Studienjahr 2020/2021
21. Mai 2021
63. Stück

PARIS LODRON UNIVERSITÄT SALZBURG

Mitteilungsblatt – Sondernummer der Paris Lodron-Universität Salzburg

126. Curriculum for the Master's Joint Degree Programme in Applied Image and Signal Processing at the University of Salzburg

(Version 2021)

Table of Contents

In its session on 18.05.2021 the Paris Lodron University of Salzburg Senate formally approved the curriculum for the master's degree programme in Applied Image and Signal Processing (AISP) finalised by the Computer Sciences curriculum committee at the University of Salzburg in its 26.03.2021 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.

The formal basis of this Master's Joint Degree Programme in Applied Image and Signal Processing is a cooperation contract between the Paris Lodron University of Salzburg (PLUS) and the Salzburg University of Applied Sciences (SUAS). Besides financial and administrative-technical regulations, in this cooperation contract an AISP board is defined, consisting of teaching personnel of both institutions as well as students, which serves as a contact point for all administrative bodies of both institutions. Furthermore, for all the indivdual course admission regulations and examinations, the corresponding regulations of the institution hosting the course are applied as defined in the contract.

§ 1 General Provisions

(1) The number of ECTS points necessary to complete a degree in the master's programme in Applied Image and Signal Processing is 120. This corresponds to four semesters of study.

(2) Graduates of the master's programme in Applied Image and Signal Processing hold a Master of Science in Engineering degree (abbreviated MSc).

(3) In order to be admitted to the master's programme in Applied Image and Signal Processing, students must hold a bachelor's degree in an equivalent or related field (i.e. engineering or natural sciences, such as computer sciences, mathematics, artificial intelligence, mechatronics/engineering, electronics, automation technology, media and computing, and computational engineering) from an accredited Austrian or foreign institute of higher education (cf. UG § 64 para. 3).

In particular, courses with the following contents need to be contained in the three core areas of the degree completed:

- Computer Science: Procedural programming, usage and programming of classical algorithms and data structures (lists, arrays, sorting), employment of libraries (mathematics libraries, I/O).
- Mathematics: Foundations of real and complex analysis, linear algebra (matrix computations, (systems of) equation solving), probability calculus and descriptive statistics (reference numbers, correlation, regression).
- Signal Processing: Foundations of Signal Processing (Time- and Frequency Analysis, Fourier Series, Laplace- and Z-Transform, convolution, sampling, linear time invariant systems).

(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 worth up to 45 ECTS points; these requirements must be satisfied by the end of the master's programme. Based on the suggestion of the AISP board, 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.

(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) This Master's Joint Degree Programme is carried out together with the Salzburg University of Applied Sciences GmbH degree programme "Information Technology and Systems Management" (ITS). The number of students who can be admitted on this programme is limited to 20 places per academic year from the beginning of the winter semester. The selection of candidates is made on the basis of an interview (teleconference in English), conducted by both institutions, in which the necessary English language proficiency as well as a sound command of the required skills in programming, mathematics, and signal processing (see (3) above) are evaluated. The selection process consists of a formal examination of the application supporting documents in order to assess expertise in the above mentioned core areas, as well as the evaluation of other qualifications outlined in the application supporting documents. In case the student's expertise does not match the requirements summarised in (3) in the core areas of computer science or signal processing, the student may be required to complete additional work worth up to 4 ECTS points (as specified by the academic personell conducting the interview), whereas a mismatch of core qualifications in mathematics cannot be compensated. These 4 ECTS are a subset of the 45 ECTS described in (4) above and will be specified in the certificate of admission (where it will also be specified that completion of these 4 ECTS will be a prerequisite for enrolling into Master Seminar 1).

§ 2 Overview of the degree programme and professional skills

(1) Overview of the degree programme

The Joint Degree Master's programme on Applied Image and Signal Processing is meant to deepen and strengthen students' competences in foundations and applications of image and signal processing technology.
Compulsory modules convey state-of-the-art knowledge and methods in fundamental areas, where a distinction is made among formal foundations, general methodology, and techniques for processing of various data types including audio, visual data, geometry data, etc.
The elective module facilitates to follow individual interests in application areas of image and signal processing focusing on strongly research oriented topics and also reflecting research work conducted at the two institutions offering the programme.

