 Motion models
   - 1.3 Navigation by odometry
   - 1.4 Holonomic and non-holonomic motion
   - 1.5 Errors

2. Local Navigation
   - 2.1 Basic concepts
   - 2.2 Path finding
   - 2.3 Obstacle avoidance

3. Localization
   - 3.1 Basic concepts
   - 3.2 Triangulation
   - 3.3 GPS
   - 3.4 Probabilistic localization
   - 3.5 Uncertainty of motion

4. Sensor Fusion
   - 4.1 Sensors
   - 4.2 Elaborating data from sensors
   - 4.3 Kalman filter
   - 4.4 Extended Kalman filter
   - 4.5 Tracking objects

5. Motion Planning
   - 5.1 Path planning
   - 5.2 Motion prediction
   - 5.3 Trajectory generation

Literature

Compulsory Reading

Further Reading

- Koch, W., & Springer-Verlag GmbH. (n.d.). Tracking and sensor data fusion methodological framework and selected applications . Berlin, Heidelberg: Springer.
- Mitchell, H. B. (2007). Multi-sensor data fusion: An introduction . Berlin, Heidelberg: Springer.
- Valencia, R., & Andrade-Cetto, J. (2018). Mapping, planning and exploration with Pose SLAM . Cham: Springer.
- Wang, P. K.-C. (2015). Visibility-based optimal path and motion planning . Cham: Springer.

Study Format Distance Learning

Study Format	Course Type
Distance Learning	Case Study

Information about the examination	
Examination Admission Requirements	**BOLK:** yes **Course Evaluation:** no
Type of Exam	Written Assessment: Case Study

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
110 h	0 h	20 h	20 h	0 h	150 h

Instructional Methods

- ☐ Learning Sprints®
- ☑ Course Book
- ☐ Vodcast
- ☑ Shortcast
- ☑ Audio
- ☐ Exam Template
- ☐ Review Book
- ☐ Creative Lab
- ☑ Guideline
- ☑ Live Tutorium/Course Feed

Master Thesis

Modulcode: DLMMTHE

Modultyp	Zugangsvoraussetzungen	Niveau	ECTS	Zeitaufwand Studierende
s. Curriculum	See study and exam regulation (SPO).	MA	20	600 h

Semester	Dauer	Regulär angeboten im	Unterrichtssprache
s. Curriculum	Minimum 1 semester	WiSe/SoSe	Deutsch

Modulverantwortliche(r)

Degree Program Advisor (SGL) (Master Thesis) / N.N. (Thesis Defence)

Kurse im Modul

- Master Thesis (DLMMTHE01)
- Thesis Defence (DLMMTHE02)

Art der Prüfung(en)

Modulprüfung	Teilmodulprüfung
	Master Thesis • Study Format "Fernstudium": Written Assessment: Master Thesis Thesis Defence • Study Format "Fernstudium": Presentation: Colloquium

Anteil der Modulnote an der Gesamtnote

s. Curriculum

Lehrinhalt des Moduls

Master Thesis

- Written Master Thesis

Thesis Defense

Thesis Defence

Qualifikationsziele des Moduls

Master Thesis

Nach erfolgreichem Abschluss sind die Studierenden in der Lage,

- The objective of this module is the completion of a written assignment, in line with scientific methodology, that demonstrates the student's capabilities through independent investigation of a topic pertaining to the master program's area of focus.

Thesis Defence

Nach erfolgreichem Abschluss sind die Studierenden in der Lage,

- The main objective of the thesis defense is for the student to prove their competence in research methodology and the specific subject matter. The students should also be able to actively participate in a subject specific discussion at a higher academic level with subject area experts. Additionally, the defense will evaluate the academic presentation skills and overall communication skills of the student.

Bezüge zu anderen Modulen im Studiengang	Bezüge zu anderen Studiengängen der IUBH
This module is similar to other modules in the field of Methods.	All Master Programmes in the Business & Administration field.

