JACOBS
UNIVERSITY

Study Program Handbook

Intelligent Mobile Systems

Bachelor of Science

Subject-specific Examination Regulations for Intelligent Mobile Systems (Fachspezifische Prüfungsordnung)

The subject-specific examination regulations for Intelligent Mobile Systems are defined by this program handbook and are valid only in combination with the General Examination Regulations for Undergraduate degree programs (General Examination Regulations = Rahmenprüfungsordnung). This handbook also contains the program-specific Mandatory Module and Examination Plans (Appendix 1a / 1b).

Upon graduation, students in this program will receive a Bachelor of Science (BSc) degree with a scope of 180 ECTS (for specifics see chapter 3 of this handbook).

Version	Valid as of	Decision	Details
Fall 2018 - V1	01.09.18	Academic Senate August 29, 2018	Master Version

Contents

1 The Intelligent Mobile Systems Study Program

1.1 Concept

This program covers engineering methods and technologies that are relevant for freeing artificial mobile systems from permanent human supervision, i.e., that enable mobile systems to perform autonomous intelligent operations. Application areas include the automotive and transport industries, robotics and automation, communication technologies, marine technology, and logistics. The program also includes transdisciplinary aspects related to the study of processes that enable mobility in intelligent natural systems. Hands-on experiences with technical systems and methods are provided in first-class labs.

1.2 Specific Advantages of the IMS Program at Jacobs University

- IMS is the flagship program of the university in the focus area Mobility. It has been designed to be very interdisciplinary incorporating concepts from various engineering disciplines such as Computer Science, Electrical Engineering, Mechanical Engineering, and Logistics.

- While programs on Automation, Robotics, and Mechatronics exist in other universities, what makes IMS stand out is that, in addition to covering the aforementioned areas, it puts a special emphasis on the key concepts of Intelligence and Autonomy which are important for the man-made systems of the future. Hence, students are given a solid background in fields such as Control Systems, Machine Learning, Computer Vision, Planning, and Optimization.

- The IMS program is geared towards the world-renowned automation and robotics industry in Germany. As confirmed by keyword-searches on popular job-portals, engineers with additional skills in Vision, Machine Learning, and Robotics are much sought after by the well-established German and European automobile industry. An extended internship in the fifth semester allows students to gain industrial experience and make contacts for potential future job opportunities.

- Many IMS faculty members have research-groups that are well-funded by EU and DFG projects. Hence, ample opportunities exist for students to get involved and gain research experience.

1.3 Program-Specific Qualification Aims

By the end of this program, students will be capable of designing and implementing complete intelligent mobile systems that carry out complex tasks in challenging environments without permanent human supervision.
Concretely, students will be able to:

- demonstrate knowledge of kinematics and dynamics of multi-body systems
- design and develop linear and nonlinear control systems
- design basic electronics circuits

- show competence about operational principles of motors and drives
- design and develop Machine Learning algorithms and techniques for pattern-recognition, classification, and decision-making under uncertainty
- design and develop Computer Vision algorithms for inferring 3D information from camera images, and for object recognition and localization
- model common mechanical and electrical systems which are part of intelligent mobile systems
- design robotics systems and program them using popular robotics software frameworks
- formulate and solve optimization problems of both theoretical and practical natures, in continuous as well as discrete settings.

1.4 The Jacobs University Employability and Personal Development Concept

Jacobs University's educational concept aims at fostering employability which refers to skills, capacities, and competencies which transcend disciplinary knowledge and allow graduates to quickly adapt to professional contexts. Jacobs University defines employability as encompassing not just technical skills and understanding but also personal attributes, competencies and qualities enabling students to become responsible members of their professional and academic fields as well as of the societies they live in. Graduates of JU will be equipped with the ability to find employment and to pursue a successful professional career, which means that graduates will be able to:

- acquire knowledge rapidly, gather, evaluate and interpret relevant information and evaluate new concepts critically to derive scientifically funded judgements;
- apply their knowledge, understanding and methodological competences to their activity or profession to solve problems;
- present themselves and their ideas effectively and to negotiate successfully;
- demonstrate understanding and knowledge of business principles and processes and to manage projects efficiently and independently;
- take responsibility for their and their team's learning and development.

