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120. Curriculum for the Master's Degree Programme in Data Science at the University of Salzburg

(Version 2021)

In its session on 27.04.2021, the Paris Lodron University of Salzburg Senate formally approved the curriculum for the master's degree programme in Data Science, finalised by the Data Science curriculum committee at the University of Salzburg in its 28.01.2021 meeting in the version that follows.

The legal basis for the curriculum is the 2002 Federal Act on the Organisation of Universities and their Studies (Universities Act 2002 – UG), Federal Law Gazette No. 120/2002, and the section of the Statutes of the University of Salzburg pertaining to university studies.

§ 1 General Provisions

(1) The number of ECTS points necessary to complete a degree in the master's programme in Data Science is 120. This corresponds to four semesters of study.

(2) Graduates of the master's programme in Data Science hold a Master of Science degree (abbreviated MSc).

(3) In order to be admitted to the master's programme in Data Science, students must hold a bachelor's degree from a recognized domestic or foreign university or post-secondary educational institution (see UG 2002 §64 para. 5). The bachelor's degree shall be in Computer Science, Mathematics, Statistics, or a field considered equivalent to one of the above.

(4) If a student's bachelor's degree is not deemed equivalent to an acceptable extent, the student may be admitted conditional on a required completion of additional work worth up to 45 ECTS points; these requirements must be satisfied by the end of the master's programme. Only the Rectorate or a member of staff at the University of Salzburg designated by the Rectorate is authorised to make a determination of equivalency and thus whether a student will be admitted.

(5) All graduation requirements to be fulfilled by students have been assigned ECTS points. One ECTS point equals 25 hours of study, which corresponds to the average number of hours required to achieve the expected learning objectives. An academic year consists of 1500 hours, corresponding to 60 ECTS points.

(6) Students with disabilities and/or chronic illnesses will not be subject to any form of discrimination in their studies. The University is committed to the basic principles laid out in the UN Convention on the Rights of Persons with Disabilities and Austrian non-discrimination laws as well as the policy of positive action.

(7) Examinations for all mandatory classes in this programme can be taken in English. Students may also take courses in German offered as equivalent to the courses taught in English. The total number of credits earned in courses taught in German in Modules BM, CM, and EM must not exceed the number of credits earned in courses taught in English.

§ 2 Overview of the degree programme and professional skills to be acquired

(1) Overview of the degree programme

After four very successful years of the first Data Science master's programme in Austria, the present curriculum marks the step from a German into an English program. This internationalization step has also been used to update the curriculum and to make adaptations based on the experiences of the previous years.

The master's programme in Data Science centers around how to make sense of data effectively, knowledgeably, and responsibly, in order to advance knowledge and insight. Providing solutions to the challenges associated with the relatively new field of Data Science is of vital importance for enterprises, governments and other organizations, as well as for individuals. In addition, generating, modeling, analyzing, and interpreting data is central in today's scientific endeavor at universities and other research institutions.

The skills and knowledge needed to tackle today's Data Science challenges, and to develop meaningful solutions, require more than what is provided in traditional curricula in statistics and computer science. Today's Data Scientist has to develop a holistic view on data from often

rather heterogeneous sources, scrutinize critically, analyze using adequate statistical methods, extract relevant information, and correctly interpret the results obtained. On a technical level, the data deluge requires understanding and experience regarding large and often distributed systems for data storing and processing. Making sense of these data encompasses numerous activities, from finding and organizing the data to evaluating their quality, exploratory data analysis, modeling, analyzing, and interpreting the data, to an understandable presentation of results. The Data Science curriculum represents a bridge from raw data to information, from information to knowledge, and from knowledge to making well-grounded decisions.

(2) Professional skills and competences (Learning Outcomes)

The master's programme serves to further develop the competences that the student has already begun to acquire in the context of the preceding bachelor program. The specific qualification profile is based on a competence model comprising the following core proficiencies:

- area-specific state-of-the-art competence in data preparation and cleaning, data management, exploratory data analysis, visualization, statistical modeling, regression methods, dependence modeling, machine learning, and data mining.
- advanced competence in (depending on the selected elective modules) database systems, analysis of algorithms, processing of visual data, remote sensing, geographic information systems, and hardware-oriented signal processing.
- competence in integrating and communicating facts and ideas that transcend one's specialized training: focused but interdisciplinary analysis of problems within a particular topic through the integration of relevant facts and theories from other disciplines.

The master's programme is designed such that students can acquire these competences to an extent corresponding to level 7 of the European Qualifications Framework. This means that graduates of the programme will have an area-specific, highly developed understanding of a problem that lays the groundwork for innovative approaches in research. They will possess a critical awareness of theoretical questions that will enable them to deepen their understanding in any area of Data Science. They will have the cognitive and practical abilities necessary for planning, structuring, and completing research projects and will be able to communicate findings to non-experts. Students who choose an interdisciplinary topic for their master's thesis will, in addition, possess the ability to integrate methods and theories from various fields and to tie their Data Science knowledge to other sciences.

