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88. Curriculum for Master's Degree Programme "Copernicus Master in Digital Earth" at the University of Salzburg

(Version 2019)

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In its session on January 22, 2019 the Paris Lodron University of Salzburg Senate formally approved the curriculum for the European joint master's degree programme "Copernicus Master in Digital Earth" finalised by the Geoinformatics and Geography curriculum committee at the University of Salzburg in its December 12, 2018 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 this master's programme is 120. This corresponds to four semesters of study.

(2) Graduates of the double degree Erasmus Mundus Joint Master Degree programme "Copernicus Master in Digital Earth – MSc CDE" will be awarded the academic degree "Master of Science", abbreviated "MSc", with another corresponding degree awarded by UPOL (University Olomouc, Czech Republic) or UBS (Université Bretagne Sud, France).

(3) In order to be admitted to this master's programme, students must hold a bachelor's degree in a geospatial discipline or from an equivalent programme at an internationally recognised tertiary educational institution (cf. UG 2002 § 64 para. 5), and the admission by the Consortium of the Erasmus Mundus Joint Master Degree programme.

(4) If a student's bachelor's degree is not deemed equivalent to an acceptable extent, the student may be required to complete additional work up to 45 ECTS points; these requirements must be satisfied by the end of the master's programme. Only the Rectorate or a person designated by the Rectorate is authorised to make a determination of equivalency.

(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.

§ 2 Overview of the degree programme and professional skills

(1) Overview of the degree programme

The "MSc CDE" is carried out as an Erasmus Mundus Joint Master Degree Programme coordinated by the University of Salzburg, Interfaculty Department of Geoinformatics together with University Olomouc, Czech Republic (UPOL) and Université Bretagne Sud, France (UBS), referred to as the Consortium.

Copernicus is the European Union's Earth Observation Programme, looking at our planet and its environment for the ultimate benefit of all European citizens. It offers information services based on satellite Earth Observation and in situ (non-space) data. Copernicus is attributed to the discipline of Geoinformatics, which offers highly sought-after qualifications well founded in concepts and technologies of geospatial computing, tied into inter- and multidisciplinary application domains.

The knowledge and skills acquired throughout the programme's modules are based on the common grounding of spatial sciences and a 'Digital Earth' perspective, based on concepts typically acquired during undergraduate Geography, Surveying, Environmental Studies, Cartography or Planning programmes.

The MSc CDE aims at the building of advanced competences in geospatial data acquisition and data management, data analytics and simulation as well as interactive communication. Graduates are expected to interface with different spatially oriented application domains, contribute to solving problems across societies, economies and environments as well as leading teams assigned pertinent tasks.

Graduates in particular will be qualified to work in the domains of Copernicus services, i.e. Atmosphere (CAMS), Marine Environment (CMEMS), Land (CLMS), Climate Change (C3S), Emergency Management (EMS) and Security.

(2) Professional skills and competences (Learning Outcomes)

Geoinformatics has been established as a methodology-oriented, cross-disciplinary subject based on spatial concepts and approaches. Such 'spatial view' competences for a Digital Earth are invaluable within any subject-specific context whilst widely applicable across domains such as planning, resource management, logistics, mobility, marketing, nature and environmental protection, and security. Graduates will be confident in using key interfaces pertinent to spatial information processing.

Graduates with a CDE Master's degree are able to answer research questions, including the development of hypotheses, definition of objectives, selection of methods, implementation of workflows, collection, analysis and interpretation of data as well as a written and oral communication and interpretation of outcomes in a decision support context.

The study programme provides application-oriented knowledge based on relevant theories and methods. Discipline-specific ways of thinking, analytical skills and techniques as well as problem-solving competences are developed in core areas of Copernicus and Digital Earth, especially in:

- Geospatial data acquisition and visual / cartographic communication;
- Data modelling and spatial data management;
- Data analytics across the spectrum of Geoinformatics: georeferenced data and data streams; in-situ, remote and mobile sensing; statistics;
- Spatial analysis, as well as dynamic system simulation;
- Standards for architectures of open and distributed systems and spatial data infrastructures;
- Development of geospatial applications.

Graduates of the MSc CDE programme will be able to independently plan and manage complex projects and applications in Geoinformatics as well as to cooperate on projects in spatial data infrastructures. The aim is to support and enhance decision-making in all application domains of Copernicus.

The study programme is scientifically based, provides a broad range of academic analysis and research methods, and prepares students for a doctoral degree programme.

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

Graduates of the MSc CDE programme develop a focus on methodological and technical areas of expertise, thus emphasizing career perspectives in public administration (e.g. spatial data infrastructures and geoinformatics services and application development, as well as in application domains such as in spatial planning, regional management, mobility, environment and nature conservation) and in business across a broad spectrum of industries. The study programme covers all areas of geospatial data collection and data management, spatial analytics, communication of results and decision support, interaction with of spatial information, as well as aspects of general management.

