Bachelor Data Science

(First enrollment from winter semester 2022/2023)

Module contents

22th December 2023

Current information (such as specific course offerings, dates, rooms, etc.) can always be found on KU.Campus each semester

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Preliminary course “Mathematics for Data Science“

Module title	Preliminary course “Mathematics for Data Science“
Module number	82-105-DS26-H-0923
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Felix Voigtlaender
Module examiner	
Credit points (ECTS)	0
Learning outcomes	• Ability to calculate with polynomials, matrices, and vectors, an to simplify given mathematical expressions • ability to correctly use and understand foundational concepts, notation, and symbols of mathematics (e.g.: sets, logical operations (and, or, not, …), and functions) • Ability to solve linear systems of equations and quadratic equations • ability to compute derivatives and anti-derivatives using the chain rule, the product rule, partial integration, and substitution • Ability to qualitatively sketch a curve (including asymptotics, extrema, etc.) • Ability to check a function for continuity and differentiability • Ability to check simple sequences for convergence
Contents/topics	The preliminary course refreshes high school mathematics at university level and thus provides a preview of the mathematical lectures in the first semester. Content: Review of the mathematical foundations, including logic, elementary set theory, functions, computing with polynomials, determining the zeros of polynomials (e.g. p,q-formula); linear systems of equations; computing with matrices and vectors; basics of analysis (elementary functions, derivatives and rules of differentiation); sequences and convergence; continuity; differentiability; connection between differential and integral calculus (fundamental theorem of analysis, partial integration and substitution); determining extreme values using differential calculus (everything mostly without proofs).
Formal requirementsfor participation	None
Recommended requirements for participation:	None

Teaching and examination language	English
Teaching and learning methods/course types	Lecture (VL) / Exercise (UE)
ECTS awarding criteria	None (no ECTS)
Workload / distribution of ECTS credits	The preliminary course lasts roughly two weeks (Monday-Friday) before the start of the semester. There is a lecture (45+45 minutes) in the morning and an exercise class (60 + 60 minutes) in the afternoon.
Module grade	No exam; no grade
Applicability to other degree programs/course admittance	
Course rotation	Winter semester
Remarks	

Mandatory Modules of the 1st Semester

Linear Algebra 1

Module title	Linear Algebra 1
Module number	82-105-L-MAT03-H-0512
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Mathematics BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Susanne Danz
Module examiner	
Credit points (ECTS)	10
Learning outcomes	Thorough understanding of the problems, definitions and proof techniques, as well as independent and correct solving of computational and correct mathematical deduction of mathematical results from the range of topics of the module.
Contents/topics	Groups and fields, especially complex numbers; vector spaces, linear mappings, matrices; linear systems of equations, Gaussian method, determinants
Formal requirements for participation	None
Recommended requirements for participation:	---
Teaching and examination language	German (English for Data Science BSc)
Teaching and learning methods/course types	Lecture (VL) (5 SWS) / Exercise (UE) (2 SWS)
ECTS awarding criteria	performance record assessed with at least "sufficient": Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester.
Workload / distribution of ECTS credits	face-to-face/independent study in lecture: 3.5 ECTS, corresponds to 105 hours

	preparation and follow-up (includes coursework): 4.5 ECTS, equivalent to 135 hours preparation assessment: 2 ECTS, corresponds to 60 hours
Module grade	assessment
Applicability to other degree programs/course admittance	BSc Mathematics Lehramt Mathematik für Gymnasien - Interdisziplinärer lehramtsgeeigneter Bachelorstudiengang Mathematik, Ausrichtung Gymnasium
Course rotation	Winter semester
Remarks	For Data Science: in agreement with the lecturer, German may be chosen as the language of the examination.

Analysis 1 for Data Science

Module title	Analysis 1 for Data Science
Module number	82-105-DS01-H-0822
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Data Science
Module coordinator	Ray, Nadja
Module examiner	
Credit points (ECTS)	5
Learning outcomes	Understanding of basic definitions and results, penetration of simple proof ideas from the subject area, Knowledge of techniques necessary to solve problems.
Contents/topics	Problem- and application-oriented introduction to the fundamentals of analysis (sequences, limits, continuity) as well as differential and integral calculus of one variable. The lecture has essentially the same scope of topics as Analyis I for Bachelor students of mathematics, but partly omits proofs.
Formal requirements for participation	None
Recommended requirements for participation:	---
Teaching and examination language	English
Teaching and learning methods/course types	Lecture (VL) (2 SWS) / Exercise (UE) (1 SWS)
ECTS awarding criteria	performance record assessed with at least "sufficient": Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester.
Workload / distribution of ECTS credits	face-to-face/independent study in lecture: 1.5 ECTS, corresponds to 45 hours

	preparation and follow-up (includes coursework): 2.5 ECTS, equivalent to 75 hours preparation assessment: 1 ECTS, corresponds to 30 hours
Module grade	assessment
Applicability to other degree programs/course admittance	
Course rotation	Winter semester
Remarks	in agreement with the lecturer, German may be chosen as the language of the examination.