Master Thesis

Kurscode: DLMMTHE01

Niveau	Unterrichtssprache	SWS	ECTS	Zugangsvoraussetzungen
MA	Deutsch		18	See current study and exam regulations (SPO)

Beschreibung des Kurses

The aim of the master thesis is to effectively apply the knowledge acquired throughout the master course to an academic paper that has a thematic reference to the master program. The thesis can consist of an empirical study or theoretical research. The thesis is an independent piece of work, that, with the guidance of a supervisor, seeks to scientifically analyze and critically discuss a chosen issue, and suggest possible solutions. The chosen topic from the student's area of specialization should demonstrate their acquired competence in the functional area, yet also enrich and round out the student's scientific knowledge. This will optimally prepare the student for the needs of their future career path.

Kursziele

Nach erfolgreichem Abschluss sind die Studierenden in der Lage,

- The objective of this module is the completion of a written assignment, in line with scientific methodology, that demonstrates the student's capabilities through independent investigation of a topic pertaining to the master program's area of focus.

Kursinhalt

- The master thesis should clearly state the topic and research question, and should, through extensive research, reflect the current state of the field in question. The student should demonstrate their knowledge in the form of an independent and solution oriented paper, using theoretical and/or empirical norms.

Literatur

Pflichtliteratur

Weiterführende Literatur

- Bui, Y. N. (2013). How to Write a Master's Thesis (2nd ed.). SAGE Publications, Incorporated.
- Turabian, K. L. (2013). A Manual for Writers of Research Papers, theses, and dissertations (8th ed.). University of Chicago Press.
- Further subject specific literature

Studienformat Fernstudium

Studienform	**Kursart**
Fernstudium	Online Lecture

Informationen zur Prüfung	
Prüfungszulassungsvoraussetzungen	**BOLK:** Nein **Evaluation:** Nein
Prüfungsleistung	Written Assessment: Master Thesis

Zeitaufwand Studierende					
Selbststudium	**Präsenzstudium**	**Tutorium**	**Selbstüberprüfung**	**Praxisanteil**	**Gesamt**
540 h	0 h	0 h	0 h	0 h	540 h

Lehrmethoden

- ☐ Learning Sprints®
- ☐ Skript
- ☐ Vodcast
- ☐ Shortcast
- ☐ Audio
- ☐ Musterklausur
- ☐ Repetitorium
- ☐ Creative Lab
- ☐ Prüfungsleitfaden
- ☐ Live Tutorium/Course Feed

Thesis Defence

Course Code: DLMMTHE02

Study Level	Language of Instruction	Contact Hours	CP	Admission Requirements
MA	English		2	See current study and exam regulations (SPO)

Course Description

The thesis defense takes place after the written master thesis has been handed in by the student. The examiners (the supervisor and a second examiner) will invite the student to the defense. During the presentation, the student will demonstrate that he/she personally has independently produced the content and the results of their written thesis. The thesis defense consists of a presentation where the student discusses the most significant research outcomes and the results of their thesis, followed by a question-and-answer session chaired by the examiners.

Course Outcomes

Nach erfolgreichem Abschluss sind die Studierenden in der Lage,

- The main objective of the thesis defense is for the student to prove their competence in research methodology and the specific subject matter. The students should also be able to actively participate in a subject specific discussion at a higher academic level with subject area experts. Additionally, the defense will evaluate the academic presentation skills and overall communication skills of the student.

Contents

- The thesis defense consists of a presentation of the results and applied method of the master thesis, followed by a question-and-answer session chaired by the examiners.

Literature

Compulsory Reading

Further Reading

- Subject specific literature chosen by the student

Study Format Fernstudium

Study Format	Course Type
Fernstudium	Online Lecture

Information about the examination	
Examination Admission Requirements	**BOLK:** no **Course Evaluation:** no
Type of Exam	Presentation: Colloquium

Student Workload					
Self Study	**Presence**	**Tutorial**	**Self Test**	**Practical Experience**	**Hours Total**
60 h	0 h	0 h	0 h	0 h	60 h

Instructional Methods

- ☐ Learning Sprints®
- ☐ Course Book
- ☐ Vodcast
- ☐ Shortcast
- ☐ Audio
- ☐ Exam Template
- ☐ Review Book
- ☐ Creative Lab
- ☐ Guideline
- ☐ Live Tutorium/Course Feed