§ 3 Structure of the programme

A Programme Board consisting of one representative per Consortium partner plus two representatives from associate partners governs all matters not exclusively under the jurisdiction of individual partners (including but not limited to assignment to specialisation tracks, agreement to internship options, thesis supervision and decisions regarding summer schools).

The MSc CDE programme comprises 7 modules with a total number of 72 ECTS points. 12 ECTS points assigned each for elective subjects (ES) and an obligatory internship. The master's thesis incl. a research methods and academic writing module, an ePortfolio and the Master's exam is rated 24 ECTS points.

The first academic year at PLUS includes the modules B1-B5, 6 ECTS of ES with a total of 48 ECTS, plus a summer school (SS) to be completed as one from the options offered by the Programme Board.

Alternative specialization tracks (GV or DS) with 24 ECTS are completed at one of the designated partner universities in semester 3, typically leading to a master's thesis in line with the respective track and co-supervised at this partner university.

The obligatory internship typically is conducted in blocked mode (1 or 2 periods) outside of course (semester) periods, but also can be completed as equivalent part-time activity.

Development of the master's thesis concept is supported by a course based on online resources on research methods and academic writing (4 ECTS total) integrated with supervision.

Throughout the programme a personal portfolio ('ePortfolio') has to be maintained. It contains individual presentations of materials resulting from coursework and internships. The portfolio is developed in a suitable digital online format, e.g. as a website, blog or storymap.

	ECTS
B1 – Orientation Project	6
B2 – Methods in Geoinformatics	12
B3 – Spatial Analysis and Modeling	6
B4 – Geo Application Development (B4+ B5 = total of 18, only 1 IP course from B4 or B5 is to be completed)	6 | 12
B5 – Spatial Data Infrastructures	6 | 12
SS – International Summer School	6
GeoDSc – @UBS: GeoData Science *or* GeoVis – @UPOL: Geovisualisation and Geocommunication	24
ES - Elective subjects	12
Master Thesis (incl ePortfolio and Master's exam)	24
Internship	12
Total	**120**

§ 4 Course Types

The programme contains the following course types:

Lecture (VO) provides an overview of a subject or one of its sub-areas and its theoretical approaches and presents different teachings and methods. The contents are mainly presented in lecture style. Attendance is not mandatory but highly recommended.

Lab / Practical (UE) serves the acquisition, testing and optimization of practical skills and knowledge in the field of study or one of its sub-areas. Course participation is continuously assessed and attendance is mandatory.

Excursion (EX) supports experiential and applied learning outside of classrooms and is focussed on active learning through contact with real world phenomena and experiences. Course participation is continuously assessed and attendance is mandatory.

Pro-seminar (PS) is a scientifically oriented course in preparation for seminars. Students acquire fundamental knowledge and skills for scientific research through practical as well as conceptual work. Course participation is continuously assessed and attendance is mandatory.

Seminar (SE) is a graduate level scientific course. It serves the acquisition of advanced expertise as well as the discussion and reflection of scientific topics based on active participation of the students. Course participation is continuously assessed and attendance is mandatory. The focus of each seminar will be outlined in the course description (e.g. supervision seminar, empirical seminar, project seminar, interdisciplinary seminar, ...).

Interdisciplinary Project (IP) integrates approaches, concepts and methods from various disciplines for holistic problem solving across disciplines, including practical as well as conceptual synergies. Course participation is continuously assessed and attendance is mandatory.

§ 5 Required courses and plan of study

The following table contains a list of modules and courses in the MSc CDE programme. The semester structure serves as a recommendation designed to ensure that the order in which courses are taken builds on a sequence of knowledge acquisition and that the workload of 60 ECTS points in an academic year is not exceeded. If there are no stated prerequisites, modules and courses can however be taken in any order in accordance with requirements outlined in §12.

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

Erasmus Mundus Joint Master Degree Programme "Copernicus Master in Digital Earth"								
Module	**Course**	**SHrs**	**Type**	**ECTS**	**Semester with ECTS**			
					I	**II**	**III**	**IV**
(1) Compulsory Modules								
B1 – Orientation Project								
Orientation Project			IP	6	6			
Subtotal B1				6	6			
B2 - Methods in Geoinformatics (select 2 or 12 ECTS)								
Advanced Remote Sensing		4	PS	6	6			
Multivariate Statistics and Spatial Statistics		4	UE|PS	6		6		