(3) Importance and relevance of the degree for society, the scientific community and the labour market

Since they are combining analytic capabilities with soft skills (communication and teamwork), it is not surprising that Data Scientists are worldwide among the most sought-after experts, and the labor market is still projected to grow with attractive positions for Data Scientists. Being able to extract relevant features and essential information from ever-growing complex data sets is not only key for the scientific community and industry, it is also key for society in general, also considering the General Data Protection Regulation.

Furthermore, studies in Data Science at the master's level are an important contribution to a well-rounded education in other areas and can constitute a useful complement to an academic career in the natural, technical, or social sciences, as well as in other areas.

Graduates of the master's programme in Data Science often pursue careers in the following fields:

- They are members of analytics teams in medium-sized to larger companies, or they are the single Data Scientist in a smaller company or a start-up.
- They work in government agencies dealing with data, for example, within Statistics or Data Science units.

- They work in research institutions, including universities, research hospitals, and other entities pursuing scientific endeavors.
- They develop software for data processing and analysis.
- They provide consulting services to private and public institutions for projects in the field of Data Science

§ 3 Structure of the programme

The master's programme in Data Science comprises 3 module groups with a total number of 81 ECTS points. In addition, there are 12 ECTS points assigned for free elective courses and 3 ECTS points for a compulsory internship. The master's thesis is worth 20 ECTS points and the master's exam is worth 4 ECTS points.

	ECTS
Bridge Module	12
Compulsory Modules	39
Elective Modules	30
Total Module Groups	81
Free elective courses	12
Master's thesis	20
Master's exam	4
Compulsory internship	3
Total	**120**

§ 4 Course Types

The programme contains the following course types:

Lecture courses (VO) provide an overview of an area or subarea as well as the theoretical approaches to it and present various methods and points of view. The content is communicated primarily in lecture format. A lecture course does not carry mandatory attendance.

Exercises (UE) communicate practical skills in working with classical and modern techniques from different sub-fields of data science, including, but not limited to, statistics, machine learning, data mining, or data management. Exercises carry mandatory attendance.

Lectures with exercises (VU) combine a theoretical introduction into a subarea with the communication of practical skills. Lectures with exercises do not carry mandatory attendance.

Exercises with lectures (UV) also combine a theoretical introduction into a subarea with the communication of practical skills. However, here the emphasis on practical skills dominates. Exercises with lectures carry mandatory attendance.

Proseminars (PS) stand between exercises and seminars and contain elements of both: practicing the application of data science skills is combined with discussion and reflection on scientific themes. Proseminars carry mandatory attendance.

Seminars (SE) are courses leading deeper into a focused subject matter. They serve the acquisition of deeper specialized knowledge and the capacity for discussion and reflection on scientific themes, usually in the context of collaborative learning on the part of the student. Seminars carry mandatory attendance.

Through the choice of free electives, also other course types may apply. They are explained in their respective home curriculum.

§ 5 Required courses and plan of study

The following contains a list of modules and courses in the master's programme Data Science. The division into semesters serves as a recommendation designed to ensure that the order in which the courses are taken builds on knowledge acquired successively and that the workload of 60 ECTS points in an academic year is not exceeded. If there are no prerequisites, modules and courses can however be taken in a different order in accordance with § 12.

Detailed descriptions of the modules including the knowledge, methods and skills to be acquired can be found in Annex I: Module descriptions.

Master's degree programme in Data Science								
Module	**Course**	**SHrs**	**Type**	**ECTS**	**Semester with ECTS**			
					I	**II**	**III**	**IV**
(1) Bridge Module (BM)								
In the bridge module, courses with a total of **12 ECTS points shall be chosen**. The course „Introduction to Data Science" is mandatory. In order to obtain the other 11 ECTS points, students propose their individual course maps which need to be approved by the curriculum committee ahead of enrolling in the courses. The individual course map may not contain courses completed previously by the students in their individual academic careers, as the purpose of this module is to serve as a bridge from fields such as computer science, mathematics, and statistics into the interdisciplinary field Data Science.								
	Introduction to Data Science	1	VU	1	1			
	Introduction to Computer Science and Systems	2	VO	3	3			
	Basic Elements of Statistics	2	VO	2	2			
	Basic Elements of Statistics	2	UE	3	3			
	Elementary Data Mining	2	VU	3		3		
	Elementary Probability	4	VO	4		4		
	Elementary Probability	2	UE	3		3		
	Mathematical Statistics	2	VO	3	3			
	Mathematical Statistics	1	UE	2	2			
	Applied Statistics	2	UV	3		3		
	Databases 1	2	VO	2		2		
	Databases 1	1	PS	2		2		
	Databases 2	2	VO	2	2		(2)	
	Databases 2	1	PS	2	2		(2)	
	Algorithms and Data Structures	4	VO	4		4		
	Algorithms and Data Structures	2	PS	4		4		
Total for Bridge Module BM				**12**				
(2) Compulsory Modules (CM)								
Module Statistical Methods (CM1)								
	Statistics, Visualization, and More Using R	2	SE	4		4		
	Regression Methods and Computational Statistics	2	VO	3			3	
	Regression Methods and Computational Statistics	2	UE	3			3	
Subtotal for Module CM1		6		10		4	6	
Module Databases (CM2)								
	Similarity Search in Large Databases	2	VO	2.5			2.5	
	Similarity Search in Large Databases	1	PS	2.5			2.5	
	Non-Standard Database Systems	2	VO	2.5				2.5
	Non-Standard Database Systems	1	PS	2.5				2.5
Subtotal for Module CM2		6		10			5	5

