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

(Version 2016)

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In its session on 08.03.2016 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 Department curriculum committee at the University of Salzburg in its 17.12.2015 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 Joint Degree master's 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 individual 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, mechatronics/engineering, electronics, automation technology, media and computing, and computational engineering) from an accredited Austrian or foreign institute of higher education (cf. UG2002 §64 para. 5).

In particular, in the core area of computer sciences a level of at least 18 ECTS points (or, if ECTS points cannot be applied, 12 semester hours) is required (e.g. high-level programming languages, object-oriented programming, procedural programming, algorithms and data structures, Mathematica/Matlab). In addition, in the core area of mathematic, a level of at least 12 ECTS points or 9 semester hours is required (e.g. fundamentals of analysis, linear algebra and stochastic modelling).

(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 Joint Degree Master's programme is carried out as a Joint Degree Master's programme 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 (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 and mathematics 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.

§ 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 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. 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 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 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 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 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 image and signal processing systems)
- Software development including 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 programme in Applied Image and Signal Processing comprises 8 modules (including an elective module) with a total number of 86 ECTS points. In addition, there are 6 ECTS points assigned for elective courses and 2 ECTS points for the master's exam. The master's thesis is worth 26 ECTS points.

	ECTS
Digital Signal Processing 1	11
Mathematics and Modelling	13
Image Processing and Computer Vision 1	14
Digital Signal Processing 2	8
Audio and Media	9
Knowledge Discovery and Computer Vision	12,5
Applied Sciences and Methods	8,5
Elective module (Selected Topics in Applied Image and Signal Processing)	10
Elective courses	6
Master's thesis	26
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 5. and 6. are used exclusively at the University of Applied Sciences Salzburg):

1. Lectures (VO) introduce students to different areas of the subject and provide subject-specific 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. **Lectures combined with Proseminars (UV)** combine parts of lectures and proseminars in a course tailored according to specific didactic considerations. UVs allow for the connecting of theoretical content with practical application.
4. **Seminars (SE)** promote scientific work and discussion and require students to develop their own scientific contributions.

5. **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.
6. **Projects (PT)** 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. In all courses attendance is obligatory with the exception of lectures at the University of Salzburg.

§ 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 the Salzburg University of Applied Sciences (course name given in red letters) and recommended for courses held at the University of Salzburg (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 joint 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 – Digital Signal Processing 1 (DSP1)								
Digital Signal Processing 1		3	ILV	4	4			
Digital Signal Processing 1		1	PT	2	2			
Signals and Systems 1		2	ILV	2	2			
Hardware Oriented Signal Processing 1		1	ILV	1,5	1,5			
Hardware Oriented Signal Processing 2		1	UV	1,5	1,5			
Subtotal for Module 1		8		11	11			
Module 2 – Mathematics and Modelling (MAM)								
Selected Topics in Mathematics and Modelling		2	ILV	3	3			
Advanced Mathematics for Computer Science		3	VO	4	4			
Advanced Mathematics for Computer Science		2	PS	3	3			
Applied Statistics		2	ILV	3		3		
Subtotal for Module 2		9		13	10	3		
Module 3 – Image Processing and Computer Vision 1 (VPR-IPCV1)								
Image Processing and Imaging		2	VO	2	2			
Image Processing and Imaging		1	PS	2	2			
Geometric Modelling		2	VO	2,5	2,5			
Geometric Modelling		1	PS	2,5	2,5			
Filterbanks and Wavelets		2	VO	2,5		2,5		
Filterbanks and Wavelets		1	PS	2,5		2,5		
Subtotal for Module 3		9		14	9	5		

Module 4 – Digital Signal Processing 2 (DSP2)							
Digital Signal Processing 2	3	ILV	4		4		
Digital Signal Processing 2	1	PT	2		2		
Signals and Systems 2	2	ILV	2		2		
Subtotal for Module 4	6		8		8		
Module 5 – Audio and Media (AAM)							
Media Data Formats	2	VO	2		2		
Media Data Formats	1	PS	2		2		
Audio Processing	2	VO	2,5		2,5		
Audio Processing	1	PS	2,5		2,5		
Subtotal for Module 5	6		9		9		
Module 6 – Knowledge Discovery and Vision (KDI-IPCV2)							
Data Mining	2	ILV	2,5			2,5	
Pattern Recognition 1	2	ILV	2,5			2,5	
Pattern Recognition 2	2	UV	2,5			2,5	
Computer Vision	2	VO	2,5			2,5	
Computer Vision	1	PS	2,5			2,5	
Subtotal for Module 6	9		12,5			12,5	
Module 7 – Applied Sciences and Methods (ASM)							
IT-Projectmanagement and Softwareprojects	2	ILV	3,5			3,5	
Master Seminar 1 (PLUS)	1	SE	1,5			1,5	
Master Seminar 1 (SUAS)	1	SE	1,5			1,5	
Master Seminar 2	1	SE	2				2
Subtotal for Module 7	5		8,5			6,5	2
Total for Compulsory Modules	52		76	30	25	19	2
(2) Elective modules according to § 6							
Total for Elective Module Catalogues			10			10	
(3) Elective courses according to § 7							
Elective courses					5	1	
Master's thesis							**26**
Master's exam							**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 the University (PLUS) as well as at the University of Applied Sciences (SUAS).