Graduates of JU will also be equipped with a foundation to become globally responsible citizens, which includes the following attributes and qualities:

- graduates have gained intercultural competence; they are aware of intercultural differences and possess skills to deal with intercultural challenges; they are familiar with the concept of tolerance;
- graduates can apply problem-solving skills to negotiate and mediate between different points of view and to manage conflicts;
- graduates can rely on basic civic knowledge; they are able to analyse global issues of economic, political, scientific, social or technological nature; they are able to evaluate situations and take decisions based on ethical considerations;
- graduates are able and prepared to take on responsibility for their professional community and society.

1.5 Career Options

Careers in research and development or management tracks in automotive and transport, robotics and automation, communication technologies, marine technology and logistics industries. Given the increasing need for automation of daily life tasks through intelligent mobile systems, there is a significant number of career options in addition to the core ones that are covered in the program.

1.6 More Information and Contact

For more information please contact the study program chair:

Dr. Francesco Maurelli
Professor of Marine Systems and Robotics
Email: f.maurelli@jacobs-university.de
Telephone: +49 421 200-3111

or visit our program website: http://imsys.user.jacobs-university.de/

2 The Curricular Structure

2.1 General

The undergraduate education at Jacobs University equips students with the key qualifications necessary for a successful academic, as well as professional career. By combining disciplinary depth and transdisciplinary breadth, supplemented by skills education and extracurricular elements, students are prepared to be responsible and successful citizens within the societies they work and live in.

The curricular structure provides multiple elements enhancing employability, transdisciplinarity, and internationality. The unique Jacobs Track, offered across all study programs, provides a broad range of tailor-made courses designed to foster career competencies. These include courses which promote communication, technology, business, (German) language, and management skills. The World Track, included in the third year of study, provides extended company internships or study abroad options. Thus students gain training on the job and intercultural experiences. All undergraduate programs at Jacobs University are based on a coherently modularized structure, which provides students with a broad and flexible choice of study plans to meet their major as well as minor study interests.

The policies and procedures regulating undergraduate study programs at Jacobs University in general can be found on the website.

2.2 The Jacobs University 3C-Model

Jacobs University offers study programs according to the regulations of the European Higher Education Area. All study programs are structured along the European Credit Transfer System (ECTS), which facilitates credit transfer between academic institutions. The three-year undergraduate program involves six semesters of study with a total of 180 ECTS credits. The curricular structure follows an innovative and student-centered modularization scheme - the 3C-Model - which groups the disciplinary content of the three study years according to overarching themes:

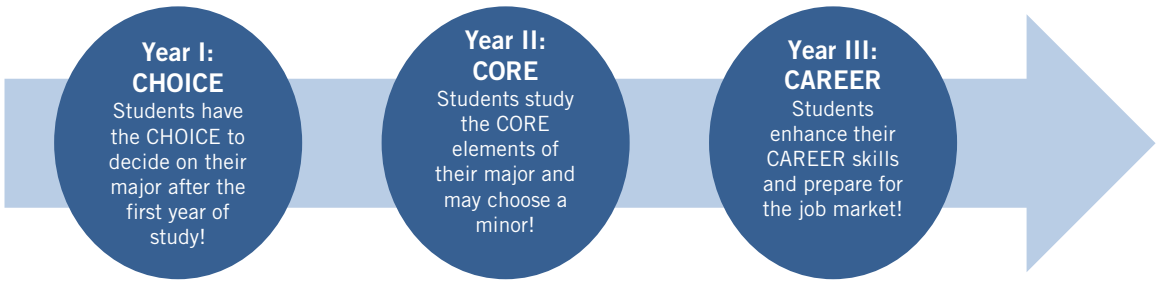


Figure 1: The Jacobs University 3C-Model

2.2.1 YEAR 1 - CHOICE

The first study year is characterized by a broad offer in disciplinary and interdisciplinary education. Students select three CHOICE modules from a variety of study programs. As a unique asset, our curricula allow students to select their study program freely from among the three selected CHOICE modules during their first year of study.