Module Knowledge Discovery (CM3)							
Advanced Data Mining	2	VU	4			4	
Machine Learning	2	VO	3		3		
Machine Learning	1	PS	3		3		
Subtotal for Module CM3	5		10		6	4	
Module Statistical Practice, Case Studies, Ethics (CM4)							
Case Studies	2	SE	3			3	
Interpreting and Presenting Scientific Results	2	SE	2			2	
Data Ethics and Identity	2	SE	4		4		
Subtotal for Module CM4	6		9		4	5	
Total for Compulsory Modules	**23**		**39**		**14**	**20**	**5**
(3) Elective Modules according to § 6 (EM)							
Three elective modules need to be completed. An elective module is considered completed if **at least 10 ECTS points** in this module have been earned. Two of the elective modules have to be from EM1-EM6.							
Module Statistical Methods and Econometrics (EM1)							
For this module, a list of eligible courses will be made available at the beginning of every academic year or semester.							
Subtotal for Module EM1			10				
Module Advanced Computer Science (EM2)							
Advanced Algorithms and Data Structures	3	VO	3			3	
Advanced Algorithms and Data Structures	2	PS	4			4	
Advanced Databases	2	VO	2	2			
Advanced Databases	1	PS	2	2			
Distributed Systems	2	VO	2		2		
Distributed Systems	1	PS	2		2		
Seminar for Computer Science	2	SE	5	5			
Subtotal for Module EM2			10				
Module Image Processing (EM3)							
Image Processing and Imaging	2	VO	2	2			
Image Processing and Imaging	1	PS	3	3			
Computer Vision	2	VO	2.5			2.5	
Computer Vision	1	PS	2.5			2.5	
Imaging Beyond Consumer Cameras	2	VO	2.5		2.5		
Imaging Beyond Consumer Cameras	1	PS	2.5		2.5		
Subtotal for Module EM3			10				
Module Multimedia Technology (EM4)							
Audio Processing	2	VO	2.5		2.5		
Audio Processing	1	PS	2.5		2.5		
Hardware Oriented Signal Processing 2	1	UV	1.5	1.5			
Filterbanks and Wavelets	2	VO	2.5				2.5
Filterbanks and Wavelets	1	PS	2.5				2.5
Multimedia Technologies	1	SE	2.5			2.5	
Subtotal for Module EM4			10				

Module Remote Sensing (EM5)							
Remote Sensing and Image Processing	2	VO	3	3			
Praxis: Analyse von Fernerkundungs-aufnahmen (English group: Image Processing and Analysis)	2	UE	3	3			
Analysis and Modeling (Remote Sensing)	2	SE	4		4		
Advanced Remote Sensing	4	UE	6			6	
Subtotal for Module EM5			10				
Module Geographic Information Systems and Science (EM6)							
Design of Geospatial Data Models	2	VO	3	3			
Introduction to Geoinformatics	2	VO	2		2		
Praxis: Geographische Informations-systeme (English group)	2	UE	4		4		
GIScience: Theory and Concepts	2	SE	4			4	
OpenGIS. Standards, Architectures, and Services	2	VO/PS	3		3		
Subtotal for Module EM6			10				
Flexible Elective Module (EM7)							
Students may propose one flexible elective module themselves. This shall consist of thematically coherent courses amounting to at least 10 ECTS. Each proposed module needs to be submitted to the Data Science curricular committee for evaluation and possible acceptance six weeks ahead of enrollment into the courses, along with a proposed title and course map. In order to facilitate choices, details for acceptable flexible elective modules will be made available by the curricular committee in regular intervals (e.g., on the program web page). Examples for such modules include Bioinformatics, Digital Communication, Empirical Social Sciences, and Human Computer Interaction, among others. The purpose of allowing for these flexible elective modules is to give greater flexibility to students in choosing relevant topics of their interest, to provide the possibility to take advantage of temporary course offerings (e.g., by visiting scientists), and to respond timely to important topics of the day without formal revisions of the curriculum. However, students may choose to elect all three of their elective modules from EM1-EM6 instead.							
Subtotal for Module EM7			10				
Total for Elective modules			**30**				
(4) Free elective courses			**12**				
(5) Compulsory internship			**3**			**3**	
(6) Master's thesis			**20**				**20**
(7) Master's exam			**4**				**4**
Sum total			**120**		**60**	**60**	