(2) Professional skills and competences (Learning Outcomes)

This Joint Degree Master's programme broadens and extends the students' knowledge and provides preliminary scientific training for the profession. It builds on a relevant Bachelor's degree and offers detailed specialised training based on research-oriented teaching. Courses cover introductory and advanced topics from fields such as artificial intelligence methods, image and signal processing, as well as their formal and methodological foundations combined with numerous areas of application. The knowledge and skills acquired provide our graduates with flexible access to jobs and encourage innovations in the area of image and signal processing conducted with state-of-the-art methodology. Writing a Master's thesis serves to prove that the student is qualified to work independently on academic topics based on a correct methodology, thereby laying the ground for further PhD study. In this way, the qualifications for further scientific research are met. In particular, graduates are able to autonomously solve complex problems by applying and developing further image and signal processing systems. This programme explicitely refers to questions of ethics and sustainability (see the corresponding recommendation in § 7(2)) and implicitly also addresses gender questions in order to raise awareness of the role gender plays in research and development of artificial intelligence-based image and signal processing systems, whilst creating a forum in which to explore different approaches to software and hardware by different users. The following learning outcomes will be reached when completing the programme:

- Students are able to understand the fundamental theoretical concepts of image and signal processing.
- Students have knowledge about state-of-the-art algorithms, tools, and software libraries when using artificial intelligence technology and model-driven methodologies in image and signal processing.
- Students are skilled in solving real-world as well as research oriented problems by applying appropriate hard- and software systems in image and signal processing.
- Students are aware of a set of current application fields of image and signal processing and are able to conduct application oriented software projects in those fields.
- Students are able to read and understand scientific publications in the area of image and signal processing and are capable to implement algorithms which map the publications in working software prototypes.
- Students are able to systematically test and evaluate image and signal processing related applications and are able to write documentation according to commonly accepted scientific working principles.

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

Image and signal processing systems, especially those driven by artificial intelligence-based technology, are an integral part of a huge variety of IT-systems, ranging from autonomously driving cars, surveillance systems, medical imaging, vision-based quality control in production, to personalised systems like consumer cameras and smartphones with many corresponding apps. Therefore, graduates will be highly welcome in a wide range of companies in the IT-field.

Graduates of the Master's Joint Degree Programme in Applied Image and Signal Processing are expected to often pursue careers in the following fields in particular:

- Industry Research and Development (hard- and software development for artificial intelligence driven image and signal processing systems, respectively)
- Software development including artificial intelligence as well as image and signal processing aspects
- Academic careers in image and signal processing
- Project management and project lead in image and signal processing related fields
- Consulting and training lead in image and signal processing related fields

§ 3 Structure of the programme

The Master's Joint Degree Programme in Applied Image and Signal Processing comprises 8 modules with a total number of 87 ECTS points. In addition, there are 6 ECTS points assigned for elective courses. The master's thesis is worth 25 ECTS points, the master's exam 2 ECTS points.

	ECTS
Visual Data Processing & Representation	8
Mathematics and Modelling	16
Digital Signal Processing	10
Data Science & Analytics	17
Audio and Media	9
Visual Computing	10
Applied Sciences and Methods	7
Elective module (Selected Topics in Applied Image and Signal Processing)	10
Elective courses	6
Master's thesis & Master Seminar 2	25
Master's exam	2
Total	**120**

§ 4 Course Types

The programme contains the following course types (note that types 1. & 2. are used exclusively at the Paris Lodron University of Salzburg, while types 4. and 5. are used exclusively at the University of Applied Sciences Salzburg):

1. **Lectures (VO)** introduce students to different areas of the subject and provide subjectspecific methods and techniques.
2. **Proseminars (PS)** introduce students to specialist discussions and lines of argument, whilst observing the practical aims of the course. Students are required to actively participate in class by dealing with the practical examples and special issues of a subject area.
3. **Seminars (SE)** promote scientific work and discussion and require students to develop their own scientific contributions.
4. **Integrated courses (ILV)** combine knowledge input with experience-based learning. They connect theory-based lectures with practical problem-based exercises carried out by students in order to deepen knowledge of the subject matter. The exercises are undertaken in small groups and are designed to be adaptable to a variety of objectives.
5. **Individual Training (IT)** are independent and problem-based solving exercises on complex and practical issues of a larger scope taken by individual students or small groups. Project management is the responsibility of the student(s), including the allocation of time, in consultation with project supervisors. In addition to providing specialised expertise, the theoretical knowledge of project management is applied and developed in practice (methodological competence) and understanding of the various interdisciplinary connections will be deepened. Another focus is to promote social communication skills, in particular the ability to work in a team.

With the exception of lectures, all courses involve continuous assessment and attendance is obligatory.

§ 5 Required courses and plan of study

The following contains a list of modules and courses in the master's programme in Applied Image and Signal Processing. The allocation of the courses to specific semesters is mandatory for those courses held at SUAS (course name given in red letters) and recommended for courses held at PLUS (course names given in green letters), 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 Applied Image and Signal Processing								
Module	**Course**	**SHrs**	**Type**	**ECTS**	**Semester with ECTS**			
					I	**II**	**III**	**IV**
(1) Compulsory modules								
Module 1 – Visual Data Processing and Representation (VPR)								
Image Processing and Imaging		2	VO	2	2			
Image Processing and Imaging		1	PS	2	2			
Imaging Beyond Consumer Cameras		2	VO	2	2			
Imaging Beyond Consumer Cameras		1	PS	2	2			
Subtotal for Module 1		6		8	8			
Module 2 – Mathematics & Modelling (MAM)								
Selected Topis in Mathematics & Modelling		4	ILV	5	5			
Fourier Analysis, Filter Banks & Wavelets		3	VO	3		4		