Geovisualization and Advanced Cartography	4	PS					
Geodata Acquisition	4	UE|PS|EX					
Spatial Simulation	4	PS					
Additional options identified by CK		UE|PS					
Subtotal B2	12		12	6	6		
B3 - Spatial Analysis and Modelling							
Methods in Spatial Analysis	2	PS	2	2			
Analysis and Modelling	2	SE	4		4		
Subtotal B3	4		6	2	4		
B4 - Geo-Application Development							
Basics of Software Development	2	VO	3	3			
Practice: Software Development	2	PS	3		3		
Application Development (see §3)	3	IP	6		6		
Subtotal B4	7		6 |12	6	9		
B5 - Spatial Data Infrastructures							
Design of Geospatial Data Models	2	VO|PS	3	3			
OpenGIS: Standards, Architectures and Services	2	VO|PS	3		3		
SDI Services Implementation (see §3)	3	IP	6		6		
Subtotal B5	7		6 |12	3	9		
SS - International summer school							
International summer school(s)		IP|EX	6		6		
Subtotal summer school			6				
GeoVis – Geovisualisation and Geocommunication (UPOL)							
Principles of Geovisualisation		PS				6	
Thematic Cartography		SE				6	
Design in Geovisualisation		UE				6	
Web Cartography		UE				6	
Subtotal GeoVis Geovisualisation			24			24	
GeoDSc – GeoData Science (UBS)							
Artificial Intelligence		UE				6	
Computer Vision		UE				6	
Big Data		UE				6	
Interactive Data Visualisation		UE				3	
Active and multi-temporal		UE				3	

Remote Sensing							
Subtotal GeoDSc GeoData Science			24			24	
Total for compulsory modules			72				
(2) Electives cf § 7			**12**	**4**	**2**		**6**
(3) Internship			**12**		**6**	**6**	
(4) Master thesis							
ePortfolio			1				1
Scientific methods and writing and supervision			4				4
Master's exam			1				1
Thesis			18				18
Subtotal Master thesis			24				24
Total			**120**	**60**		**60**	

§ 6 Optional specialization tracks and mobility periods

(1) All students spend the first academic year at PLUS in order to acquire a set of core Geoinformatics competences.

(2) At the time of application for admission, candidates select and prioritize at least one specialization track offered by the Consortium. The assigned specialization can be changed until the end of the first semester with the agreement of the Programme Board.

(3) Students will move to the selected joint programme specialization track partner for the second academic year.

(4) The Programme Board can identify and define additional focus subjects based on demand and according to available course offerings.

§ 7 Elective subjects

(1) In the MSc CDE programme students are to complete elective courses totalling 12 ECTS points (according to module ES). 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.

(2) Elective subjects can be completed at any programme partner university and at any time throughout the programme. Students are particularly encouraged to take online courses, MOOCs and other international offerings as electives, as long as these are offered by recognized Higher Education Institutions.

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

§ 8 Master thesis

(1) The master thesis serves to demonstrate that students have acquired the ability to perform independent academic research in the area of Geoinformatics corresponding to §2 and according to current academic research methods and standards.

(2) The topic of the master thesis should be chosen in such a way that it is reasonable and appropriate for completion of the thesis within six months.

(3) The topic of the master thesis must be taken from the selected specialisation track of the student. 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. UG2002 §80 para. 2) or equivalent.

(5) Extensive thesis topics jointly researched and developed by more than one student are admissible as long as individual's contribution and results are well documented and can be separately and independently assessed.

(6) The Master thesis is co-supervised by two faculty members from the consortium, one from PLUS and one from the university representing the chosen specialization track selected by the student. These faculty members supervising the thesis must be qualified according to the regulations of their own institution.

(7) If agreed by the Programme Board and conforming with institutional regulations at the degree awarding partner institutions, the Master thesis can be also produced with the support of one or more experts from an associated partner institution of the consortium.

(8) The Master thesis has to be submitted in English language.

(9) Due to the double degree character of this programme, a single thesis is submitted in identical form at two partner institutions as a graduation requirement.

§ 9 Internship (work placement)

(1) As part of the MSc CDE programme, students must complete a compulsory internship related to the programme comprising 8 weeks, which is comparable to full-time employment and corresponding to 12 ECTS points. The internship should enable students to use the knowledge and skills they have gained during their studies.

(2) The internship is to be completed at a university where less than one full semester of study is being completed, or at a non-university MSc CDE programme partner, or at another 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) Students with disabilities and/or chronic illnesses will be supported in the completion of their internship by the University (Office of the Rectorate for 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.

(4) An internship certificate issued by the host institution and serving as a basis for recognizing a completion of this requirement has to document these items:

1. Institution and location where the internship has been completed.
2. Timeframe / duration and workload (hours per week) of the internship.
3. Description of assigned tasks and responsibilities.
4. Written assessment of internship by supervisor at host institution.

As part of their 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.
- Familiarity with professional environments of Geoinformatics applications

§ 10 International study

As an international multi-partner joint degree programme taught in English language, the MSc CDE has an inherently international character and does not require specific provisions for further enhancing the international experience of students.

In addition to studying for the first academic year at PLUS and the second year at the selected specialization partner, students are exposed to further experiences aimed at integrating the student body across partners as well as offering options beyond the Consortium:

- Summer schools will be offered across the entire partnership, in addition the Programme Board will identify additional SS opportunities worldwide.
- Periods of study at associate partner institutions can support the development of the master's thesis.
- Students are encouraged to leverage international online courses approved by the Programme Board either as Elective Subjects or, based on demonstrated academic equivalence, instead of compulsory courses or modules.