§ 6 Elective courses

(1) In the master's programme in Data Science, students are to complete elective courses totalling 12 ECTS points. These elective courses are designed to further the acquisition of additional professional skills and strengthen individual areas of focus within a student's course of study. They can be completed at any accredited postsecondary institution.

(2) Should the courses chosen as electives for 12 ECTS points have a demonstrable connection to this master's programme, the electives can constitute a supplementary certificate in a specific area (Wahlfachmodul), which is recorded on the master's degree certificate.

(3) The following constitute a non-exhaustive list of recommended areas in which a supplementary certificate could be acquired: Biology, Computer Science, Economics, Gender Studies, Geography, Geoinformatics, Human Computer Interaction, Linguistics, Literature, Mathematics, Philosophy, Psychology, Physics, Political Science, and Sociology. Most other disciplines can be combined with Data Science in interesting ways, as well.

§ 7 Master's thesis

(1) The master's thesis serves to demonstrate that students have acquired the ability to perform independent academic research in areas that include, but are not limited to, Statistics, Machine Learning, Data Mining or Data Management according to current academic research methods and standards.

(2) The topic of the master's thesis should be chosen in such a way that it is reasonable and appropriate for completion of the thesis within six months (cf. UG 2002 §81 para. 2).

(3) The topic of the master's thesis must be taken from a module in the master's curricu- lum. The student may suggest a topic or choose from a number of topics provided by one of the available thesis advisors.

(4) It is to be noted that both the student's work on the topic and advisor's work with the student are governed by Austrian copyright law, Federal Law Gazette No. 111/1936 (cf. UG 2002 §80 para. 2).

(5) The master's thesis may be written in English or German.

§ 8 Compulsory Internship

(1) As part of the master's programme in Data Science, students must complete a compulsory internship related to the programme comprising 2 weeks, which is comparable to full-time employment (this corresponds to 3 ECTS points). The internship should enable students to use the knowledge and skills they have gained during their studies so far.

(2) The internship is generally to be completed outside of the University in an institution pre-approved by the responsible body. Pre-approval of the internship and the selected institution is required and must be granted by the responsible body.

(3) Should it not be possible to complete the internship outside the University, students may in exceptional cases complete an internship by participating in research projects at the University, as far as this is possible and as far as this receives approval from the responsible body.

(4) Students with disabilities and/or chronic illnesses will be supported in the completion of their internship by the University (Office for Family, Gender, Disability & Diversity). Should the requirements of potential internships be rendered impossible to fulfil due to architectural and/or structural barriers, students with disabilities and/or chronic illnesses will be given the opportunity to complete this part of the curriculum in a different form.

As part of their practice-oriented internships, students can gain the following qualifications (among others):

- Ability to put the theoretical knowledge acquired in the field of study into practice in a professional context
- Acquaintance with different scenarios in which theoretical concepts can be used
- Acquisition of soft skills such as teamwork, communication skills, planning and organisational skills in a professional context.

§ 9 Study abroad

Students in the master's programme in Data Science are recommended to spend a semester of study abroad. This semester abroad should ideally be scheduled in the second or third semester of study. Course transfers for the courses completed at the university abroad will be granted by the responsible body. Documents needed for the assessment of transfer courses are to be provided by the student.

Steps will be taken to ensure that the semester abroad can be completed without causing a delay in a student's course of study when the following conditions are met:

- at least 30 ECTS credits are earned in each semester of study abroad
- the content of the courses completed during the period of study abroad is not identical to courses already completed at the University of Salzburg
- confirmation by formal notification in writing before beginning the study abroad period of which courses and/or exams planned to be taken abroad are transferable to the University of Salzburg

In addition to field-specific knowledge and skills, students stand to gain the following qualifications by studying abroad:

- acquisition and consolidation of field-specific knowledge in a foreign language
- acquisition and consolidation of general foreign-language skills (comprehension, conversation, etc.)
- acquisition and consolidation of organisational skills gained by independently navigating the bureaucracy and organisational structure of a university abroad as well as daily challenges of student life abroad
- becoming acquainted with international student exchange programmes and broadening one's perspectives in one's own field of study
- acquisition and consolidation of intercultural communication skills

Students with disabilities and/or chronic illnesses will be assisted in their search for a study abroad opportunity and in planning for their semester abroad by the Office for Family, Gender, Diversity & Disability.