Fourier Analysis, Filter Banks & Wavelets	2	PS	4		3		
Applied Statistics	3	ILV	4		4		
Subtotal for Module 2	12		16	5	11		
Module 3 – Digital Signal Processing (DSP)							
Digital Signal Processing 1	3	ILV	5	5			
Digital Signal Processing 2	3	ILV	5		5		
Subtotal for Module 3	6		10	5	5		
Module 4 – Data Science and Analytics (DSA)							
Data Science	3	ILV	5	5			
Analytics & Knowledge Discovery	2	ILV	3	3			
Natural Computation	2	VO	2	2			
Natural Computation	1	PS	2	2			
Machine Learning	3	ILV	5		5		
Subtotal for Module 4	11		17	12	5		
Module 5 – Audio and Media (AAM)							
Audio Processing	2	VO	2.5		2.5		
Audio Processing	1	PS	2.5		2.5		
Media Data Formats	2	VO	2		2		
Media Data Formats	1	PS	2		2		
Subtotal for Module 5	6		9		9		
Module 6 – Visual Computing (VIC)							
Computer Vision	2	VO	2.5			2.5	
Computer Vision	1	PS	2.5			2.5	
Geometric Modelling	2	VO	2.5			2.5	
Geometric Modelling	1	PS	2.5			2.5	
Subtotal for Module 6	6		10			10	
Module 7 – Applied Sciences and Methods (ASM)							
Master Seminar 1	2	SE	3			3	
Agile Project Management	2	ILV	3			3	
Ethics & Sustainability	1	ILV	1			1	
Subtotal for Module 7	5		7			7	
Total for Compulsory Modules	52		77	30	30	17	0
(2) Elective modules according to § 6							
Total for Elective Module Catalogues			10			10	
(3) Elective courses according to § 7							
Elective courses			6			3	3
Master's thesis		**IT (if written at SUAS)**	**23**				**23**
Master Seminar 2		**SE**	**2**				**2**
Master's exam			**2**				**2**
Sum total			**120**	**60**		**60**	

§ 6 Elective module catalogues and/or bundled elective modules

The Master's programme requires 10 ECTS points of an obligatory elective module from the area "Selected Topics in Applied Image and Signal Processing", of which 5 ECTS points must be earned at PLUS as well as at SUAS.

Elective Module – Selected Topics in Applied Image & Signal Processing								
Module	**Course**	**SHrs**	**Type**	**ECTS**	**Semester with ECTS**			
					I	**II**	**III**	**IV**
Module 8 – Selected Topics in Applied Image & Signal Processing (STA)								
Natural Language Processing		2	ILV	3				
Applied Natural Language Processing		1	ILV	2				
Reinforcement Learning		2	ILV	3				
Applied Reinforcement Learning		1	ILV	2				
Medical Imaging		2	VO	3				
Medical Imaging		1	PS	2				
Biometric Systems		2	VO	3				
Biometric Systems		1	PS	2				
Media Security		2	VO	3				
Media Security		1	PS	2				
Computational Geometry		2	VO	3				
Computational Geometry		1	PS	2				
Advanced Machine Learning		2	VO	3				
Advanced Machine Learning		1	PS	2				
Total for elective module				10			10	

§ 7 Elective courses

(1) In the master's programme in Applied Image and Signal Processing, students are to complete elective courses totalling 6 ECTS points. These elective courses are designed to further foster 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) It is recommended to cover elective courses by taking a third 5 ECTS course from the § 6 elective module courses list in the third semester. Further recommendations for non-German speaking students include to take English-taught courses at PLUS and SUAS.

§ 8 Master's thesis

(1) The master's thesis, which must be written in English, serves to demonstrate that students have acquired the ability to perform independent academic research in the area of Applied Image and Signal Processing 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 § 81 para. 2).

(3) The topic of the master's thesis must be taken from a module in the master's curriculum. 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 § 80 para. 2).

(5) The topic of the master's thesis is established in the course "Master Seminar 1" and the core concepts of the thesis are presented and defended in the course "Master Seminar 2". The master's thesis and the course "Master Seminar 2" are conducted at either institution and are supported by a supervisor according to the institutions' corresponding regulations. The master's thesis consists of two parts: The main body of the thesis, and an extended abstract, the formatting of which should be in line with a conference paper or a publication in a journal.

§ 9 Internship

There are neither recommended nor compulsory internships qualified to cover ECTS of the master's program.