Elective Module – Selected Topics in Applied Image and Signal Processing								
Module	**Course**	**SHrs**	**Type**	**ECTS**	**Semester with ECTS**			
					I	**II**	**III**	**IV**
Module 8 – Selected Topics in Applied Image and Signal Processing (STA)								
Medical Imaging (SUAS)		3	ILV	5			5	
Platform Specific Signal Processing (SUAS)		3	ILV	5			5	
Data Science (SUAS)		3	ILV	5			5	
Biometric Systems (PLUS)		2	VO	2,5			2,5	
Biometric Systems (PLUS)		1	PS	2,5			2,5	
Media Security (PLUS)		2	VO	2,5			2,5	
Media Security (PLUS)		1	PS	2,5			2,5	
Computational Geometry (PLUS)		2	VO	2,5			2,5	
Computational Geometry (PLUS)		1	PS	2,5			2,5	
Machine Learning (PLUS)		2	VO	2,5			2,5	
Machine Learning (PLUS)		1	PS	2,5			2,5	
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 (i) taking the course ``Ethics and Sustainability'' at SUAS in the second semester (1 ECTS) and by (ii) 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. UG2002 §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. UG2002 §80 para. 2).

(5) The topic of the master's thesis is established in the course "Master Seminar 1". The master's thesis is conducted at either institution and is 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 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 and 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 Disability & Diversity.

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

(1) The maximum overall number of the master's programme in Applied 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
Lectures combined with Proseminars (UV)	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.

(3) Students in the bachelor'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 study)
- 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

For courses which are held at SUAS, the examination regulations of the Salzburg University of Applied Sciences are applied together with the admission requirements laid down there. This means, for example, that at the time of entry into force of this curriculum courses can only be completed, if all examinations of the preceding semester are passed successfully. This regulation also applies for courses involving continuous assessment, which, although they have already started, can only be completed under the above-mentioned conditions. For further details please see the current examination regulations of the Salzburg University of Applied Sciences.

The admission requirements for the following exams for courses held at PLUS are as follows:

Course/Module:	**Prerequisite(s):**
Master Seminar 1	Advanced Mathematics for Computer Science (VO) Image Processing and Imaging (VO and PS)
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 2016.

§ 16 Transitional provisions

(1) Students enrolled in the curriculum for the master’s programme of study in Applied Image and Signal Processing at Paris Lodron University of Salzburg (2012 Version, Mitteilungsblatt – Sondernummer 46, June 15th) when this curriculum comes into force have until 30.09.2017 to complete the programme in which they are enrolled.

Provided that no further provisions are listed here, changes effective when this curriculum comes into force are to be applied to all students according to § 8 (2) of the Statutes of the University of Salzburg.

Annex II contains a course equivalency list.

Annex I: Module descriptions:

Module description	**Digital Signal Processing 1**
Module code	DSP 1
Total workload	11 ECTS
Learning outcomes	Students are able to 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 discretisation and can apply important transformations, e.g. Fourier-, Laplace and z-transformation. They can transform continuous to discrete time systems e. g. with help of the impuls invariant or bilinear transformation and understand the restrictions. They understand basic algorithms in digital signal processing like FFT, convolution and correlation. They have profound knowledge in designing and implementing digital filters and are also familiar with their applications. They understand the operation of A/D and D/A converters and are able to simulate continuous and discrete time systems with standard tools. They have experience in measuring and analysing signal and system properties in a Lab environment.
Module content	Digital Signal Processing: Theory of discrete signals and systems: discrete Fourier transformation (FFT), power density spectrum, discrete convolution and correlation, interpolation, implementation in Matlab and C; z-transform, z transfer function, stability and frequency response of discrete systems, discretisation of continuous systems (bilinear transformation, impulse invariant transformation); Digital filters: principle and design of FIR filters, simulation with simulation tools (e.g. Matlab), principle and design of IIR filters, filter implementation in Matlab and C. Signals and Systems: Basic signal and system properties, time and frequency domain, Fourier series and Fourier transformation (FT), FT of single impulses and periodic signals, power density spectrum (Parseval), convolution, convolution property, dirac impulse, dirac impulse sequence; stochastic signals, variance and power of stochastic signals, autocorrelation and cross correlation sampling theorem, aliasing, zero order hold sampling, quantisation, quantisationerror; Laplace transformation, transfer function, pole zero map: discrete time signals and systems, z-transform, z-transfer function. Hardware Oriented Signal Processing: Signal acquisition, sensors, signal amplifiers, digital-analog-converters (DACs), types of DACs, analog-digital-converters (ADCs), ADC-types and architectures, measurement devices and –systems, measurement and analysis of signal properties; motivation for the use of special processors for digital signal processing; features of classical digital signal processos (DSPs): zero overhead loops, pointer increment access, circular addressing, multiply-accumulate instructions, accumulate registers; features of modern DSPs: very large instruction words (VLIW), streaming single instrucion multiple data (SIMD), multi-core, media processors; programming practices on a DSP emulator.
Courses	Digital Signal Processing 1 (3 SHrs, ILV, 4 ECTS) Digital Signal Processing 1 (1 SHrs, PT, 2 ECTS) Signals and Systems 1 (2 SHrs., ILV, 2 ECTS) Hardware Oriented Signal Processing 1 (1 SHrs., ILV, 1,5 ECTS) Hardware Oriented Signal Processing 2 (1 SHrs., UV, 1,5 ECTS)
Type of exam	Indivudual course assessment

Module description	**Mathematics and Modelling**
Module code	MAM
Total workload	13 ECTS
Learning outcomes	On completion of the module, students are able to understand specialiced articles from the field of theoretical IT, to use mathematical modelling methods to solve real world problems and to translate those into respective algorithms. In particular, they have the ability to employ estimation theory and inferential statistics methods to analyse complex problems and they understand the mathematical basics of stochastic simulation. they are aware of the basic principles of Fourier theory and potential applications in signal and image processing and do have experience in solving corresponding exercises. They understand the relation between differential equations and correpsponding real world problems. Knowledge of theoretical basics and formal methods are rounded off by proficiency in working with mathematical software.
Module content	Selected Topics in Mathematics and Modelling: Selected chapters from analysis (multidimensional differentiation and integration), algebra (vector spaces with inner product, eigenvalue theory, orthonormal bases, coordinate transformation, examples of vector spaces and applications), numerics (error analysis, conditioning and algorithmics) and *Matlab* (CLI and programming). Advanced Mathematics for Computer Science: Fourier Series, Fourier Integrals, Fast Fourier Transform, Applications of Fourier Analysis to Signal and Image Processing, Introduction to Ordinary Differential Equations. Applied Statistics: Estimation theory: point and interval estimators, confidence intervals; application to stochastic simulations: random number generators, simulation model, result analysis; statistical test theory: comparison of mean values, significance, outlook ANOVA; application within datamining: preprocessing, feature extraction, outlook: PCA
Courses	Selected Topics in Mathematics and Modelling (2 SHrs., ILV, 3 ECTS) Advanced Mathematics for Computer Science (3 SHrs., VO, 4 ECTS) Advanced Mathematics for Computer Science (2 SHrs., PS, 3 ECTS) Applied Statistics (2 SHrs., ILV, 3 ECTS)
Type of exam	Individual course assessment

Module description	**Image Processing and Computer Vision 1**
Module code	VPR-IPCV1
Total workload	14 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 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. On the theoretical side, students are able to understand the theoretical basics of filterbanks and wavelets. They are familiar with the mathematical methods of filterbanks with perfect reconstruction. They know the explicite 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.
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-levelimage processing (interpolation, spatial domain enhancement, edge detection, spatial domain feature descriptors – histograms, LBP, SIFT, multiscale blobs), Image segemtation techniques, Morphological image processing, Video Processing (motion estimation, de-interlacing, superresolution), 3D from 2D (shape from focus, stereo processing) 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. Filterbanks and Wavelets: 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.
Courses	Image Processing and Imaging (2 SHrs., VO, 2 ECTS) Image Processing and Imaging (1 SHrs., PS, 2 ECTS) Geometric Modelling (2 SHrs., VO, 3 ECTS) Geometric Modelling (1 SHrs., VO, 2 ECTS) Filterbanks and Wavelets (2 SHrs., VO, 3 ECTS) Filterbanks and Wavelets (1 SHrs., VO, 2 ECTS)
Type of exam	Individual course assessment