§ 10 Allocation of places in courses with a limited number of participants

(1) The maximum number of participants in the master's programme in Data Science for the following course types is limited as follows:

Lectures (VO)	no limit
Lectures with exercises (VU)	no limit
Exercises (UE), proseminars (PS), and exercises with lectures (UV)	30
Seminars	30

(2) For courses used also in other curricula, the participant limits may vary.

(3) In instances in which courses with a restricted number of participants are oversub- scribed, priority of enrollment will be given to students for whom the course is part of the curriculum.

(4) Students in the master's programme in Data Science will be given places in courses based on the total number of ECTS credits they have earned in the programme so far. If multiple students registering for a particular course have earned the same number of ECTS credits, the available places in this course will be allocated based on the following criteria in the order listed below:
- a student was on the waiting list in the course in the previous academic year
- a student has completed a greater number of courses and/or exams

- a student has completed a greater number of semesters in the programme of study
- average grading score weighted according to ECTS credit
- random selection

Available places will be allocated to students from other programmes using the same criteria in the same order.

(5) For students participating in international exchange programmes, additional places constituting at least ten percent of the maximum number of participants in each course will be made available. These places will be allocated randomly.

§ 11 Examination regulations

(1) Courses will be graded by the instructor. A module counts as completed when the required number of ECTS points have been earned. The evaluation of the whole module is determined on the basis of the grades for the courses that compose it. It is calculated in accordance with the number of credits assigned to the courses (see Satzung der Universität Salzburg, I. Teil: Studienrecht § 19 (3)). The final grade for each module will be recorded in the certificate of completion of the master's exam.

(2) The master's programme is considered finished when

- all modules (BM, CM, EM), the free elective courses, and the internship have been successfully completed.
- the master's thesis has been accepted, and
- the commissional master's exam (see §14) has been passed.

§ 12 Master's examination before examining committee

(1) The master's programme in Data Science concludes with a master's examination before an examining committee. The master's examination carries 4 ECTS points.

(2) Students must have successfully completed all of the required courses, the compulsory internship, and the master's thesis in order to be eligible to take the master's ex- amination.

(3) The master's examination consists of three parts of approximately equal weight. The first one will be a presentation of the master's thesis with discussion (at most 20 minutes), the second one will be about the scientific area of the master's thesis, and the third one will be from a different module suggested by the student and subject to approval by the curricular committee.

§ 13 Effective date

The curriculum comes into force 1 October 2021.

§ 14 Transitional provisions

(1) Students enrolled in the curriculum for the master's programme of study in Data Science at Paris Lodron University of Salzburg (2018 Version, Mitteilungsblatt – Sondernummer 105, 23.05.2018) when this curriculum comes into force have to complete the programme in which they are enrolled until 30.09.2024.

(2) Students subject to a different curriculum may during any period of registration decide to change into this curriculum. An irrevocable written declaration is to be submitted to the Office of Admissions (Studienabteilung), should a student wish to change curricula.

(3) Annex II contains a course equivalency list.

Annex I: Module Descriptions:

Module	**Bridge Module (BM)**
Module Code	BM
ECTS Points	12 ECTS
Learning Outcomes	Upon completion of the module, students have an elementary understanding regarding Data Science in a more narrow and in a wider sense, and they are familiar with exemplary areas in which Data Science is used. Students possess a solid knowledge regarding basic methods and concepts from statistics and computer science which are assumed later in the Data Science curriculum, with a particular focus on those methods and concepts that they have not yet familiarized themselves with in their previous studies. After completing this module, students are able to correctly and appropriately use the basic statistical, as well as the computer science terminology.
Content	Introduction to Data Science: – importance of this field – application areas – relevance for society, science, industry, and trade. Foundations of statistics and computer science. Elements of data mining methods and the knowledge discovery process, principles of modeling and some basic data mining methods (e.g. decision trees, Bayes classifiers, clustering). Other details according to individual course portfolio.
Courses	Introduction to Data Science (VU, 1 SHrs, 1 ECTS) Other courses with a total of 11 ECTS. Course choices based on previous studies and degrees.
Evaluation	Individual exams per course

Module	**Statistical Methods (CM1)**
Module Code	CM1
ECTS Points	10 ECTS
Learning Outcomes	Students are experienced users of the statistics software R, they are able to transform, aggregate, and enrich data, summarize the data in state-of-the-art graphics and extract relevant information. Students understand the frequentist approach to statistics, correctly interpret errors of first and second kind, p-values and confidence regions and are aware of limitations and assumptions underlying standard inferential procedures. Students have a good overview of standard regression techniques, they are able to choose parametric and nonparametric approaches appropriately, they know how to evaluate the model performance via simulations and resampling using R. Students use the statistical terminology correctly.