§ 10 Study abroad

Students in the master's programme in Applied Image and Signal Processing are recommended to spend a semester of study abroad. This semester abroad should ideally be scheduled in the third or fourth semester of study. Course transfers for the courses completed at the university abroad will be granted by the responsible body (following the corresponding recommendations of the AISP board whenever possible). 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 PLUS or SUAS.
- confirmation by formal notification in writing (to the AISP board) before beginning the study abroad period of which courses and/or exams planned to be taken abroad are transferable to PLUS or SUAS.

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 of the Rectorate for Family, Gender, Disability & Diversity.

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

(1) The maximum number of participants in the master's programme in Applied Image and Signal Processing for the following course types is limited as follows (relevant only for courses given at PLUS):

Lectures (VO)	no limit
Proseminars (PS)	25
Seminars (SE)	20

(2) In instances in which courses with a restricted number of participants are oversubscribed, priority of enrolment will be given to students for whom the course is part of the curriculum. Because of the limited number of students admitted to the programme, the participation for the courses provided for the Joint Degree Master's programme is guaranteed for them.

(3) Students in the bachelors's and master's programme in Computer Science will be given places in courses based on the total number of ECTS credits they have earned in the respective 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
- study advance (sum of completed ECTS credits in the programme of stady)
- 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 credits
- random selection

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

(4) 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.

§ 12 Admission requirements for exams

The admission requirements for the following exams are as follows:

Course/Module:	**Prerequisite(s):**
Master Seminar 2	Master Seminar 1

§ 13 Examination regulations

(1) The modules of this curriculum are assessed via individual course examinations.

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

§ 14 Master’s examination before examining committee

(1) The master’s programme in Applied Image and Signal Processing concludes with a master’s examination worth 2 ECTS credits before an examining committee.

(2) Students must have successfully completed all of the required courses and the master’s thesis in order to be eligible to take the master’s examination.

(3) The master’s examination before an examining committee (consisting of three persons; Master’s thesis supervisor, as well as one lecturer of courses relevant for the curriculum of each institution) consists of an oral examination including the following components: (1) presentation of the Master's thesis; (2) discussion and defence of the Master's thesis; (3) an oral examination on core subjects (e.g. obligatory electives); and (4) further interdisciplinary content relevant to the curriculum. Items (3) and (4) are carried out in relation to the background of the Master's thesis and establish curricular links, thus creating the characteristics of a thesis defence.

§ 15 Effective date

The curriculum comes into force 1 October 2021.

§ 16 Transitional provisions

Students enrolled in the curriculum for the Master’s Joint Degree Programme in Applied Image and Signal processing at Paris Lodron University of Salzburg (2016 Version, Mitteilungsblatt – Sondernummer 62, March 17th) when this curriculum comes into force have until 30.09.2022 to complete the programme in which they are enrolled.

Annex II contains a course equivalency list.

Annex I: Module descriptions:

Module description	**Visual Data Processing & Representation**
Module code	VPR
Total workload	8 ECTS
Learning outcomes	On completion of the module, students are able to understand the difference of varying imaging sensor devices and have knowledge about fundamental algorithms and procedures in spatial-domain image processing and computer vision. Students have first experiences in usage of image processing and vision libraries and toolboxes and are able to apply their knowledge in focused projects. Furthermore, students are able to understand the varying non-standard acquisition techniques as discussed in the lecture and have knowledge about fundamental algorithms and procedures in the respective areas.
Module content	Image Processing and Imaging: Imaging Sensors (visible & non-visible light, stereo & multiview acquisition, 3D sensing, medical imaging), Autofocus systems (active and passive), Low-level limage processing (interpolation, spatial domain enhancement, edge detection, spatial domain feature descriptors – histograms, Image segmentation techniques, Morphological image processing Imaging beyond Consumer Cameras: Video processing techniques (motion, superresolution), stereo and multiview acquisition and processing, time of flight, lightfield cameras, structured light, LIDAR imaging, 3D from 2D (shape from focus, shape from shading, shape from texture), microscopy imaging, satellite imaging
Courses	Image Processing and Imaging (2 SHrs., VO, 2 ECTS) Image Processing and Imaging (1 SHrs., PS, 2 ECTS) Imaging beyond Consumer Cameras (2 SHrs., VO, 2 ECTS) Imaging beyond Consumer Cameras (1 SHrs., PS, 2 ECTS)
Type of exam	Individual course assessment