Module description	**Digital Signal Processing 2**
Module code	DSP2
Total workload	8 ECTS
Learning outcomes	Students know the principles of continuous filters and continuous control applications. They know details in digital filter design, e.g. advantages and disadvantages of different filter types and design methods. They understand the problem of quatisation errors of filter coefficients and how to design 2^{nd} order sections IIR-filters. They know how to design special filters like notch filters or comb filters. They are able to implement digital filters in a standard programming language, e.g. in C. Students understand the concept of adaptive signal processing, e.g. adaptive LMS filter. They know how to design and implement simple digital controllers. They are familiar with the basics of digital data transmission. They understand the basics of 2D-signal processing and can design standard 2D-filters. They can solve complex signal processing problems on a given hardware platform.
Module content	Digital Signal Processing: filter structures, 2^{nd} order section IIR filters, frequency transformations, special filters (notch filter, comb filter), implementation in Matlab and C; principle and theory of adaptive FIR filters (LMS-filter); basics of digital controlling, simple digital controller (design and implementation); transmission of digital signals, 2D signal processing basics. Signals and Systems: stability examination of continuous and discrete systems (root locus); analog standard filters (Butterworth, Tschebyscheff, Cauer, Bessel); principle of controlling, control loop, design of simple con-

	trollers, pid controller, fuzzy logic
Courses	Digital Signal Processing 2 (3 SHrs., ILV, 4 ECTS) Digital Signal Processing 2 (1 SHrs., PT, 2 ECTS) Signals and Systems 2 (2 SHrs., ILV, 2 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 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. They also 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.
Module content	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), 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).
Courses	Media Data Formats (2 SHrs., VO, 2 ECTS) Media Data Formats (1 SHrs., PS, 2 ECTS) Audio Processing (2 SHrs., VO, 2,5 ECTS) Audio Processing (1 SHrs., PS, 2,5 ECTS)
Type of exam	Individual course assessment

Module description	**Knowledge Discovery and Vision**
Module code	KDI-IPCV2
Total workload	12,5 ECTS
Learning outcomes	Building on database system basics, the students understand the theory and practice of information retrieval as well as information procurement from extensive datasets. They are familiar with the basics of data warehousing such as the integration and separation of data from distributed and differently structured data sets. The students are able to select and apply suitable data mining methods, i.e. implement statistical-mathematical methods for the detection of patterns and correlations in data. Furthermore, students are able to understand the theoretical framework for most methods in classical statistical pattern recognition and have gained in experience in using and applying classical methodologies in this area. On completion of the module, students are also able to understand and apply Fourier- and Wavelet based image filtering techniques as well as image restauration approaches. The handling of external and internal cam-

	era parameters will be covered theoretically and practically and fundamental concepts of object recognition, classification, and tracking in image and video material has been trained. Student will be familiar with the most prominent techniques in 3D scene reconstruction.
Module content	Data Mining: Object-relational database systems; data warehousing; data management in distributed systems; design of analytical information systems; integrated data management in an industrial environment; XML and databases; selected chapters from advanced database technologies (e.g. OLAP, information retrieval, knowledge discovery). Pattern Recognition: Pattern recognition process (data preprocessing, feature extraction, feature reduction, classification); training and testing methods, error types and performance analysis, min-risk and min-error, Baysian Decision Theory, PCA; nearest neighbor methods, neural networks, support vector machines, clustering algorithms, decision trees, and probabilistic methods. Computer Vision: Transform-based Image Processing (Fourier, Wavelets, frequency filtering), Image Restauration (Inverse & Pseudoinverse Filtering, Wiener filtering), Camera calibration, Camera distortion correction, Object detection and tracking, 3D scene construction (laser scanners, scene reconstruction from video)
Courses	Data Mining (2 SHrs., ILV, 2,5 ECTS) Pattern Recognition 1 (2 SHrs., ILV, 2,5 ECTS) Pattern Recognition 2 (2 SHrs., UV, 2,5 ECTS) Computer Vision (2 SHrs., VO, 2,5 ECTS) Computer Vision (1 SHrs., PS, 2,5 ECTS)
Type of exam	Individual course assessment