Content	SE: Statistics, Visualization and More Using R Introduction to key R-packages used for – data manipulation, – flexible and interactive graphics – reporting Regression Methods and Computational Statistics – Univariate linear regression – Multivariate linear regression – Overfitting – Multicollinearity – Model fitting (via least squares) – Asymptotic properties of estimators – Nonparametric regression – Simulating data for evaluating the performance and key properties of the introduced concepts – Application of the techniques presented in the lecture – Practical exercises complementing the approaches introduced in the lecture – Simulation of data and analysis of real data sets – Model evaluation
Courses	Statistics, Visualization and More Using R (SE, 2 SHrs, 4 ECTS) Regression Methods and Computational Statistics (VO, 2 SHrs, 3 ECTS) Regression Methods and Computational Statistics (UE, 2 SHrs, 3 ECTS)
Evaluation	Individual exams per course

Module	**Databases (CM2)**
Module Code	CM2
ECTS Points	10 ECTS
Learning Outcomes	Students have knowledge of advanced techniques for storing, managing, and retrieving data, critical understanding of the problems of large amounts of data and complex queries as well as an overview of the state of the art and current challenges in the field of databases Students have acquired the ability to independently design innovative systems for data management from scratch and select and professionally use existing systems according to requirements. Assessment of data management systems with regard to their possibilities and limitations for specific requirements and estimation of the effects of advanced data management systems on the development of information technology new services and the organizational structure of companies
Content	Similarity search in large databases: – Basics of similarity queries – Distance measures – Filter techniques – Quantity-based

	– Metric search techniques – Index structures for fuzzy predicates Non-standard database systems: – CAP theorem – NoSQL databases – Databases on modern hardware – Databases for special applications
Courses	Similarity Search in Large Databases (VO, 2 SHrs, 2.5 ECTS) Similarity Search in Large Databases (PS, 1 SHrs, 2.5 ECTS) Non-Standard Database Systems (VO, 2 SHrs, 2.5 ECTS) Non-Standard Database Systems (PS, 1 SHrs, 2.5 ECTS)
Evaluation	Individual exams per course

Module	**Knowledge Discovery (CM3)**
Module Code	CM3
ECTS Points	10 ECTS
Learning Outcomes	Students have knowledge about the (theoretical) foundations of machine learning and data mining techniques, as well as software libraries and systems in this field. Students have the ability to analyze learning and mining techniques, and can adapt or adjust existing techniques to specific problem settings. They also have the ability to use existing software libraries and implement methods independently. Assessment of machine learning and data mining techniques with regard to their possibilities and limitations for specific requirements and problem settings.
Content	Advanced Data Mining: – rule learning (propositional rules, inductive logic programming) – robust regression – support vector machines – ensemble methods (random forests, bagging, boosting, mixture of experts, stacking) – clustering (density-based clustering, fuzzy clustering, mixture of Gaussians, cluster shapes, noise clustering) – model complexity (information criteria, minimum description length) – feature selection – dimensionality reduction – outlier detection – handling missing values. Machine Learning: – Foundations of statistical learning theory (PAC learning, Uniform convergence, VC dimension, Rademacher complexity) – Analysis of classic learning algorithms (e.g., Boosting, SVMs, or Nearest Neighbor).

Courses	Advanced Data Mining (VU, 2 SHrs, 4 ECTS) Machine Learning (VO, 2 SHrs, 3 ECTS) Machine Learning (PS, 1 SHrs, 3 ECTS)
Evaluation	Individual exams per course

Module	**Statistical Practice, Case Studies, Ethics (CM4)**
Module Code	CM4
ECTS Points	9 ECTS
Learning Outcomes	Students are capable to perform valid descriptive and inferential analyses of real data, according to guidelines of good scientific practice, They can examine clearly formulated hypotheses and are able to present their results correctly and comprehensibly, in front of audiences with and without Data Science knowledge. Students know relevant frameworks for dealing with data, paying particular attention to standards of ethics, privacy, and identity. They are capable to relate this knowledge to concrete questions and data. That way, they can recognize conflicts or difficulties pertaining to the use of data.
Content	Case Studies: – Statistical analyses of real data, originating from interdisciplinary or applied contexts – Examination of clearly formulated hypotheses – Discussion of Data Science techniques and their applicability. Interpreting and Presenting Statistical Analyses: – Knowledgeable interpretation of results – Correct and comprehensible presentation of findings in front of audience with and without Data Science background. Data Ethics and Identity: – Privacy and identity of people in their relation to data that are being obtained, stored, or analyzed – Ethical questions surrounding the use of data
Courses	Case Studies (SE, 2 SHrs, 3 ECTS) Interpreting and Presenting Scientific Results (SE, 2 SHrs, 2 ECTS) Data Ethics and Identity (SE, 2 SHrs, 4 ECTS)
Evaluation	Individual course grades