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

(1) For the admission to and priorities in all individual courses, the admission regulations of the institution hosting the course are applied.

(2) All applicable prerequisites for prioritizing the admission to courses will be made available to students at the beginning of the programme.

§ 12 Admission requirements for exams

(1) For the admission to all course exams, admission regulations of the institution hosting the respective course are applied. At the University of Salzburg, no exam admission requirements beyond the assessment and attendance rules specified in §4 are applicable.

(2) All requirements for the admission to exams will be made available to the students at the beginning of the respective course.

§ 13 Examination regulations

(1) All courses with the exception of type VO require course attendance and are continuously assessed. Lectures (VO) are assessed based on a single written or oral exam at the end of the course. All modules listed in §5 can be assessed through module or individual course exams (or combinations thereof) at the discretion of course instructors, nonwithstanding stated continuous assessment requirements.

(2) For all the individual course or module examinations, the examination regulations of the institution hosting the exam are applied.

(3) All institutions hosting exams will apply their national, legally binding general grading system for course examination. A common grading system based on the ECTS grading table and including conversion rules is established by the consortium and made available to the students at the beginning of their studies.

(4) The supervisor of the master thesis confirms the successful completion of the ePortfolio requirement.

§ 14 Master’s exam before an examination committee

(1) This master’s programme will be completed with a master’s exam before an examination committee administered by PLUS.

(2) Candidates must have successfully completed all required courses, the compulsory internship, the ePortfolio as well as received a positive evaluation of the master’s thesis in order to be eligible to take the master’s exam.

(3) The Master's exam consists of one examination subject (thesis defence).

§ 15 Effective date

The curriculum comes into force 1 October 2019.

§ 16 Transitional provisions

No transitional provisions apply.

Annex I: Module descriptions:

Module title	**Orientation Project**
Module code	B1
Total workload	6 ECTS
Learning Outcomes	Students are building adequate expectations and adjusting to the requirements of the MSc CDE programme depending on their respective (and different) first degrees. Based on admission interviews, students receive recommendations to compensate any deficiencies from their undergraduate studies, particularly in the areas of informatics / computing as well as basic GIS skills, basic spatial literacy and cartographic competences, fundamental understanding of spatial sciences and general quantitative methods. In addition, students enhance their general orientation in scientific methods and scientific writing in a dedicated set of classes, as a preparation for supervised and independent work in advanced classes. This module guides students towards establishing their individual ePortfolio. Coursework aiming at adjusting prerequisites will secure coverage of knowledge according to: - Foundations of Geoinformatics: CF3, CF4, CF5-1,4,5, DA4, DM1-4, GD12, OI51-2, GS3 - Cartography and Visualization: GD1-5, GD10, CV2, CV3, CV4-1, CV6-1-3, DN2
Module content	Orientation regarding structure of entire curriculum and student life at CDE partner universities. Integration with student cohort. Perspectives on professional outlook and career development. Planning and design of one's individual course of study, including specific methodology and / or domain emphases. Personal SWOT analysis and translation of outcomes into action. Written communication in science. Structuring of documents according to media and target audience. Scientific writing in English language. Adequate use and referencing of sources, empirical evidence and pertinent tools. Elementary research design. Professional ethics.
Courses	- IP Orientation Project
Type of exam	Submission of several individual and group mini-projects aiming at orientation, social environments and geomedia / geospatial communication. These projects serve as assignments graded from a combination of peer and teacher assessment.

Module title	**Methods in Geoinformatics**
Module code	B2
Total workload	12 ECTS
Learning Outcomes	Students will be able to apply the selected methods in project-oriented work and take methodological responsibilities in working groups and complex workflows. Depending on individual choices, students will: - Design and implement advanced geovisualisation interfaces for use-case oriented media, devices and user experiences [DM5-3, DN2-4, GS3-3]. - Decide on adequate Remote Sensing data sources and work-flows across available passive and active sensors. - Apply the Object-Based Image Analysis (OBIA) paradigm to the extraction of features and monitoring of change across remote sensing application domains. - Select and implement advanced geodata acquisition processes using e.g. photogrammetry, LiDAR, in-situ and mobile sensors, crowdsourcing and UAV platforms, including real-time data streams [DN1-6, components from GD]. - Prepare and support decisions through (geo-)simulation [DA5-3,4, GC]. - Choose and apply spatial- and geo-statistical methods to analyse multidimensional and multivariate data sets to explain and model complex relations and processes [CF6, AM7, AM8, AM9-2,4, GC2-4]. - Manage information extraction from large ('big') data sets, including flow of data, DBMS aspects and pattern analysis [AM10].
Module content	Students are offered a selection of core geoinformatics methodologies like remote sensing, geovisualisation or data analysis, sharpening personal competence profiles in combination with choices in electives, IP courses, seminar and thesis topics. All courses have a strong practice orientation, combining conceptual foundations with a view towards applications. Depending on courses, chosen content will vary and include combinations from: Remote Sensing – field and mobile data acquisition. Advanced sensors. Hyperspectral and Microwave analysis. Radiometric correction. OBIA with transferable rules and app development. | Geovisualisation – use case analysis and UX design. Design of flexible and responsive interfaces. Navigation of perspective views. | Data and process analysis – advances spatial statistics and pattern analysis. Geostatistics. Big data analysis. Process simulation with individual based vs aggregate/lumped approaches. | …
Courses	All courses are taught as practicals, fostering problem-oriented and experiential learning through individual or group assignments. - Advanced Remote Sensing - Multivariate Statistics | Spatial Statistics | Geostatistics - Geovisualization and Advanced Cartography - Geodata Acquisition - Modeling Geographical Systems, Spatial Simulation - Location Based Services, Big Data Analytics
Type of exam	Teacher and peer assessment of individual assignments, optionally presentations and portfolio entries, plus overview tests.