Module description	**Mathematics and Modelling**
Module code	MAM
Total workload	16 ECTS
Learning outcomes	Students can apply functions in several variables to model problems. They are able to analyze the change behavior of these functions and to determine critical points. They can approximate complex functions by multidimensional polynomials (especially with tangent planes and second order Taylor polynomials). They are able to use gradient based methods to find local minima. They understand selected problems of convex optimization and can solve them with mathematical software. Students are able to calculate the most important matrix decompositions and apply eigenvalue theory to perform the principal components analysis for data. Students can solve multidimensional integrals. They understand the notion of a vector space (VS) with inner product and relate to it in different application areas. They master the coordinate transformation for the change of basis in finite dimensional VSs and are familiar with the relationship to Fourier analysis. They know selected application areas of the mentioned methods. Further, students are able to understand the theoretical basics of Fourier transform, filterbanks and wavelets. They are familiar with the mathematical methods of filterbanks with perfect reconstruction. They know the explicit formula of the Daubechies filters and wavelets and can apply these filters to digital signals and images. Furthermore, the students understand the mathematical basics of the theory of wavelets and the construction of compactly supported orthogonal wavelets from quadrature mirror filters. Students are

	able to apply techniques from Fourier and Wavelet theory to the analysis of signals with varying dimensionality, both in terms computer programs as well as in terms of theoretical considerations. Students can also apply methods of inferential statistics to data and communicate the results obtained both verbally and graphically. They can describe data with models and are able to represent dependencies of random variables with graphical models. They know statistical standards and are able to plan, conduct and document experiments. They know applications of random number generators in the area of generative models and can produce corresponding data with mathematical software.
Module content	Selected Topics in Mathematics and Modelling: Vector valued functions on n-dimensional domains, vector fields, scalar fields, partial derivatives, gradient operator, Jacobi and Hessian matrix, directional derivative, Taylor series in several variables, critical points, local minima, maxima and saddle points, convex optimization and applications. Integral calculus, Pre-Hilbert (inner-product) space, (orthonormal-) basis and basis transformation, Eigenvalues, Eigenvectors, matrix decompositions and applications (PCA). Fourier Analysis, Filter Banks and Wavelets: Discrete and continuous Fourier theory, definition and examples of filters, filterbanks with perfect reconstruction, orthogonal and biorthogonal filterbanks, the Daubechies product filter, multiresolution analysis and wavelets, the fast wavelet transform. Applied Statistics: Estimation theory: Point and interval estimators, maximum likelihood method, method of moments, parametric and non-parametric models (kernel density estimators, normal distributions, mixed models), statistical tests, study design and analysis of variance. Data visualization. Outlook: Random numbers and randomization; Graphical models and applications.
Courses	Selected Topics in Mathematics and Modelling (4 SHrs., ILV, 5 ECTS) Fourier Analysis, Filter Banks and Wavelets (3 SHrs., VO, 3 ECTS) Fourier Analysis, Filter Banks and Wavelets (2 SHrs., PS, 4 ECTS) Applied Statistics (3 SHrs., ILV, 4 ECTS)
Type of exam	Individual course assessment

Module description	**Digital Signal Processing**
Module code	DSP
Total workload	10 ECTS
Learning outcomes	Students understand the basic mathematical concepts to describe continuous and discrete time signals and systems and know the relations between time and frequency domain. They are familiar with the foundations of signal sampling and discretization and can apply important transformations, e.g. Fourier-, Laplace and z-transformation. They understand basic algorithms in digital signal processing like FFT, convolution and correlation. They can transform continuous to discrete time systems e. g. with help of the impulse invariant or bilinear transformation and understand the restrictions. They have profound knowledge in designing and implementing digital filters and are also familiar with their applications. Students also have experience in simulation of DSP algorithms in a lab environment and are able to implement discrete systems with help of simulation software and low-level programming languages. Further, students know details in digital filter design such as advantages and disadvantages of different filter types and design methods. They understand the problem of quantization of filter coefficients and how to design 2nd order sections IIR filters. They know how to design special filters like notch, comb or median filters and are able to implement them in a low-level programming language (e.g. C). Students understand the concept of adaptive signal processing and can implement an adaptive LMS filter e.g. for noise cancellation.

	In general, they can solve complex signal processing problems on a given hardware platform. Students understand the problems of numerical programming. They know common number formats and understand details of fixed point and floating-point arithmetic. They understand the principle of applying standard DSP algorithms also for 2D-signals
Module content	Digital Signal Processing 1: Theory of discrete signals and systems, discrete Fourier transformation, FFT, power density spectrum, discrete convolution and correlation, interpolation, calculations in z-domain, z-transfer function, stability and frequency response of discrete systems, discretization of continuous systems (bilinear transformation, impulse invariant transformation), digital filters, principle and design of FIR filters, principle and design of IIR filters, IIR filter structures, quantization problems frequency transformations, simulation of signal processing algorithms and implementation of discrete systems in lab environment (e.g. Matlab, Python, C) Digital Signal Processing 2: Designing IIR filters with 2nd order sections, notch filters and comb filters with simulation tools (e.g. Matlab) and with low level programming language (e.g. C), principle and theory of adaptive FIR filters (LMS-filter) including implementation in low level programming language, quality enhancement with help of oversampling, polyphase filters, theory and simulation of sigma delta converter, numerical programming, fixed-point and floating-point number representation, floating point arithmetics, rounding, numerical analysis, basics of 2D signal processing.
Courses	Digital Signal Processing 1 (3 SHrs, ILV, 5 ECTS) Digital Signal Processing 2 (3 SHrs, ILV, 5 ECTS)
Type of exam	Individual course assessment