Introduction to Statistics

Module title	Introduction to Statistics
Module number	82-105-MAT19-H-0610
Level of qualification	Bachelor (UNI)
Degree program hosting the module	B.Sc. Mathematik
Institutional anchoring	Mathematisch-Geographische Fakultät
Subjects involved	Mathematics
Module coordinator	Krebs, Johannes
Module examiner	Krebs, Johannes
Credit points (ECTS)	5
Learning outcomes	Understanding of elementary statistical problems and methods related to questions from empirical applications.
Contents/topics	Descriptive statistics, elementary probability, statistical estimation and test procedures.
Formal requirements for participation	
Recommended requirements for participation:	
Teaching and examination language	German
Teaching and learning methods/course types	Lecture (VL) (2 SWS), Exercises (UE) (1 SWS)
ECTS awarding criteria	course assessment at least "ausreichend" (sufficient): [Written examination (60 - 90 minutes) or oral examination (20 - 30 minutes), voluntary exercises can be offered during the semester]
Workload / distribution of ECTS credits	Lecture or corresponding self-study: 1.5 ECTS credit points (45 hours) Preparation and reworking, accompanying exercises: 2.5 ECTS credit points (75 hours), Preparation of examination: 1 ECTS credit point (30 hours)

Module grade	Assessment
Applicability to other degree programs/course admittance	B.Sc. Data Science
Course rotation	Winter semester
Remarks	

Introduction into Programming

Module title	Introduction into Programming
Module number	82-105-DS02-H-0822
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Felix Voigtlaender
Module examiner	
Credit points (ECTS)	5
Learning outcomes	Basic knowledge about programming in Python and about further tools as needed for more advanced practical modules in the Bachelor Data Science. Ability to correctly implement (relatively) simple algorithms in Python.
Contents/topics	A selection of the following topics: • Variables (including the distinction between local and global variables) and data types (in particular: bool, int, float, lists, dictionaries, strings, tuples, potentially NumPy arrays), operators, distinction between identity and equality (`is` vs. `==`), distinction between “mutable” and “immutable” types • control structures (if, for, while) and functions, basic understanding of recursion, understanding of the notion of the arguments of a function • modules (only as much as needed for using existing modules) • Fundamentals of object oriented programming, (formatted) input/output, file handling (potentially including reading/writing special file formats) • Testing and debugging, basics of exception handling • elementary understanding of algorithmic complexity and performance • vectorized formulation of mathematical operations (NumPy), elementary operations of numerical linear algebra • plotting (using matplotlib) • Usage of a version control system (e.g. git) Relevant literature e.g.: • Goodrich/Tamassia/Goldwasser: Data Structures and Algorithms in Python

	• Eric Freeman: Head First Learn to Code
Formal requirements for participation	None
Recommended requirements for participation:	None
Teaching and examination language	English (In agreement with the lecturer, German may be chosen as the language of the examination.)
Teaching and learning methods/course types	Exercise (UE) (4 SWS)
ECTS awarding criteria	portfolio examination based on “mini projects” for each chunk of topics, grade at least 4.0.
Workload / distribution of ECTS credits	face-to-face/independent study in lecture: 2 ECTS, corresponds to 60 hours preparation and follow-up, working on the exercises: 2 ECTS, equivalent to 60 hours preparation assessment: 1 ECTS, corresponds to 30 hours total= 5, corresponds to 150 hours
Module grade	assessment
Applicability to other degree programs/course admittance	BSc Digital and Data Driven Business BSc Mathematics
Course rotation	Winter semester
Remarks	In agreement with the lecturer, German may be chosen as the language of the examination.