Module title	**Spatial Analysis and Modelling**
Module code	B3
Total workload	6 ECTS
Learning Outcomes	This core area of Geoinformatics builds advanced translation skills from application domain problems towards conceptual reframing and structuring, and into the analytical methods and toolsets of Geoinformatics. Based on this knowledge of operational methods, complete workflows representing complex processes are modeled and represented in structured frameworks for spatial decision support across domains. Students will: - Be able to map conceptual spatial relations (topological and geometrical) to the body of analytical methods. [AM2-1, AM3-6, AM4-4] - Recognize the value of different metrics in the spatial as well as attribute domains (e.g. fuzzy algebra). [AM3-1] - Describe shape characteristics of spatial features as well as complex landscape structures with the aim of diagnosing change. [AM3-3] - Identify, select (including SQL clauses) and statistically describe spatial features based and their distance to and/or topological relations with a target feature. [AM2-2,3, AM4-1,3] - Estimate values of a continuous (real or thematic) surface based on sample points through interpolation methods. [AM3-5] - Select adequate interpolation methods (based on characteristics of surface theme, measurement level, sample density) and assess quality of results. [AM6-2] - Derive characteristics of continuous surfaces as a basis for advanced models. [AM6-1, AM3-2] - Develop and adequately parameterized basic models of surface runoff, groundwater dynamics, visibility, solar irradiation and diffusion / spreading over inhomogeneous surfaces. [AM6-3,4,5] - Apply topological relations for combination of spatial themes (overlay analysis), derive and implement weighting schemes. [AM4-2] - Find best routes (paths) across fields and networks. [AM11-3,4,6] - Allocate areas and features to service centres, distinguish from ('optimal') location analysis. [AM11-7, AM12-1,4] - Choose classification and regionalization methods according to specific requirements and contexts. - Design, implement and validate complex workflows and process models built from individual methods and operations. [AM5-6,78] - Move from data analysis to generation of context-specific information and the creation of higher level domain knowledge. [AM1-1,2]
Module content	Topological relationships (Egenhofer). Map Algebra. Distance metrics. Spatial query operators. Fuzzy metrics and algebra. Shape and landscape metrics. Interpolation methods (trend surface, IDW, … and cross reference to statistical methods like Kriging). Surface descriptors. Spatial models with gravity and radiative mechanisms. Cost surface modeling. Network: Dijkstra algorithm. Vector and raster overlay, incl. weighted overlay and AHP. Allocation and location analysis. Nodal and homogeneous regionalization. Process model building. Spatial decision support strategies.
Courses	Through a combination of a practical class including extensive lab components with an advanced seminar, students develop broad competences across the spectrum of analytical methods (optionally including spatial statistical and remote sensing methods), as well as a

	deeper understanding and critical appreciation of results through application experience of selected methods and their parameterization contexts. - PS Methods in Spatial Analysis - SE Analysis and Modeling
Type of exam	Assessment of individual lab assignments plus overview test. Presentation of seminar (project) paper with peer and teacher assessment.