Module description	**Data Science & Analytics**
Module code	DSA
Total workload	17 ECTS
Learning outcomes	Upon completion of this module, students know about types and ingredients of data science projects, entitle their structure and identify different types of team members. They understand the concepts of data, models and algorithms and use specific language to describe data. They discuss the appropriateness of a data collection or intended data acquisition process with respect to a data science project. Students are introduced to the classical approach for extracting information from data with different kind of representation (numerical, categorial, one-hot or text). They collect, pre-process and visualize this data to gain basic data understanding. They follow the design cycle for supervised methodology by implementing data-specific feature generation, sampling of training and testing data, training selected (simple) classifiers and evaluating their performance. The students use state-of-the-art development tools and scalable technology and argue their approach content-wise. Further, this module leads students to classical approaches on Exploratory Data Analysis for data with different kind of representation (numerical, categorical, text). For implementing a knowledge discovery process, they apply methods to reduce the dimensionality of data, cluster it and apply various visualization methods. Students are familiar with the fundamental concepts of Natural Computation and understand theoretical foundations as well as application potential. Finally, students understand the assumptions and restrictions implied by a specific model choice in view of statistical learning theory setup and the "no free lunch" theorem. They select from a collection of well-known and widely available ML algorithms, accordingly, parameterize models and assess the impact of different design choices on the network complexity of neural networks. Students detect overfitting and underfitting during the training process

	and take corresponding counter measures such as regularization. They apply the machine learning models to different types of data (text, images, numerical) for tasks such as classification, representation learning and object detection.
Module content	Data Science: Definition of Terminology, Design Cycle, Extended Design Cycle, Sampling, Pre-processing, Normalization, Performance Measures, Cross Validation, Training Policies, K-nearest Neighbour and Minimum Distance Classifier, NLP Pre-processing and Features, Low Level Image Features Analytics and Knowledge Discovery: Analytics, EDA Parallel Lines, Boxplots, Kernel Density Estimators, Basic Coding, Curse of Dimensionality, PCA, tSNE, Kmeans, hierarchical clustering, Spectral clustering, Distances and similarities Natural Computation: Genetics and Evolution, Global Optimisation, Artificial Evolution, Biological Neural Networks, Artificial Neural Networks Machine Learning: Statistical Learning Theory, no free lunch, learning curve, loss functions, bias and variance; Models: Maximum Entropy (Logistic Regression), Artificial Neural Networks, SVM (Kernel SVM, Multi-Class SVM, One-Class SVM), Naive Bayes, Minimum Risk
Courses	Data Science (3 SHrs, ILV, 5 ECTS) Analytics and Knowledge Discovery (2 SHrs, ILV, 3 ECTS) Natural Computation (2 SHrs, VO, 2 ECTS) Natural Computation (1 SHrs, PS, 2 ECTS) Machine Learning (3 SHrs, ILV, 5 ECTS)
Type of exam	Individual course assessment

Module description	**Audio and Media**
Module code	AAM
Total workload	9 ECTS
Learning outcomes	On completion of the module, students are able to understand basic principles of audio processing, design and implement audio effects and subsystems which meet sound quality, computational performance, and real-time requirements, and embed them into various applications and platforms. They also understand basic principles of compression techniques for image, audio, and video data and know the major formats developed for these data types. In particular, they should be aware of the respective advantages and disadvantages of the respective formats and should be able to identify suited formats for a given target application taking constraints into consideration.
Module content	Audio Processing: Sampling, quantization, linear shift-invariant systems, impulse response, FIR/IIR filters, Fourier methods, convolution theorem, equalizers, audio effects (phaser, wah-wah, delay, flanger, chorus), stereo effects, spatial effects (reverberation, localization, feedback delay networks), pitch shifting/stretching, non-linear effects (compressor, limiter, noise gate, overdrive), time-frequency methods, coding (predictive, psychoacoustics, MPEG), application program interfaces (data format, threading, block delay), control interfaces (MIDI, VST, DSSI). Media Data Formats: Foundations of Data Kompression (quantisation, lossless coding, error metrics), Image data formats (Vector vs. bitmap, Lossless (PNG, lJPEG, GIF) & lossy (JPEG, JPEG2000, JPEG XR,...), Video data formats (MPEG. H.26X, scalable video)
Courses	Audio Processing (2 SHrs., VO, 2.5 ECTS) Audio Processing (1 SHrs., PS, 2.5 ECTS) Media Data Formats (2 SHrs., VO, 2 ECTS) Media Data Formats (1 SHrs., PS, 2 ECTS)
Type of exam	Individual course assessment