Basics of Information Systems

Module title	Basics of Information Systems
Module number	82-021-D3B02-H-0721
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Marcel Oliver
Module examiner	
Credit points (ECTS)	5
Learning outcomes	Students • know the basics of algorithms. • know the basic hardware and software structure of computers and understand how the components function and how they interact in information processing. • know the architectural basics of computer networks and protocols, especially on the Internet. • know database management systems and languages for structured communication with databases. • know basic modelling and testing tools of computer science and are able to apply them.
Contents/topics	Computer science: Introduction and history • Basics of algorithmics (definition and notation forms of algorithms; simple data types, operators and control structures using the example of a programming language) • Functionality of a computer (representation of information (numbers and characters); arithmetic operations, switching networks and switching mechanisms; computer architectures: components, functionality and interaction (hardware and software)) • Networks and distributed systems (information transmission, network stack and protocols; Internet-based systems and technologies) • Databases and information system (Relational database models / SQL) • Information processing (formal languages and finite automata)

	• System and software modeling e.g. UML
Formal requirements for participation	None
Recommended requirements for participation:	None
Teaching and examination language	English (In agreement with the lecturer, German may be chosen as the language of the examination.)
Teaching and learning methods/course types	Lecture (VL) (2 SWS) / Exercise (UE) (2 SWS)
ECTS awarding criteria	performance record assessed with at least "sufficient": Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester; or portfolio examination.
Workload / distribution of ECTS credits	45 h = Time of attendance lecture and tutorial or self study 75 h = Preparation and postprocessing lecture and tutorial 30 h = Exam preparation 150 h = Total workload total= 5, corresponds to 150 hours
Module grade	assessment
Applicability to other degree programs/course admittance	BSc Digital and Data Driven Business BSc Mathematics
Course rotation	Winter semester
Remarks	In agreement with the lecturer, German may be chosen as the language of the examination.

Mandatory Modules of the 2nd Semester

Linear Algebra 2

Module title	Linear Algebra 2 and Analytic Geometry
Module number	82-105-L-MAT25-H-0512
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Mathematics BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Susanne Danz
Module examiner	
Credit points (ECTS)	10
Learning outcomes	Thorough understanding of the problems, definitions and proof techniques, as well as independent and correct solving of computational and correct mathematical deduction of mathematical results from the range of topics of the module.
Contents/topics	Scalar products, norms; orthogonal mappings, unitary matrices, adjoint mapping; eigenvalues, eigenvectors, diagonalizability; Jordan normal form; analytic geometry (e.g. affine mappings, quadrics)
Formal requirements for participation	None
Recommended requirements for participation:	---
Teaching and examination language	German (English for Data Science BSc)
Teaching and learning methods/course types	Lecture (VL) (5 SWS) / Exercise (UE) (2 SWS)
ECTS awarding criteria	performance record assessed with at least "sufficient": Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester.

Workload / distribution of ECTS credits	face-to-face/independent study in lecture: 3.5 ECTS, corresponds to 105 hours preparation and follow-up (includes coursework): 4.5 ECTS, equivalent to 135 hours preparation assessment: 2 ECTS, corresponds to 60 hours
Module grade	assessment
Applicability to other degree programs/course admittance	BSc Mathematics Lehramt Mathematik für Gymnasien - Interdisziplinärer lehramtsgeeigneter Bachelorstudiengang Mathematik, Ausrichtung Gymnasium
Course rotation	Winter semester
Remarks	Teaching and examination language in the Data Science BSc program English, German or English can be chosen as the examination language in consultation with the lecturer.

Analysis 2 for Data Science

Module title	Analysis 2 for Data Science
Module number	82-105-DS10-H-0822
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Data Science
Module coordinator	Ray, Nadja
Module examiner	
Credit points (ECTS)	5
Learning outcomes	The students - expand their knowledge of basic concepts of subject area and explain them - reproduce and deepen knowledge of basic principles and classify them - apply and deepen knowledge of basic techniques of analysis - discuss and optimize simple multidimensional functions - recognize the cross-connection to linear algebra
Contents/topics	Problem- and application-oriented introduction to differential calculus of several variables including e.g. - Normed spaces, continuous mappings between normed spaces, concepts of open, closed, compact - Banach's fixed point theorem, Arzela-Ascoli's theorem - Differential calculus in several variables: Partial derivative, Jacobi matrix, Hessian matrix, Schwarz theorem, extrema, inverse function, implicit functions theorem, optimization with constraints (Lagrange formalism), linearization, Taylor formula in several variables
Formal requirements for participation	None
Recommended requirements for participation:	Analysis 1 for Data Science
Teaching and examination language	English
Teaching and learning methods/course types	Lecture (VL) (2 SWS) / Exercise (UE) (1 SWS)

ECTS awarding criteria	performance record assessed with at least "sufficient": Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester.
Workload / distribution of ECTS credits	face-to-face/independent study in lecture: 1.5 ECTS, corresponds to 45 hours preparation and follow-up (includes coursework): 2.5 ECTS, equivalent to 75 hours preparation assessment: 1 ECTS, corresponds to 30 hours
Module grade	assessment
Applicability to other degree programs/course admittance	
Course rotation	Winter semester
Remarks	in agreement with the lecturer, German may be chosen as the language of the examination.