Module title	**Geo-Application Development**
Module code	B4
Total workload	6|12 ECTS
Learning Outcomes	Participants in this module will gain a well-structured understanding of software development from a software engineering (SWE) perspective, enabling them to work as geospatial experts in development teams and to successfully communicate with software developers. Based on the foundations of programming and development, students acquire competences in at least two development environments and languages, enabling them to design simple software programs, to customize existing applications, and to automate basic workflows. This includes practical skills in geo-application development in the areas of web applications, mobile applications, or desktop analytical applications. Having completed this module, students are able to carry out basic development tasks on a variety of platforms and architectures with an emphasis on understanding and translating demands from typical geospatial application domains. This key competence is developed and verified through a development project in one of the selected IPs. Students will be able to: - Design and carry out software projects in accordance with standardized and structured SWE processes [DA7-1, DA7-2, DA6-1, DA6-3] - Select the appropriate programming or scripting language according to the specific goals of a software project [DA5-4 , DA6-3 , DA7-1, DA2-4] - Apply their basic knowledge of modeling software systems for communication between different stakeholders in a SWE project [DA1-2, DA1-5, DA2-4, DA6-2] - Programmatically access external code libraries and Application Programming Interfaces (APIs) of commercial off-the-shelf (COTS) and open source software in their own programs to achieve their goals [DA7-2, DA1-5, DA6-3] - Develop software programs to pre-process and analyze spatial data (read, manipulate, store, visualize, classify) that are available in a variety of formats (CSV, ShapeFiles, GML, KML, raster formats etc.) [DA7-1, DM1-2] - Integrate data from service-oriented architectures (SOA), including OGC Web Services (OWS) into their software programs through service-based data access [DA7-2] - Read and understand the documentation of software libraries - Create user interface components in selected development environments [DA6-2] - Batch analysis tasks in the application domains of GIS and remote sensing [DA6-3], - Develop geo-applications for different platforms (desktop, web, mobile, …) and application domains (GIS, remote sensing) [DA7-2, CV5-1, CV4-5]
Module content	Principles of software engineering. Procedural and object-oriented programming principles. Approaches to modeling software systems using UML. Service-oriented Architectures. OGC Web Services (OWS). Client-side and server-side scripting languages (e.g., JavaScript, Python, or similar). Object-oriented programming vs. scripting. Server-side OO programming and scripting (e.g. JSP, Python, PHP, or similar). Programmatic database access. Program development for spatial data pre-processing. APIs in commercial off-the-shelf (COTS) and/or open source software.Web Mapping. Web GIS. Batch pro-

	cessing for GIS and remote sensing analysis and classification tasks. Basic GUI design.
Courses	Through a combination of an introductory lecture and a lab exercise as well as an IP (selectable from different application domains) including extensive practical components, students develop broad competences across the spectrum of application development methods on different platforms and programming languages (at least two) as well as different application domains (optionally including remote sensing applications). - VO Basics of Software Development - PS Practice: Software Development - Selectable IPs: o IP Application Development (web|mobile|desktop) o IP Application Development (remote sensing applications)
Type of exam	Assessment of individual lab assignments plus overview test. Presentation of focus topic with peer and teacher assessment. Major development project in one of the selected IPs.

Module title	**Spatial Data Infrastructures**
Module code	B5
Total workload	6|12 ECTS
Learning Outcomes	A spatial data infrastructure (SDI) comprises technology, standards, policies, organisational/legal aspects, human resources and related activities to integrate, exchange, process, maintain and preserve geo-spatial data and information. Students will: - Be able to describe the main components of SDIs and know key objectives, benefits and current state-of-the-art of such initiatives [OI5-1]. - Understand the conceptual strategies, organizational requirements and legal frameworks for leveraging the advantages of open geographic data infrastructures [DA3-3, GS1]. - Recognize the importance of standardized data models to store, analyse and manipulate geographic phenomena. - Be able to explain the role of metadata for spatial data sharing across distributed networks [GD12]. - Be able to describe the existing spatial data sharing policies including intellectual property rights, security issues, privacy issues, Open Government data initiatives [GS5-4, OI5-6]. - Be able to explain the Service Oriented Architecture (SOA) concept together with its underlying publish-find-bind principle. - Know internationally accepted geographic- and IT standards (OGC, OASIS & ISO) and apply these in practical projects [OI5-1]. - Be able to understand, design and implement geodata models according to standardised approaches [CF3-CF6]. - Be able to publish geodata and geoprocessing services over the web: map services, data services (editing, search, image service), and analytical services. - Be able to define the interoperability needs beyond technical issues like direct access and industry standards on a legal, semantic and organizational level [OI5-2]. - Understand the principles and techniques of spatial data organization and apply these principles and techniques to design and build spatial databases [DM2, DA4]. - Based on these concepts, the students will learn how to utilize open, shared GIS resources to design and use Open GIS data structures, workflows and processes leveraging information repositories.
Module content	**Conceptual foundations:**Geographic information - reference model, spatial schema, temporal schema, spatial referencing; spatial relationships, functions and operations; Interoperability (syntactic, semantic and technical); distributed IT architectures (private/public cloud, Internet of Things etc.); spatio-temporal information integration; spatial data infrastructure concepts (service-orientation; publish-find-bind principle; semantic web). **Technological Foundations**: Geospatial data modelling (UML, GML); application schema; GI Ontologies; domain bridging data Integration; Geospatial Data Management (Simple feature access, 13249-3 Information technology - SQL Multimedia and Application-Part 3); Spatial DBMS: Oracle Spatial, MSSQL Spatial, Postgres/PostGIS, ESRI ArcSDE etc.; geospatial network-service architectures (view, download, discovery & registry, web processing and security services); Communicating with WebGIS; GI applications services using COTS and open-source solutions; private/public cloud-computing platforms; data & metadata repositories; Big GI data & Geospatial Eventing.