Module description	**Visual Computing**
Module code	VIC
Total workload	10 ECTS
Learning outcomes	Students understand the theoretical concepts of deep learning in computer vision and are aware of the potential application areas, and are able to solve various computer vision tasks using PyTorch. Further, students have acquired an in-depth understanding of basic (mathematical) concepts used in the modeling of curves, surfaces and shapes. They have seen and used basics of differential geometry, and have been exposed to basic topological concepts of curves and surfaces. Both continuous (e.g., spline-based) and discrete (e.g., triangle-based) representations have been examined.
Module content	Computer Vision: Deep learning techniques in computer vision with deep neural networks using Python Geometric Modelling: Introduction to Bezier curves, splines and NURBs, differential geometry of curves and surfaces, discrete shape representations, meshes, shape editing, mesh fairing and simplification; application of geometric modeling.
Courses	Computer Vision (2 SHrs., VO, 2.5 ECTS) Computer Vision (1 SHrs., PS, 2.5 ECTS) Geometric Modelling (2 SHrs., VO, 2.5 ECTS) Geometric Modelling (1 SHrs., PS, 2.5 ECTS)
Type of exam	Individual course assessment

Module description	**Applied Sciences and Methods**
Module code	ASM
Total workload	7 ECTS
Learning outcomes	Students know the publication lifecycle including the review process. Furthermore, they are able to assess textual, formal and structural quality aspects of scientific papers and scientific presentations. Students have hands-on experience with various tools supporting scientific work, including LateX and Mathematica. Further, students can apply theoretical and practical project management and software engineering skills in a team, based on the practical implementation of a continuous software engineering. Finally, students are able to - analyse and reflect on ethical-moral dilemmas - evaluate opinions from a lecture in their own context of action - argue social issues with a view to their own professional environment and articulate and justify their own opinion in the group discussion.
Module content	Master Seminar 1: Systematic structuring of an exposé and its discursive defence in group situations; characteristics of a scientific working style; scientific publication cycle; introduction to philosophy of science and epistemology; structured literature research, assessment of the quality of publications (quality indices), compilation of state-of-the-art including bibliography with respect to the chosen topic of the master's thesis, definition of the theoretical framework and corresponding vocabulary of concepts. Agile Project Management: The focus is on the creation of software engineering projects to cope with the digitalization of companies. Project management and software engineering skills are to be applied in the practical implementation. Among other things, business case & product innovation (using business canvas & value proposition canvas), project organization (process-oriented and agile procedure models, roles, work packages, milestones, reporting, results). The project implementation is carried out with

	templates from Software Engineering for the development, documentation and communication of software architectures using ARC42 (Context, Requirements, Constraints, Concept of Operations, Major building blocks/components, Block diagram, interfaces, workflow, control flow). Ethics & Sustainability: The need for professional-ethical orientation has never been as great as it has become in the past decade. At this stage, we are being confronted with the topic of ethics from all directions: bioethics, medical ethics, animal ethics, ethics and politics, ethics and economy, ethics as a school subject instead of religion… from personalized ethics to environmental ethics, from day-to-day to systems ethics…. our very existence seems to be sailing in a sea of ethical and morally charged issues – particularly because the two terms – ethics and sustainability – are being used more and more ambiguously and prolifically. This lecture will therefore attempt to shed some light on the question of terminology and to sensitize participants to the questions behind professional ethics and sustainability.
Courses	Master Seminar 1 (PLUS, 2 SHrs., SE, 3 ECTS) Agile Project Management (2 SHrs., ILV, 3 ECTS) Ethics & Sustainability (1 SHrs., ILV, 1 ECTS)
Type of exam	Individual course assessment

Module description	**Selected Topics in Applied Image and Signal Processing**
Module code	STA
Total workload	10 ECTS
Learning outcomes	On completion of the module, students are able to apply their knowledge gained in more general courses to specific application areas and will learn to select the most appropriate techniques and methods in actual, application oriented fields.
Module content	(Applied) Natural Language Processing: Natural Language Processing with Deep Neural Networks, e.g. Recurrent Neuronal Networks, Attention-Models, Transformers or BERT. Contextualized representations, Subword tokenization, Beam Search. Methods: Dialog-based Agents and Systems; Artificial Intelligence; task-oriented dialog systems and chatbots; Natural Language Generation, Interaction and Understanding; Question Answering, Slot Filling. Applications: Dialog systems and chatbots. Tools: Python, scikit-learn, nltk, tensorflow/keras/PyTorch, dialogflow. (Applied) Reinforcement Learning: Markov Decision Process, Definition of RL, Components of RL (Agent, Policy, Model), Model and Non-model based RL, Optimization of RL, Deep RL, Reinforcement Learning Algorithms; RL by use of Physics Engines. Medical Imaging : On completion of the course students are able to understand basics of different medical imaging modalities and their application in a clinical environment. Furthermore knowledge on basic anatomy and image representation as well as on methods dealing with advanced segmentation and registration of 4d data and 3D model rendering is given in a medical context. Students will also be able to apply their knowledge gained from prior courses onto medical images for the purpose of analysis, visualisation and diagnostics. Modalities covered include US, X-Ray, CT, MRT, MRI, fMRI. Biometric Systems: Introduction to biometric systems, Short review of non-visual based modalities (voice, keystroke, EEG, ECG, …), Fingerprint Recognition, Face Recognition, Eye-based System (Iris & Retina recognition), Ear biometrics, Gait, Biometric fusion, security, privacy Media Security: Media Encryption (image, video, audio, 3D-data), Media Authentication (Robust hashing, robust signatures, watermarking), Information Hiding (watermarking, steganography), Media Forensics