Hands-on Machine Learning and Data Science

Module title	Hands-on Machine Learning and Data Science
Module number	82-105-DS07-H-0822
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Felix Voigtlaender
Module examiner	
Credit points (ECTS)	10
Learning outcomes	In-depth intuitive understanding of the most important methods and software libraries of applied machine learning. Independent solving of practical problems using machine learning methods. Ability to decide for a given problem which machine learning algorithms (e.g., linear regression, ridge regression, logistic regression, (boosted) decision trees, SVMs, neural networks) are suitable for the problem. Ability to use various metrics to critically assess whether the model obtained provides the desired performance. Ability to improve the performance of a trained model using common techniques (e.g. regularisation, data augmentation).
Contents/topics	Fundamental intuitive understanding of questions, concepts and methods of supervised and unsupervised machine learning, as well as the relevant software libraries, in order to be able to put this knowledge into practice. The focus is on intuitive understanding and applications as well as examples using the computer. A mathematical analysis will be covered in later lectures. Questions and concepts: Overfitting, Empirical risk minimisation, Data splitting (training, validation, test set), Model classes, Loss functions, Feature normalisation, Performance measures (Precision, Recall, F1 score), Regularisation Software libraries e.g.: NumPy, Matplotlib, scikit-learn, pandas Algorithms e.g.: k-means, PCA, linear regression, ridge regression, logistic regression, Naive Bayes, (boosted) decision trees, SGD, SVMs, neural networks Relevant literature:

	• Géron: Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow • Guido and Müller: Introduction to Machine Learning with Python: A Guide for Data Scientists
Formal requirements for participation	Introduction to programming
Recommended requirements for participation:	Analysis for Data Science I, Linear Algebra I
Teaching and examination language	English (In agreement with the lecturer, German may be chosen as the language of the examination.)
Teaching and learning methods/course types	Lecture (VL) (4 SWS) / Exercise (UE) (2 SWS)
ECTS awarding criteria	performance record assessed with at least "sufficient" (4.0): Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester; or portfolio examination
Workload / distribution of ECTS credits	face-to-face/independent study in lecture: 3,5 ECTS, corresponds to 105 hours preparation and follow-up (includes exercises): 4,5 ECTS, equivalent to 135 hours preparation exam: 2 ECTS, corresponds to 60 hours total = 10, corresponds to 300 hours
Module grade	Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester; or portfolio examination
Applicability to other degree programs/course admittance	BSc Digital and Data Driven Business BSc Mathematics
Course rotation	Summer semester
Remarks	In agreement with the lecturer, German may be chosen as the language of the examination.

Algorithms and Data Structures

Module title	Algorithms and Data Structures
Module number	82-021-D3B06-H-0122
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Marcel Oliver
Module examiner	
Credit points (ECTS)	5
Learning outcomes	Students • can explain the function of algorithms and analyze their properties. • can develop simple algorithms and implement them in a programming language. • know important algorithms and data structures for sorting problems and searches as well as for graph-based problems and can apply them using examples. • can explain and apply the basics of object-oriented programming. • know algorithmic paradigms and can explain them using examples. • know different views of socio-technical systems and human-machine interfaces. • are able to evaluate and design information systems not only in terms of technical aspects but also with regard to social and cognitive aspects.
Contents/topics	• Properties of algorithms, e.g. efficiency, complexity, recursion • Data structures array, list, tree and graph • Sorting and search algorithms • Graph Algorithms • Basics of object-oriented programming • Algorithmic paradigms • Human-Machine Interaction • Internet of Things and networked human-machine systems • (Self)-Learning Systems (Artificial Intelligence; Cyborgs /Hybrid Intelligence)

Formal requirements for participation	None
Recommended requirements for participation:	Foundations of Information Systems, Software Engineering – Programming
Teaching and examination language	English (In agreement with the lecturer, German may be chosen as the language of the examination.)
Teaching and learning methods/course types	Lecture (VL) (2 SWS) / Exercise (UE) (2 SWS)
ECTS awarding criteria	performance record assessed with at least "sufficient": Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester; or portfolio examination.
Workload / distribution of ECTS credits	45 h = Time of attendance lecture and tutorial or self study 75 h = Preparation and postprocessing lecture and tutorial 30 h = Exam preparation 150 h = Total workload total= 5, corresponds to 150 hours
Module grade	assessment
Applicability to other degree programs/course admittance	BSc Digital and Data Driven Business BSc Mathematics
Course rotation	Summer semester
Remarks	In agreement with the lecturer, German may be chosen as the language of the examination.