2.2.2 YEAR 2 - CORE

In the second year, students take three in-depth, discipline-specific CORE modules. One CORE module can also be taken from a second, complementary discipline, which allows students to incorporate a minor study track into their undergraduate education. Students will generally qualify for a minor if they have successfully taken at least one CHOICE module and one CORE module in a second field, and this extra qualification will be highlighted in the transcript.

2.2.3 YEAR 3 - CAREER

During their third year, students must decide on their career after graduation. In order to facilitate this decision, the fifth semester introduces two separate tracks. By default students are registered for the World Track.

1. **The World Track**
   In this track there are two mandatory elective options:

   - **Internship**
     The internship program is a core element of Jacobs Universitys employability approach. It includes a mandatory semester-long internship off-campus (minimum 16 weeks in full-time) which provides insight into the labor market as well as practical work experience related to the respective area of study. Successful internships may initiate career opportunities for students.
     As an alternative to the regular internship, a limited number of students have the opportunity to prepare in a structured manner the formation of their own start-up in the 5th semester, and can attain 20 ECTS for this study-related achievement. Jacobs University cooperates with the City Accelerator Bremen (CAB) to which students can be admitted. There are several requirements which must be fulfilled before the 5th semester in order to be admitted to the CAB, i.e. attendance of specific seminars and workshops and the successful presentation of the business idea within the framework of a competition (pitch). The module is successfully completed, when the student / team of students have submitted the business plan to CAB.

     For further information, please contact the Career Services Center (http://www.jacobs-university.de/career-services/contact).

   - **Study Abroad**
     Students can take the opportunity to study abroad at one of our partner universities. Courses recognized as study abroad credits need to be pre-approved according to the

Jacobs University study abroad procedures and carry minimum of 20 ECTS credits in total. Several exchange programs allow you to be directly enrolled at prestigious partner institutions worldwide. Jacobs University's participation in Erasmus+, the European Unions exchange program, provides an exchange semester at a number of European universities including Erasmus study abroad funding.

For more information, please contact the International Office (http://intoffice.user.jacobs-university.de/outgoing/).

2. **The Campus Track**
   Alternatively, students may also opt to follow the Campus Track by continuing their undergraduate education at Jacobs, namely by selecting an additional CORE module during their third year and redistributing the remaining courses and modules across the third year. This opportunity can be used by students to more intensively focus on their major or to fulfill the minor requirements for a second field of interest.

In the sixth semester, all students select from a range of specialization courses within their study program and concentrate on their Bachelor thesis in the context of a Project/Thesis Module.