	Computational Geometry: The methodologies of computational geometry allow one to investigate solutions of numerous geometric problems that arise in application areas such as image processing, computer-aided design, manufacturing, geographic information systems, robotics and graphics. This course offers an introduction to computational geometry: We will discuss geometric searching, convex hulls, Voronoi diagrams, straight skeletons, triangulations, and robustness issues. Advanced Machine Learning: Machine learning is the study of how to program computers to "learn" from available input data. In other words, it is the process of converting experience (in the form of training data) into expertise to solve a variety of different tasks (e.g., classification, regression, etc.). We will cover a formal-mathematical understanding of this idea. Fundamental concepts such as probably approximately correct (PAC) learning, Vapnik–Chervonenkis theory and applications thereof are major topics considered. Further, the theoretical understanding of the learning process is applied in the analysis of popular learning algorithms such as Boosting or support vector machines (SVMs).
Courses	Natural Language Processing (SUAS, 2 SHrs., ILV, 3 ECTS) Applied Natural Language Processing (SUAS, 1 SHrs., ILV, 2 ECTS) Reinforcement Learning (SUAS, 2 SHrs., ILV, 3 ECTS) Applied Reinforcement Learning (SUAS, 1 SHrs., ILV, 2 ECTS) Medical Imaging (PLUS, 2 SHrs., VO, 3 ECTS) Medical Imaging (PLUS, 1 SHrs., PS, 2 ECTS) Biometric Systems (PLUS, 2 SHrs., VO, 3 ECTS) Biometric Systems (PLUS, 1 SHr., PS, 2 ECTS) Media Security (PLUS, 2 SHrs., VO, 3 ECTS) Media Security (PLUS, 1 SHr., PS, 2 ECTS) Computational Geometry (PLUS, 2 SHrs., VO, 3 ECTS) Computational Geometry (PLUS, 1 SHrs., PS, 2 ECTS) Advanced Machine Learning (PLUS, 2 SHrs., VO, 3 ECTS) Advanced Machine Learning (PLUS, 1 SHr., PS, 2 ECTS)
Type of exam	Individual course assessment

Module description	**Master‘s Thesis & Master Seminar 2**
Module code	MTE
Total workload	25 ECTS
Learning outcomes	The students are able to present and discuss their own scientific work in a peer group situation. They can argue logically and in line with scientific standards as well as understand the importance of a methodical approach. Further, students are able to independently write sound academic papers based on common international standards. They can proceed methodically and systematically. They can analyse and present problems, provide solutions as well as formulate these appropriately and critically scrutinise them. The students are able to defend their approach.
Module content	Master Seminar 2: Discursive defence of parts of the master’s thesis in group situations; presentation of scientific work as part of the state-of-the-art discussion for the thesis’ topics; discussion of recent research results in connection with collegues’ theses. Master’s Thesis: Developing and elaborating on the research questions and establishing a contentwise argumentation of a topic in applied image and signal processing with special consideration of a scientifically sound and structured presentation reflecting the current state of the literature.
Courses	Master Seminar 2 (1 SHrs., SE, 2 ECTS) Master‘s Thesis (23 ECTS; if written at SUAS: IT)
Type of exam	Individual course assessment

Annex II: Equivalency list

JD Master's Programm Applied Image and Signal Processing (2021)	**JD Master's Programm Applied Image & Signal Processing (2016)**
Fourier Analysis, Filter Banks and Wavelets (VO+PS, 7 ECTS)	Advanced Mathematics for Computer Science (VO+PS, 7 ECTS)
Natural Computation (VO+PS, 4 ECTS)	Pattern Recognition 1&2 (ILV+UV, 5 ECTS)
Analytics & Knowledge Discovery (ILV, 3 ECTS)	Data Mining (ILV, 2.5 ECTS)
Mathematics & Modelling (ILV, 5 ECTS) Applied Statistics (ILV, 4 ECTS)	Selected Topics in Mathematics & Modelling (ILV, 3 ECTS) Applied Statistics (ILV, 3 ECTS) Filterbanks and Wavelets (VO+PS, 5 ECTS)

Impressum
Herausgeber und Verleger:
Rektor der Paris Lodron-Universität Salzburg
Prof. Dr. Dr. h.c. Hendrik Lehnert
Redaktion: Johann Leitner
alle: Kapitelgasse 4-6
A-5020 Salzburg