Mandatory Modules of the 3rd Semester

Optimization in Data Science

Module title	Optimization in Data Science
Module number	new
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Marcel Oliver
Module examiner	
Credit points (ECTS)	5
Learning outcomes	Students will be able to formulate optimization problems and recognize different classes of optimization problems. They are able to solve optimization problems using basic methods (e.g. gradient methods and simplex methods)
Contents/topics	The course covers modeling questions from data science as optimization problems. • Unconstrained optimization (optimality conditions, gradient methods) • Convexity (convex sets, convex functions) • Linear optimization (polyhedra, KKT conditions, simplex method) • Duality of linear programs Further reading: • Jorge Nocedal, Stephen J. Wright, Numerical Optimization, Springer, 1999
Formal requirements for participation	None
Recommended requirements for participation:	Analysis for Data Science 1 and 2, Linear Algebra for Data Science 1 and 2

Teaching and examination language	English
Teaching and learning methods/course types	Lecture (VL) (2 SWS) / Exercise (UE) (1 SWS)
ECTS awarding criteria	performance record assessed with at least "sufficient": Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester.
Workload / distribution of ECTS credits	face-to-face/independent study in lecture: 2 ECTS, corresponds to 60 hours preparation and follow-up (includes coursework): 2 ECTS, equivalent to 60 hours preparation assessment: 1 ECTS, corresponds to 30 hours
Module grade	assessment
Applicability to other degree programs/course admittance	BSc Mathematics BSc Digital and Data Driven Business
Course rotation	Winter or summer semester
Remarks	in agreement with the lecturer, German may be chosen as the language of the examination.

Introduction to Stochastics

Module title	Introduction to Stochastics
Module number	82-105-L-MAT24-H-0610
Level of qualification	Bachelor (University)
Degree program hosting the module	B.Sc. Mathematics
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics
Module coordinator	Krebs, Johannes
Module examiner	Krebs, Johannes
Credit points (ECTS)	5
Learning outcomes	Students learn the fundamentals of stochastics, they study basic principles and are able to build simple models. Students learn how to work on general probability spaces and get to know advanced questions in inductive statistics and applied probability. Students learn to solve problems from various areas in stochastics and present solutions in the exercise sessions.
Contents/topics	Basic concepts of stochastics: sample space, events, probability distribution, elementary conditional probability, independence. Random variables: expected value, variance, covariance, correlation, moments, weak law of large numbers, limit theorems. The basic procedures of inferential statistics (inference): estimation, significance tests, confidence interval, inference for normally distributed observations.
Formal requirements for participation	None
Recommended requirements for participation:	
Teaching and examination language	German
Teaching and learning methods/course types	Lecture (VL) (2 SWS) / Exercise (UE) (2 SWS)

ECTS awarding criteria	course assessment at least "ausreichend" (sufficient): [Written examination (60 - 90 minutes) or oral examination (20 - 30 minutes), voluntary exercises can be offered during the semester]
Workload / distribution of ECTS credits	Lecture or corresponding self-study: 2 ECTS credit points (60 hours) Preparation and reworking, accompanying exercises: 2 ECTS credit points (60 hours), Preparation of examination: 1 ECTS credit point (30 hours)
Module grade	assessment
Applicability to other degree programs/course admittance	B.Sc. Data Science Polyvalence: - Lehramt Mathematik für GS/MS/RS und Gymnasium - Interdisziplinärer, lehramtsgeeigneter Bachelorstudiengang Mathematik, Ausrichtungen Grundschule, Mittelschule, Realschule und Gymnasium
Course rotation	Winter semester
Remarks	