Module	**Advanced Statistical Methods and Econometrics (EM1)**
Module Code	EM1
ECTS Points	10 ECTS
Learning Outcomes	Students know and master central terminology and procedures discussed in the chosen courses, and they understand the respective statistical or econometric background. Students acquire the capability for independent, task oriented, and reproducible application of advanced methods and can deploy them in an efficient problem-solving manner. Students can evaluate concepts, methods, and procedures with regard to their assumptions, applicability, interpretation, and limitations. They can estimate usefulness and limits of different tools methodically informed and application oriented.
Content	According to choice of course portfolio.
Courses	Choice of courses amounting to at least 10 ECTS points based on a list of eligible courses that is made available at the beginning of every year or semester.
Evaluation	Individual exams per course

Module	**Advanced Computer Science (EM2)**
Module Code	EM2
ECTS Points	10 ECTS
Learning Outcomes	The students know the theoretical foundations and techniques for systems handling large datasets, including distributed systems. The students are able to develop and analyze efficient methods for solving fundamental problems in the context of databases and distributed systems. They are able to select applicable techniques accordingly and combine them with and integrate them into existing IT infrastructures. The students are able to evaluate techniques for the implementation of databases and distributed systems and their influence on existing IT infrastructure. They have a good overview of theoretical foundations of computer science and of algorithms for data management and are able to evaluate their performance, capabilities and correct application to real data.
Content	Advanced Algorithms and Data Structures – advanced algorithms and data structures (e.g., randomized algorithms, complex design paradigms, amortized analysis), as well as their complexity and termination. Advanced databases: – in-depth understanding of techniques, algorithms and data structures used for the implementation of database systems. Distributed Systems: – concepts and notions of distributed and parallel systems

	– protocols – synchronization.
Courses	Selection of courses with at least 10 ECTS: Advanced Algorithms and Data Structures (VO, 3 SHrs, 3 ECTS) Advanced Algorithms and Data Structures (PS, 2 SHrs, 4 ECTS) Advanced Databases (VO, 2 SHrs, 2 ECTS) Advanced Databases (PS, 1 SHrs, 2 ECTS) Distributed Systems (VO, 2 SHrs, 2 ECTS) Distributed Systems (PS, 1 SHrs, 2 ECTS) Seminar for Computer Science (SE, 2 SHrs, 5 ECTS)
Evaluation	Individual exams per course

Module	**Image Processing (EM3)**
Module Code	EM3
ECTS Points	10 ECTS
Learning Outcomes	Students understand and can coherently explain classic, as well as more recent algorithms in the research area of image processing. Further, they know the foundations of classic and modern computer vision systems, as well as the working principles of a selected set of medical imaging techniques and 3D image acquisition techniques. Students have acquired the ability to independently apply the practical and theoretical knowledge on real-world problems in the form of developing new techniques or methods and implementing them in software. Students can assess methods in the field of image processing and computer vision with respect to their algorithmic foundations, as well as their usability in different problem settings.
Content	Image Processing and Imaging: – Image acquisition – data structures for data representation – image enhancement and restauration – edge detection techniques – segmentation and morphological operators. Computer Vision: – Principles, algorithms (both classic and modern neural network-based) and applications of computer vision techniques, such as image classification, representation of “shape”, image segmentation, generative models, etc. Imaging Beyond Consumer Cameras: – Working principles of a selected set of medical imaging modalities (X-Ray, CT, MRI, etc.) and 3D sensing techniques (Time-of-Flight imaging, Structured Light imaging, etc.) – Selected set of algorithms, particularly relevant to this kind of data (image registration, point cloud registration, nearest neighbor search, etc.)

Courses	Image Processing and Imaging (VO, 2 SHrs, 2 ECTS) Image Processing and Imaging (PS, 1 SHrs, 3 ECTS) Computer Vision (VO, 2 SHrs, 2.5 ECTS) Computer Vision (PS, 1 SHrs, 2.5 ECTS) Imaging Beyond Consumer Cameras (VO, 2 SHrs, 2.5 ECTS) Imaging Beyond Consumer Cameras (PS, 1 SHrs, 2.5 ECTS
Evaluation	Individual exams per course