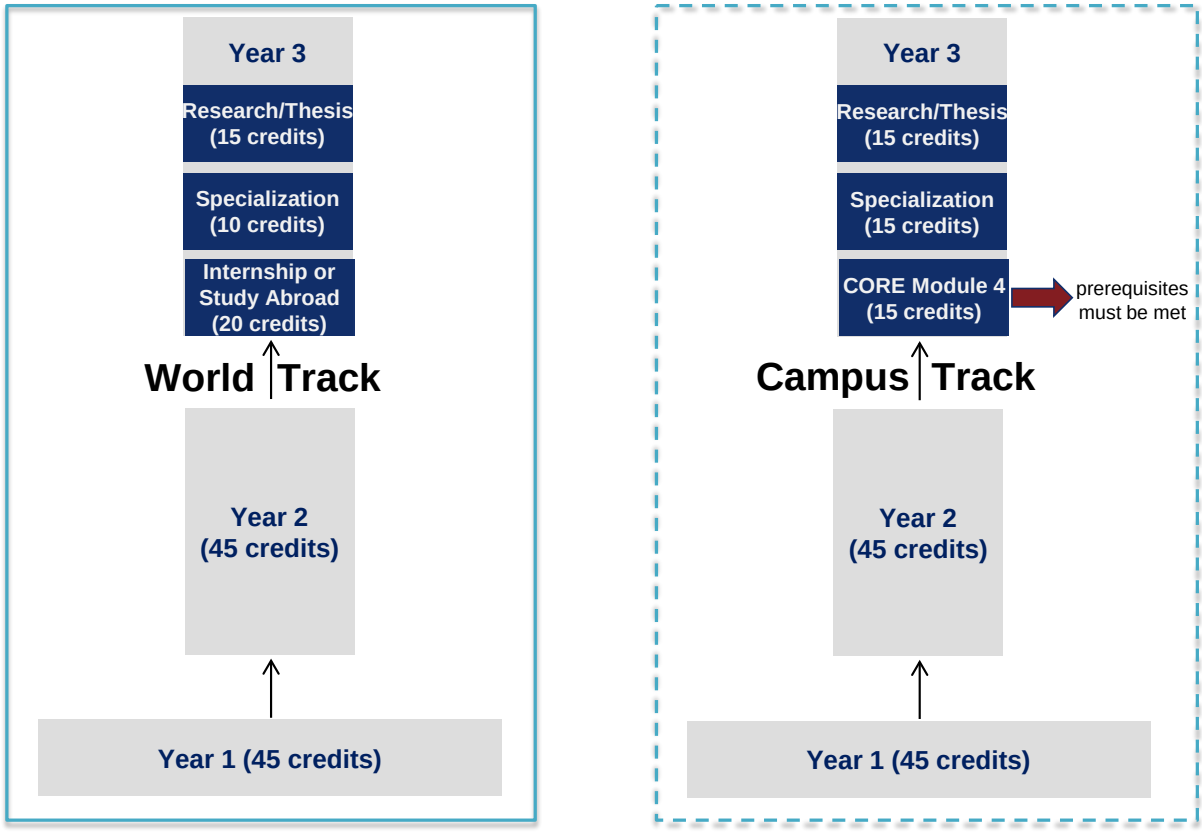


Figure 2: World Track versus Campus Track

Career Advising

Is a mandatory component of the Jacobs University's Advising and Counseling Scheme. Further components are "Academic Advising" and "Psychological Counseling and Intercultural Services". Throughout their studies all students attend a mandatory set of career skills events. The mandatory "Career Skills Advising" prepares all undergraduate students at Jacobs University for the transition from student life to working life as well as for their future career. Skills, knowledge and information which are fundamental for participation in an internship or a semester abroad will be conveyed concurrently. Essential components include information sessions, compulsory workshops on various career-relevant topics as well as participation in the annual Jacobs Career Fair.

All undergraduate students will be automatically registered for "Career Skills Advising". However, every student has to keep track of his/her individual fulfillment of requirements and has to register on CampusNet for all workshops and sessions during the official registration period at the beginning of each semester. An overview of the sequence in which events should be attended is shown in the table below.

CAREER ADVISING For Undergraduate Students matriculated Fall 2018

SEMESTER	1	2	3	4	5	6
MANDATORY BASICS	CSC-INFO Session: "CSC Services" CA01-990000		CSC-INFO Session: "World Track" CA01-990026			
MANDATORY SEMINARS	Both seminars have to be attended in your first or second semester: CSC-APPLICATION TRAINING CA01-990001 CSC-SUCCESS IN STUDIES, CAREER AND LIFE CA01-990031					
MANDATORY ELECTIVE SEMINARS (seminar program subject to availability)			Attend 2 out of several career skills seminars and workshops in your third or forth semester, i.e. ▪ Research & Contacting Employers ▪ Business Etiquette ▪ Presentation Skills ▪ Communication Skills ▪ Grad School Application Training ▪ Self-Management ▪ Time-Management ▪ Decision Making ▪ Preparing for an Interview ▪ Introduction to Project Management ▪ Career Orientation ▪ Working in Germany ▪ Stress Management			
OTHER MANDATORY COMPONENTS				CSC-JACOBS CAREER FAIR in February, on campus CA01-990003		
CAREER RELATED STUDY PROGRAM COMPONENTS					INTERNSHIP (World Track) or STUDY ABROAD (World Track) or CAMPUS TRACK (exceptional)	INTERNSHIP & STUDY ABROAD EVENT