Foundations of Data Science

Module title	Foundations of Data Science
Module number	new
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Dominik Stöger
Module examiner	
Credit points (ECTS)	10
Learning outcomes	Basic understanding of problems in data science; Knowledge and understanding of basic mathematical concepts and ability to describe them. Independent solving of applied problems by means of suitable software libraries.
Contents/topics	Basic introduction to problems in data science as well as mathematic terms to describe them appropriately, such as singular value decomposition and applications (power method, approximation by low rank matrices, principal component analysis), reconstruction of sparse vectors and low-rank matrices by linear measurements (compressed sensing and the matrix completion problem), clustering (k-means clustering and spectral clustering) and Johnson-Linstrauss embeddings. Further reading: • Blum, Hopcroft, Kannan: Foundations of Data Science • Skript Bandeira, Zhivotovskiy: Mathematics of Machine Learning (https://people.math.ethz.ch/~abandeira/Math_of_ML_Lecture_Notes2021.pdf)
Formal requirements for participation	None
Recommended requirements for participation:	Introduction to Programming, Hands-on Machine Learning and Data Science
Teaching and examination language	English

Teaching and learning methods/course types	Lecture (VL) (4 SWS) / Exercise (UE) (2 SWS)
ECTS awarding criteria	performance record assessed with at least "sufficient": Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester or portfolio.
Workload / distribution of ECTS credits	face-to-face/independent study in lecture: 3.5 ECTS, corresponds to 105 hours preparation and follow-up (includes coursework): 4.5 ECTS, equivalent to 135 hours preparation assessment: 2 ECTS, corresponds to 60 hours
Module grade	assessment
Applicability to other degree programs/course admittance	BSc Mathematics BSc Digital and Data Driven Business
Course rotation	Winter or summer semester
Remarks	For Data Science: in agreement with the lecturer, German may be chosen as the language of the examination.

Advanced Programming

Module title	Advanced Programming
Module number	new
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Marcel Oliver
Module examiner	
Credit points (ECTS)	5
Learning outcomes	Advanced knowledge of programming with Python and related software tools. Graduates can successfully use advanced Python-based solutions for specialization modules, the bachelor's thesis and beyond.
Contents/topics	A selection of the following or similar topics: • Concepts of software engineering (modularization, object-oriented programming, design patterns, documentation, testing (test-driven development, version management) • Selected advanced features of the Python programming (e.g. lambda expressions, exception handling, regular expressions, iterators, basics of functional programming, coroutines) • Performance aspects of programming with Python (compiling critical sections with Cython and/or Numba, external high-performance libraries, GPU computing) • 3D graphics and animations, GUI toolkits • Elementary concepts of parallelization
Formal requirements for participation	Introduction to Programming
Recommended requirements for participation:	Algorithms and Data Structures, Linear Algebra for Data Science 1 and 2
Teaching and examination language	English
Teaching and learning methods/course types	Practical training (P) (4 SWS)
ECTS awarding criteria	performance record assessed with at least "sufficient": portfolio

Workload / distribution of ECTS credits	face-to-face/independent study in lecture: 2 ECTS, corresponds to 60 hours preparation and follow-up (includes coursework): 2 ECTS, equivalent to 60 hours preparation assessment: 1 ECTS, corresponds to 30 hours
Module grade	assessment
Applicability to other degree programs/course admittance	BSc Mathematics
Course rotation	Winter or summer semester
Remarks	in agreement with the lecturer, German may be chosen as the language of the examination.

Mandatory Modules of the 4th Semester

Statistical Learning

Module title	Statistical Learning
Module number	
Level of qualification	Bachelor (UNI)
Degree program hosting the module	Bachelor Data Science
Institutional anchoring	Mathematisch-Geographische Fakultät
Subjects involved	Mathematics
Module coordinator	Krebs, Johannes
Module examiner	Krebs, Johannes
Credit points (ECTS)	5
Learning outcomes	Comprehensive understanding of mathematical problems, definitions, techniques in proving mathematical statements as well as solving exercises related to the topics of the module.
Contents/topics	Basic introduction to various problems in statistical learning such as statis-tical decision theory, validation methods, Bayes risk, linear algorithms, Ridge- and Lasso-estimator, classification problems, discriminant analysis, nonparametric methods. [recommended literature: Stefan Richter Statistisches und maschinelles Lernen Springer 2019, Trevor Hastie et al. The Elements of Statistical Learning 2001, Gareth James et al. An Introduction to Statistical Learning with Applications in R Springer 2017.]
Formal requirements for participation	
Recommended requirements for participation:	Introduction to Statistics
Teaching and examination language	German or English
Teaching and learning methods/course types	Lecture (VL) (2 SWS), Exercises (UE) (2 SWS)