	Standards and Regulations for Interoperability: ISO/TC211 19100 standards series, Open Geospatial Consortium; Legal acts: Laws on SDIs, Environmental INSPIRE, Public Sector Information INSPIRE Directives; privacy and security issues. **Initiatives:** Open Government Data; GSDI-Global Spatial Data Infrastructure, GEOSS-Global Earth Observation System of Systems
Courses	VO|PS Design of Geospatial Data Models VO|PS Open GIS: Standards, Architectures and Services IP: SDI Services Implementation
Type of exam	Written exams for the lectures. IP: hands-on project work with strong motivation from real world problems; detailed documentation according to corresponding standards; Evaluation of the approach to challenge in the course of the project as well as the final results.

Module title	**International Summer School – Short Intensive Programme**
Module code	SS
Total workload	6 ECTS
Learning Outcomes	As a core element in an international study programme integrating students from very diverse backgrounds and pursuing different pathways, participating in a summer school aims at several important objectives: - Social integration of student cohort through groupwork and a fulltime residential setting - Deep dive into a specific topical domain with particular professional relevance - Contact opportunity with practitioners from industry and application domains - Experience with hands-on field work and data acquisition
Module content	Depending on the chosen topic (summer schools will be offering a variety of themes), the content will allow students to build a holistic understanding of the respective theme through an immersive experience
Courses	UE Summer School
Type of exam	Integrated, continuous assessment including group work (depending on summer school theme) and individual written and optionally oral presentation of assigned topic.

Module title	**Principles of Geovisualization**
Module code	GeoVis-PRING
Total workload	6 ECTS
Learning Outcomes	Upon completion of the module, students are able to: explain the geovisualization process; - create visualizations using and combining spatial and non-spatial data; - evaluate visualization approaches of spatial data and build new ones upon the theoretical framework; - analyze and categorize available techniques in terms of quality, efficiency, and suitability for a particular data type, - evaluate available tools based on their functionality, and apply these tools to create own geovisualizations.
Module content	- Fundamental geovisualization concepts - The geovisualization process - Map and layout design - Cartographic generalization - Map projections - Use and user issues in geovisualization - Topographic mapping - Colors and labelling
Courses	PS Principles of Geovisualization Course taught with practicals, fostering problem-oriented and experiential learning through individual or group assignments.
Type of exam	written and oral examination

Module title	**Thematic Cartography**
Module code	GeoVis-THECA
Total workload	6 ECTS
Learning Outcomes	Upon completion of the module, students are able to: - compare different methods of thematic cartography; - create thematic maps using various visualization techniques based on cartographic concepts and the general typographic guidelines; - describe the relevance and influence of cartography to various associated fields. Through a combination of a practical class including extensive lab components with an advanced seminar, students develop broad competences across the spectrum of thematic methods of geovisualization (including methods for representing qualitative and quantitative data), as well as a deeper understanding and critical appreciation of results through application experience of selected methods.
Module content	- Concept of thematic mapping - Thematic maps content - Composition of thematic maps - Methods for representing qualitative data - Methods for representing quantitative data - Map Stylistics - Colours in thematic maps - Principles of cartographic visualization method selection
Courses	SE Thematic Cartography
Type of exam	Thematic map assignment and oral presentation / examination

Module title	**Design in Geovisualization**
Module code	GeoVis-DESIGN
Total workload	6 ECTS
Learning Outcomes	Upon completion of the module, students are able to: - understand current issues in design in geovisualization; - evaluate design research approaches; - analyse and process geodata within a geovisualization context; - evaluate different geovisualization techniques, principles and methodologies according to the applicability to the intended project. Through a combination of an introductory lecture and a lab exercise including extensive practical components, students develop broad competences across the scope of application development methods on different design platforms.
Module content	- Introduction to the design in geovisualization - History of computer graphics - Fundamental principles of graphic design and principles of geovisualization - Map layout and map styles - Bezier curves in geodata processes - Colours and tools for colour settings - Map symbology design - Designing infographics - Designing communication-oriented geovisualizations
Courses	UE Design in Geovisualization
Type of exam	map assignment and paper assignment