Figure 3: Career Advising

2.3 The Jacobs Track

The Jacobs Track, another stand-alone feature of Jacobs University, runs parallel to the disciplinary CHOICE, CORE, and CAREER modules across all study years and is an integral part of all study programs. It reflects our commitment to an in-depth methodological education, it fosters our transdisciplinary approach, it enhances employability, and equips students with extra skills desirable in your general field of study. Additionally, it integrates essential language courses.

Mathematics, statistics, and other methods courses are offered to all students within a comprehensive Methods Module. This module provides students with general foundations and transferable techniques which are invaluable to follow the study content not only in the study program itself but also in related fields.

The Skills Module equips students with general academic skills which are indispensable for their chosen area of study. These could be, for example, programming, data handling, presentation skills, and academic writing, scientific and experimental skills.

The transdisciplinary Triangle Module offers courses with a focus on at least one of the areas of business, technology and innovation, and societal context. The offerings comprise essential knowledge of these fields for students from other majors as well as problem-based courses that tackle global challenges from different disciplinary backgrounds. Working together with students from different disciplines and cultural backgrounds in these courses broadens the students horizon by crossing the boundaries of traditional disciplines.

Foreign languages are integrated within the Language Module. Communicative skills and foreign language competence foster students intercultural awareness and enhance their employability in a globalized and interconnected world. Jacobs University supports its students in acquiring and improving these skills by offering a variety of language courses at all proficiency levels. Emphasis is put on fostering German language skills, as they are an important prerequisite for students to learn about, explore, and eventually integrate into their host country. Hence, acquiring 10 ECTS credits in German is a requirement for all students. Students who meet the requirements of the German proficiency level (e.g. native speakers) are required to select courses in any other language program offered.

2.4 Modularization of the Intelligent Mobile Systems Program

Year 1
Take the mandatory module listed below and select two further CHOICE modules from a different study area.

Introduction to Intelligent Mobile Systems (CH09-IntroIMS)
This is an introductory module providing a strong theoretical and practical foundation for the core courses in the second year. The key components required to make man-made mobile systems intelligent are sensors, actuators, and algorithms. Students will be given an overview of basic technologies and concepts underlying each of these components. The module will cover the fundamental engineering tools to model mechanical, electrical, and mechatronic systems. A detailed introduction to linear systems theory will be provided, aided by computer simulation. Finally, you will get an introduction to basic electronics and complement your knowledge with lab exercises.

Year 2
Take all three modules or replace one with a CORE module from a different study program.

Intelligent Systems (CO22-IntelSys)
This module teaches you about core technologies and algorithms which endow a man-made system with intelligence. You will learn how machines can process sensor data, including visual data, to perceive and represent their surroundings. Once an environment representation is available, an intelligent machine, such as a robot, can act on and change its environment after deliberate planning. Utilizing its accumulated experience, the machine can learn and adapt its behavior in the future. This module covers all of these aspects and thus gives you an in-depth understanding of machine perception and learning, as well as robotics.

Automation and Control (CO23-AutoControl)
This module builds on top of the material learnt in the "Introduction to IMS" module and covers the general areas of control and automation, including also an introductory course in electronics with an accompanying lab. Topics covered include (but are not limited to): stability analysis, frequency (Laplace) domain modeling of systems, Bode plots, programmable controllers, basic electronics, and sensors and actuators used in industrial automation.