ECTS awarding criteria	course assessment at least "ausreichend" (sufficient): [Written examination (60 - 90 minutes) or oral examination (20 - 30 minutes), voluntary exercises can be offered during the semester]
Workload / distribution of ECTS credits	Lecture or corresponding self-study: 2 ECTS credit points (60 hours) Preparation and reworking, accompanying exercises: 2 ECTS credit points (60 hours) Preparation of examination: 1 ECTS credit point (30 hours)
Module grade	Assessment
Applicability to other degree programs/course admittance	BSc Digital and Data Driven Business BSc Mathematik
Course rotation	Winter Semester or Summer Semester
Remarks	

Foundations of Machine Learning

Module title	Foundations of Machine Learning
Module number	82-105-DS06-H-0822
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Felix Voigtlaender
Module examiner	
Credit points (ECTS)	10
Learning outcomes	Appreciation for and understanding of the main questions, concepts, and methods of machine learning, and especially for their mathematical/statistical formulation. Ability to correctly and independently solve theoretical as well as practical exercises (the latter using the computer). Appreciation of the fact that very flexible methods of machine learning can yield better performance, but that this usually requires more training data. Based on the obtained understanding, students are able to independently learn about, understand, and apply novel machine learning algorithms.
Contents/topics	Introduction to studying the properties of machine learning (ML) algorithms and related mathematical concepts. The algorithms that were practically introduced and applied in the module “Hands-on Machine Learning and Data Science“ are analyzed mathematically. The mathematical concepts related to ML studied in the lecture include for instance: PAC Learning, Empirical Risk Minimization, concentration inequalities, VC dimension, no-free-lunch theorem, universal consistency, bias-complexity tradeoff. The algorithms and concepts that are studied include for instance: support vector machines (SVM), kernel methods, stochastic gradient descent (SGD), Ridge regression, logistic regression, k-nearest neighbors Relevant Literature: • Shalev-Shwartz, Ben-David: Understanding Machine Learning • Mohri, Rostamizadeh, Talwalkar: Foundations of Machine Learning • Mitchell: Machine Learning • Hastie, Tibshirani, Friedman: The elements of statistical learning • Devroye, Györfi, Lugosi: A probabilistic theory of pattern recognition

Formal requirements for participation	None
Recommended requirements for participation:	Introduction to programming; Hands-on Machine Learning and Data Science; Introduction to Stochastics; Analysis for Data Science I-II, Linear Algebra I
Teaching and examination language	English (In agreement with the lecturer, German may be chosen as the language of the examination.)
Teaching and learning methods/course types	Lecture (VL) (2 SWS) / Exercise (UE) (1 SWS)
ECTS awarding criteria	performance record assessed with at least "sufficient" (4.0): Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester
Workload / distribution of ECTS credits	face-to-face/independent study in lecture: 3,5 ECTS, corresponds to 105 hours preparation and follow-up (includes exercises): 4,5 ECTS, equivalent to 135 hours preparation exam: 2 ECTS, corresponds to 60 hours total = 10, corresponds to 300 hours
Module grade	Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester
Applicability to other degree programs/course admittance	BSc Digital and Data Driven Business BSc Mathematics
Course rotation	Summer semester
Remarks	In agreement with the lecturer, German may be chosen as the language of the examination.

Data Lab

Module title	Data Lab
Module number	82-105-DS03-H-0822
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Götz Pfander
Module examiner	
Credit points (ECTS)	5
Learning outcomes	Ability to deal with comprehensive practical tasks and use data science methods to solve them. Creation of computer code in which the algorithms used are efficiently implemented. After completing the module, students are able to analyze a comprehensive data science problem in detail, formulate, program and test solutions. They are able summarize the results in a report and discuss them with their fellow students in a presentation.
Contents/topics	In small groups of students, solutions for complex tasks in the field of data science are developed independently but under supervision. Students acquire the necessary detailed knowledge of the methods used and the field of application. In doing so, they use previously acquired programming skills and their knowledge from Data Science introductory courses. They thus gain practical experience with data science methods and problems. Soft skills: - Practicing teamwork in the student groups. - Learn how to organize a long-term project. - In the case of questions with a concrete application background, explain this and, if necessary, communicate with potential users.
Formal requirements for participation	None
Recommended requirements for participation:	Introduction to Programming Hands-on Machine Learning and Data Science
Teaching and examination language	English (In agreement with the lecturer, German may be chosen as the language of the examination.)
Teaching and learning methods/course types	E.g. Lecture (VL) (2 SWS) / Exercise (UE) (1 SWS)
ECTS awarding criteria	Presentation of the results in a report of approx. 10-20 pages per group. Each participant reports on their contributions in a final

	presentation. Grading of the presentation, taking into account the report, with at least sufficient.
Workload / distribution of ECTS credits	Developing computer code (100 hours), prepare report and presentation (20 hours), contact hours with course (30 hours)
Module grade	Assessment of presentation and written report
Applicability to other degree programs/course admittance	BSc Mathematics
Course rotation	Winter semester *or* Summer semester
Remarks	In agreement with the lecturer, German may be chosen as the language of the examination.