Module description	**Applied Sciences and Methods**
Module code	ASM
Total workload	8,5 ECTS
Learning outcomes	The students are able to independently identify and develop target-oriented research topics for scientific papers and to prepare those in the form of an exposé. They can argue logically and in line with scientific standards as well as understand the importance of a methodical approach. They are proficient in networked thinking and synthetic synopsis. They know the publication lifecycle including the review process. Furthermore, they are able to assess textual, formal and structural quality aspects of scientific papers. The students are also aware of the principles, methods and processes of IT-project management, also in virtual environments (eCollaboration, virtual Project Management - "vPM") like “P2B” (www.pool2business.eu) and the prerequisites for successful IT-innovations and applications.
Module content	IT-Projectmanagement and Softwareprojects: Planning of product innovation: project definition, task structure, quality assurance, work packages, organisation, roles, phases, milestones/results, flow chart, multi-project control; implementation and controlling: conflict line/project, progress monitoring, prognosis, risk analysis, reporting system, qualitative and quantitative evaluation, documentation, software models and tools; social skills: teamwork, challenge, expectation, self-organisation, moderation, feedback, management styles, roles within a team, coaching of projects. 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 publi-

	cations (quality indices), compilation of state-of-the-art including bibliography with respect to the chosen topic of the master thesis, definition of the theoretical framework and corresponding vocabulary of concepts Master Seminar 2: Discursive defence of parts of the master thesis in group situations; presentation of scientific work;
Courses	IT-Projectmanagement and Softwareprojects (2 SHrs., ILV, 3,5 ECTS) Master Seminar 1 (SUAS, 1 SHrs., SE, 1,5 ECTS) Master Seminar 1 (PLUS, 1 SHrs., SE, 1,5 ECTS) Master Seminar 2 (1 SHrs., SE, 2 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	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. Platform Specific Signal Processing: Functional principle of modern signal processors, fixed point formats, special hardware architectures (FPGAs), modern development environments and simulation tools, speed optimization of signal processing algorithms, parallelisation in software and hardware, hardware description languages (VHDL). Data Science: Students know technical and organizational challenges imposed by big data applications and understand methods and algorithms for data-intensive software development. They are aware of the interdisciplinary aspects of big data engineering and have a basic command of established frameworks. As to particular methodology, students will be able to apply elementary matrix algebra to linear regression and extend that basic notion to the class of general linear models, multiple regression and nonlinear regression. They will develop the ability to independently apply basic regression techniques using R and to appreciate the underlying mathematical concepts. 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. 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.). Students will learn a formal-mathematical understanding of this idea. They are exposed to fundamental concepts such as probably approximately correct (PAC) learning, Vapnik–Chervonenkis theory and applications thereof. 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	Medical Imaging (SUAS, 3 SHrs., ILV, 5 ECTS) Platform Specific Signal Processing (SUAS, 3 SHrs., ILV, 5 ECTS) Data Science (SUAS, 3 SHrs., ILV, 5 ECTS) Biometric Systems (PLUS, 2 SHrs., VO, 2,5 ECTS) Biometric Systems (PLUS, 1 SHr., PS, 2,5 ECTS) Media Security (PLUS, 2 SHrs., VO, 2,5 ECTS) Media Security (PLUS, 1 SHr., PS, 2,5 ECTS) Computational Geometry (PLUS, 2 SHrs., VO, 2,5 ECTS) Computational Geometry (PLUS, 1 SHrs., PS, 2,5 ECTS) Machine Learning (PLUS, 2 SHrs., VO, 2,5 ECTS) Machine Learning (PLUS, 1 SHr., PS, 2,5 ECTS)
Type of exam	Individual course assessment

Annex II: Equivalency list

Joint Degree Master's Programme Applied Image and Signal Processing 2015				Joint Degree Master's Programme Applied Image and Signal Processing 2012			
Course	**SHrs**	**Type**	**ECTS**	**Course**	**SHrs.**	**Type**	**ECTS**
(1) Compulsory Modules							
Image Processing and Imaging	2	VO	2	Image Processing and Computer Vision	2	VO	2
Image Processing and Imaging	1	PS	2	Image Processing and Computer Vision	1	PS	2
Computer Vision	2	VO	2,5	Advanced Image Processing and Computer Vision	2	VO	2,5
Computer Vision	1	PS	2,5	Advanced Image Processing and Computer Vision	1	PS	2,5
(2) Elective Module § 6							
Platform Specific Signal Processing	3	ILV	5	Selected Topics in Hardware oriented Signal Processing	3	ILV	5
Machine Learning	2	VO	2,5	Advanced Remote Sensing and Object-based Image Analysis	3	VP	5
Machine Learning	1	PS	2,5	Advanced Remote Sensing and Object-based Image Analysis	3	VP	5
Data Science	3	ILV	5	Advanced Remote Sensing and Object-based Image Analysis	3	VP	5
(3) Elective Courses § 7			6	Computational Geometry	2	VO	2,5
				Computational Geometry	1	PS	2,5

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