Module title	**Web Cartography**
Module code	GeoVis-WECAR
Total workload	6 ECTS
Learning Outcomes	Upon completion of the module, students are able to: - demonstrate knowledge and skills in web cartography such as data processing, classification, visualization, and map design; - produce different web maps or visualizations based on the aforementioned knowledge and skills; - demonstrate good knowledge about web and mobile cartography such as Google maps, OpenStreetMap, and location-based services for mobile devices; - evaluate and analyse the suitability of various cartographic formats for set purposes and audiences. Through a combination of lectures and lab exercises as well as an individual projects selectable from different application domains. It includes extensive practical components, students develop broad competences across the spectrum of web application development methods on different platforms and programming languages.
Module content	- WebGIS 2.0, Map Application vs. Map Server - GDAL, OGR, proj4 libraries - Data formats for Web Cartography (Web services, OSM, GeoJSON) - Vector and raster tiles - Data publishing (ArcGIS Server, Maptiler, Geoserver, MapServer) - Cloud GIS (Carto, ArcGIS Online, MapBox, GIScloud) - JavaScript Libraries (Leaflet, OpenLayers) - API (Google Maps API, Mapy.cz API, ArcGIS API for JS) - Geospatial analysis and processing - Design and styling of web maps
Courses	UE Web Cartography
Type of exam	assigment web map application and written examination

Module title	**Artificial Intelligence**
Module code	GeoDSc-AI
Total workload	6 ECTS
Learning outcomes	Upon completion of the module, students will be able to : - understand the different machine learning problems and methods; - design for a given data analytics problem the appropriate solution to be used; - implement deep learning models within a standard framework.
Module content	Machine Learning: - principles of supervised learning and other machine learning paradigms; - classification and regression, with discriminative and generative models; - dimension reduction and feature selection; - anomaly detection; - training strategies and evaluation protocols; - use of software libraries. Deep Learning: - principles of neural networks; - optimization, regularization, and transfer; - main architectures (CNN, RNN, AE, GAN); - use of deep learning software frameworks.
Courses	UE - the course is taught as a combination of lectures with practical lab components.
Type of exam	Assessment of individual lab assignment plus overview test.

Module title	**Computer Vision**
Module code	GeoDSc-CV
Total workload	6 ECTS
Learning outcomes	Upon completion of the module, students will be able to : - understand advanced models and techniques for image processing; - solve realistic problems in computer vision.
Module content	Image Processing: - principles of image processing and review of basic methods; - advanced structured representations (including graphs and trees); - efficient processing methods (non-local, multiscale). Image Analysis: - global and local image features; - segmentation and object detection; - indexing and retrieval; - deep learning for computer vision.
Courses	UE - the course is taught as a combination of lectures with practical lab components.
Type of exam	Assessment of individual lab assignment plus overview test.

Module title	**Big Data**
Module code	GeoDSc-BD
Total workload	6 ECTS
Learning outcomes	Upon completion of the module, students will be able to : - understand the principles of knowledge discovery and the methods for data mining; - use software framework to design, implement and deploy a solution for big data analytics.
Module content	Data Mining & Knowledge Discovery: - principles of the knowledge discovery process; - data clustering; - frequent pattern mining; - association mining; - prediction and sequence mining; - Markovian processes, Bayesian networks and graphical models. HPC for Big Data: - principles of Big Data processing and HPC; - review of main software frameworks (e.g. Hadoop stack); - GPU-based processing (CUDA, OpenCL).
Courses	UE - the course is taught as a combination of lectures with practical lab components.
Type of exam	Assessment of individual lab assignment plus overview test.

Module title	**Active and Multitemporal Remote Sensing**
Module code	GeoDSc-RS
Total workload	3 ECTS
Learning outcomes	Upon completion of the module, students will be able to : - understand the principles of active and multitemporal remote sensing; - remember of opportunities offered those recent sensors available in remote sensing; - process the data provided by such sensors; - perform data analysis to address specific methodological tasks; - use dedicated software.
Module content	<u>Lidar</u>: - principles (including Multi-Echo, Full Wave Form, Multispectral) and sensors (ALS, MLS, TLS); - data processing (DEM and 3D points clouds); - use of dedicated software (e.g. CloudCompare). <u>SAR:</u> - principles (including Polarimetry, Interferometry) and sensors (Sentinel-1, TerraSAR-X) - data processing (speckle reduction, target detection, land cover mapping); - use of dedicated software (e.g. SNAP). <u>Time Series & Video:</u> - principles and Sensors (Sentinel-2, video from UAV); - data processing (change detection, object tracking, land cover mapping); - use of dedicated software.
Courses	UE - the course is taught as a combination of lectures with practical lab components.
Type of exam	Assessment of individual lab assignment plus overview test.

Module title	**Interactive Data Visualization**
Module code	GeoDSc-DV
Total workload	3 ECTS
Learning outcomes	Upon completion of the module, students will be able to : - understand main concepts behind human-computer interaction; - design effective GUI; - elaborate visualization strategies to ease understanding of the data.
Module content	Interaction: - concepts, theories and models of HCI; - user experience and GUI ergonomics; - GUI assessment and graphical design. Data Visualization: - principles and methods; - data transformation and dynamic querying; - statistical graphics; - programming visualization methods; - links with GIS.
Courses	UE - the course is taught as a combination of lectures with practical lab components.
Type of exam	Assessment of individual lab assignment plus overview test.

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