Module	**Multimedia Technology (EM4)**
Module Code	EM4
ECTS Points	10 ECTS
Learning Outcomes	Students have knowledge about theoretic, formal, algorithmic and practical foundations and applications of multimedia technologies. They possess critical understanding of the interdependence of hard- and software in this area. Students have an overview of the state of the art and contemporary challenges. Students are able to apply the acquired knowledge to solve problems and develop software. They are qualified to analyze the requirements of multimedia technologies and to choose software configurations for their processing. Students are capable to treat the obtained results scientifically and to put them into writing. Students can assess practical problems in the area of multimedia technologies with respect to the hard- and software resources to deploy and subject to various constraints.
Content	Dependent on course choice a selection of the following. – Fourier transformation – basics of audio processing – noise suppression – audio compression – audio formats – media processors – DSPs, SIMD programming – wavelet transformation – (QM) filter banks – sub-band transformation – multimedia applications – contemporary literature in the area of multimedia technologies
Courses	Audio Processing (VO, 2 SHrs, 2.5 ECTS) Audio Processing (PS, 1 SHrs, PS, 2.5 ECTS) Hardware Oriented Signal Processing 2 (UV, 1 SHrs, 1.5 ECTS) Filterbanks and Wavelets (VO, 2 SHrs, 2.5 ECTS) Filterbanks and Wavelets (PS, 1 SHrs, 2.5 ECTS) SE Multimedia Technologien (SE, 1 SHrs, 2.5 ECTS)
Evaluation	Individual exams per course

Module	**Remote Sensing (EM5)**
Module Code	EM5
ECTS Points	10 ECTS
Learning Outcomes	Students understand the physical foundations regarding electromagnetic radiation and can interpret them also in daily life contexts. Particularly, they can evaluate the electromagnetic spectrum, active vs. passive systems and their resolution properties regarding application in remote sensing. A wide overview regarding platforms and their orbit properties, combined with knowledge regarding sensor characteristics, enables the evaluation of different application contexts. Knowledge of data paths to the end user, for example through portals. Foundations of picture classification and quality evaluation. Integration of spatial basis data with results from remote sensing analyses. Students are able to choose problem adequate picture data including the underlying remote sensing methods. They can decide on adequate classification methods and approaches for pre- and post-processing of pictures, as well as judge quality properties at all levels of the remote sensing workflow.
Content	– Electromagnetic spectrum and its physical foundations and laws – Platforms, sensors, and resulting picture data including the organization – Portals and allocation of picture data for end users. Visualization of multispectral recordings, as well as their interpretation – Georeferencing, picture processing with focus on filters and transformations – Classification and result analysis;
Courses	Remote Sensing and Image Processing (VO, 2 SHrs, 3 ECTS) Praxis: Analyse von Fernerkundungsaufnahmen (English group: Image Processing and Analysis) (UE, 2 SHrs, 3 ECTS) Analysis and Modeling (SE, 2 SHrs, 4 ECTS) Advanced Remote Sensing (UE, 4 SHrs, 6 ECTS)
Evaluation	Individual exams per course.

Module	**Geographic Information Systems and Science (EM6)**
Module Code	EM6
ECTS Points	10 ECTS
Learning Outcomes	Students are familiar with basic structures and concepts of geographical information systems and can apply them.
Content	According to choice of course portfolio.
Courses	Design of Geospatial Data Models (VO, 2 SHrs, 3 ECTS) Introduction to Geoinformatics (VO, 2 SHrs, 2 ECTS) Praxis: Geographische Informationssysteme (UE, 2 SHrs, 4 ECTS) GIScience: Theory and Concepts (SE, 2 SHrs, 4 ECTS) OpenGIS: Standards, Architectures and Services (VO/PS, 2 SHrs, 3 ECTS)
Evaluation	Individual exams per course.

Annex II: Equivalency List:

Previous Curricula	**Curriculum 2021**
Einführung in Data Science VU (1 ECTS)	Introduction to Data Science VU (1 ECTS)
Statistik VO (2 ECTS)	Basic Elements of Statistics VO (2 ECTS)
Statistik UE (2 ECTS)	Basic Elements of Statistics UE (3 ECTS)
Data Mining VU (3 ECTS)	Elementary Data Mining VU (3 ECTS)
Wahrscheinlichkeitsrechnung VO (4 ECTS)	Elementary Probability VO (4 ECTS)
Wahrscheinlichkeitsrechnung UE (3 ECTS)	Elementary Probability UE (3 ECTS)
Mathematische Statistik VO (3 ECTS)	Mathematical Statistics VO (3 ECTS)
Mathematische Statistik UE (2 ECTS)	Mathematical Statistics UE (2 ECTS)
Angewandte Statistik UV (3 ECTS)	Applied Statistics UV (3 ECTS)
Daten und Identität SE (2,5 ECTS)	Data Ethics and Identity (4 ECTS)
Computer Science for Everyone VO (2 ECTS)	Introduction to Computer Science and Systems VU (3 ECTS)
Interpreting and Presenting Statistical Analyses SE (4 ECTS)	Interpreting and Presenting Scientific Results SE (2 ECTS)

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