Mandatory Modules of the 5th Semester

Ethics of Algorithms and Data

Module title	Ethics of Algorithms and Data
Module number	new
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Prof. Dr. Alexis Fritz, ThF
Module examiner	
Credit points (ECTS)	5
Learning outcomes	The students get an overview of the main ethical questions in dealing with technology and are prepared to take a position on them. They are able to classify current ethical challenges in the context of historical problem domains and identify relevant argumentation strategies and justification contexts and apply them to example cases. They are capable of detecting problems of technology ethics in practical applications, highlighting their backgrounds and responsibly developing proposals for solutions. Special attention will be paid to problems arising from the fields of machine learning and data science.
Contents/topics	• Subject, task and types of ethics • Historical positions of technology ethics • Identification and classification of problems in technology ethics • fundamental cross-sectional issues such as moral agency, responsibility, human-machine interaction, trust, freedom, data privacy, safety, justice, social acceptance and participation • Current challenges for technology ethics with a focus on the fields of machine learning and data science Current topics (e.g. professional ethics, technology assessment, ethics commissions and codes of ethics, autonomous driving/flying, digital communication, virtual realities, information ethics, algorithmic bias, eHealth, nursing robots, sex robots, transhumanism, digital finance, autonomous weapon systems…) are addressed in student

	presentations or working groups. In addition, other problem areas that are comparable in their relevance for discourses of technology ethics and in their complexity can also be addressed.
Formal requirements for participation	None
Recommended requirements for participation:	Basic knowledge of data science and statistics
Teaching and examination language	English (In agreement with the lecturer, German may be chosen as the language of the examination.)
Teaching and learning methods/course types	---
ECTS awarding criteria	performance record assessed with at least "sufficient": Written or oral examination with the possibility of grade improvement through voluntary exercises during the semester; or portfolio examination.
Workload / distribution of ECTS credits	40 h = Time of attendance lecture 30 h = Preparation and postprocessing lecture 80 h = Case studies preparation 150 h = Total workload total= 5, corresponds to 150 hours
Module grade	assessment
Applicability to other degree programs/course admittance	BSc Digital and Data Driven Business BSc Mathematics
Course rotation	Winter semester *or* Summer semester
Remarks	In agreement with the lecturer, German may be chosen as the language of the examination.

Mandatory Modules of the 6th Semester

Seminar in Machine Learning and related topics for B.Sc.

Module title	Seminar in Machine Learning and related topics for B.Sc.
Module number	82-105-DS19-H-0922
Level of qualification	Bachelor (University)
Degree program hosting the module	BSc Data Science
Institutional anchoring	Faculty of Mathematics and Geography
Subjects involved	Mathematics, Data Science
Module coordinator	Felix Voigtlaender
Module examiner	
Credit points (ECTS)	5
Learning outcomes	Appreciation for and understanding of specific topics and questions in Data Science. Ability to read and understand research papers. Ability to write a coherent report, to create slides, and to deliver a presentation.
Contents/topics	List of topics (different research papers from the area of Machine Learning) provided by the instructor; students can choose from these topics.
Formal requirements for participation	None
Recommended requirements for participation:	Analysis I-II, Linear Algebra I-II
Teaching and examination language	English (In agreement with the lecturer, German may be chosen as the language of the examination.)
Teaching and learning methods/course types	Seminar (SE) (2 SWS)
ECTS awarding criteria	Grade of at least 4.0 for the presentation (which is graded taking into account the quality of the written report). Active and consistent participation in the academic discourse. Compulsory attendance: Learning to discuss topics in mathematics and Data Science is an essential goal of this module. Therefore, each

	student is required to present their topic in person and to also attend the other presentations, in order to gain practice in discussing and to learn from the other presentations.
Workload / distribution of ECTS credits	Regularly attending the seminar: 1 ECTS (30 hours). Preparing and writing the report and the presentation: 4 ECTS (120 hours)
Module grade	assessment
Applicability to other degree programs/course admittance	BSc Digital and Data Driven Business BSc Mathematics
Course rotation	Winter semester *or* Summer semester
Remarks	In agreement with the lecturer, German may be chosen as the language of the examination.