Planning and Optimization (CO24-PlanOpt)
This module is focused on developing the mathematical and engineering skills required to plan for and optimize complex systems such as Intelligent Mobille Systems. It contains two courses on optimization: one focusing on quantitative methods and techniques for effective decision making, and the other dedicated to broader optimization problems, covering topics such as Lagrange multipliers, convex, and nonlinear programming. A third course focuses on planning and decision-making algorithms for autonomous systems.

Some CORE Modules require students to have taken a specific CHOICE Module. Please see the Module Handbook for details regarding pre-requisites.

Year 3
In the 3rd year students follow the World Track by default:

1. **World Track**
   5th Semester
   - Internship / study abroad

   6th Semester
   - Intelligent Mobile Systems Project / Thesis Module

   - Program-specific Specialization Module
     Exemplary course offering:
     - Dynamical Systems and Control
     - Advanced Control
     - Marine Robotics
     - Wireless Localization
     - Applied Nonlinear Control
     - Advanced Robotics
     - Model Order Reduction
     - Embedded Systems Design Lab

2. **Campus Track**
   Students who do not enter the World Track follow the Campus Track.
   5th and 6th Semester
   - Program-specific Project / Thesis Module

   - Program-specific Specialization Module
     (please see World Track for exemplary course offering)

   - Additional CORE Module

2.5 The Bachelor Thesis / Project

This module is a mandatory graduation requirement for all undergraduate students. It consists of two components in the major study program guided by a Jacobs Faculty member:

1. **A Research Project** (5 ECTS)
   and
2. **The Bachelor Thesis** (10 ECTS)

The workload for the project component is about 125 hours and for the thesis component about 250 hours.The title of the thesis will be shown on the transcript.

2.5.1 Aims

Within this module, students apply knowledge they have acquired about their major discipline, skills, and methods to become acquainted with actual research topics, ranging from the identification of suitable (short-term) research projects, preparatory literature searches, the realization of discipline-specific research, and the documentation, discussion, and interpretation of the results. Research results obtained from the Research Project can be embedded in the Bachelor Thesis.

2.5.2 Intended Learning Outcomes

1. Research Project
   This module component consists of a guided research project in the major study program. The well-defined research task must be completed and documented according to the scientific standards in the respective discipline. It involves a high degree of independence, supported by individualized instructor feedback and guidance.
2. Bachelor Thesis
   With their Bachelor Thesis students should demonstrate mastery of the contents and methods of the major specific research field. Furthermore, students should show the ability to analyze and solve a well-defined problem with scientific approaches, a critical reflection of the status quo in scientific literature, and an original development of their own ideas.

Both, the Research Project and the Bachelor Thesis, can also have an inter- or transdisciplinary nature - with the explicit permission of the supervisor.

2.5.3 Supervision

Both module components can be performed with the same Jacobs faculty member, or different ones, the latter in order to allow a broader research experience. Students are required to choose a supervisor, at the latest, by the end of the drop-add period of the semester in which the module component is taken. **The selected supervisor(s) must approve the Project topic and Bachelor Thesis topic before the student starts to work towards the module component.** The respective study program chairs will assist in the search for prospective supervisor(s).

2.5.4 Registration

World Track students register for both components, at the earliest, in their 6th semester.
Campus Track students register for the Project component in the 5th and for the Bachelor Thesis component, at the earliest, in their 6th semester.

The registrations must be made before the end of the respective drop/add periods.

Later enrolment is possible for those students pursuing a second major or those who graduate late for other reasons. These students perform their (second) thesis earliest in the 7th semester of their studies. They have to contact the Student Records Office for individual registration.

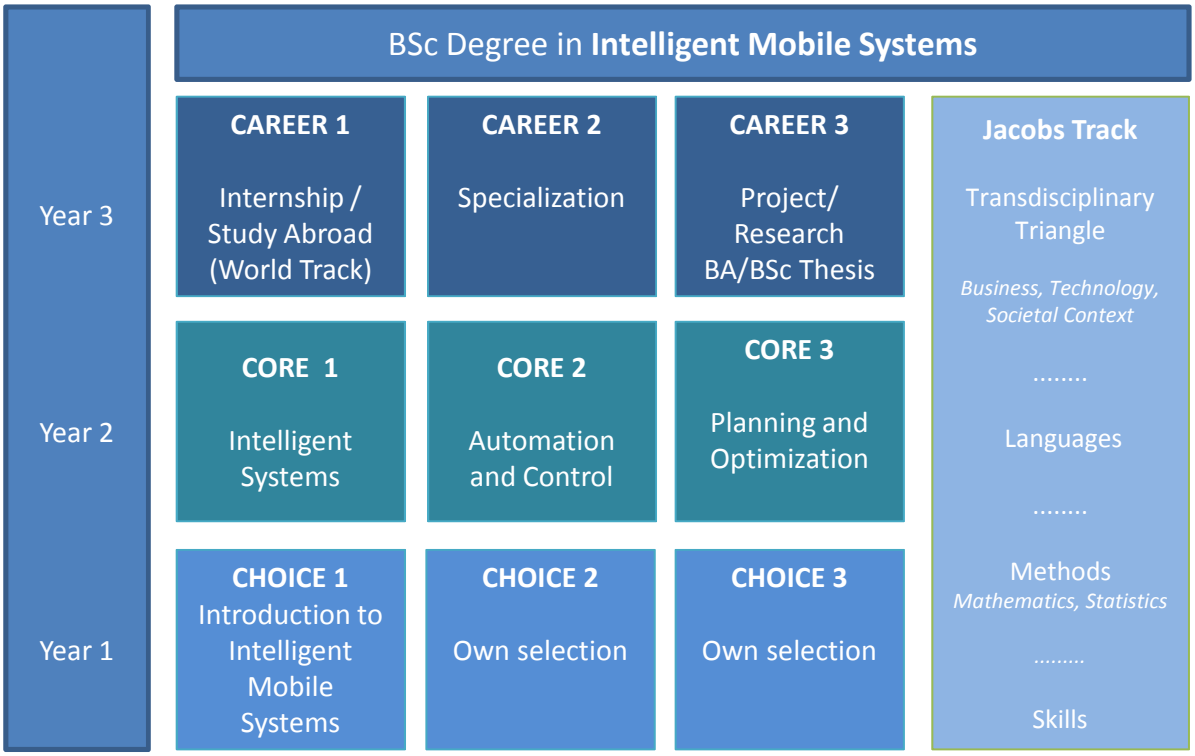
Students are allowed to extend their thesis related work into the intersession or summer break upon approval of the thesis supervisor and Student Records. Students are not allowed to register for different Bachelor Thesis courses in the same semester.

2.5.5 Formal Regulations for the Bachelor Thesis

- Timing
  The Thesis work has to be generated within the semester of registration. The semester period has 14 weeks.
- Extent
  The document must be between 15-25 pages in length, including references, but excluding appendices or supporting information. Deviations in length and format can be determined within individual study programs and should be communicated to all registered students by the study program chair.
- Cover page
  The cover page must show the title of the Bachelor Thesis, the university's name, the month and year of submission, the name of the student and the name of the supervisor.
- Statutory Declaration
  Each Bachelor Thesis must include a statutory declaration signed by the student confirming it is their own independent work and that it has not been submitted elsewhere. The respective form can be found on the Student Records Office website.
- Submission
  The Bachelor Thesis must be submitted as a hard copy (pdf-file) to the supervisor and additionally to the Student Records Office via online form on the Student Records Office website.

  Deadline for submission of the Bachelor Thesis is May 15 (unless specified otherwise by the Student Records Office).

2.6 Structure



YEAR 1 *Take three CHOICE modules, two free selection*

YEAR 2 *Take three CORE modules, one CORE module can be substituted by a CORE module from a second study program to pursue a minor*

YEAR 3 *Alternatively Campus Track with a 4th CORE module instead of internship/study abroad module*

Figure 4: Intelligent Mobile Systems Module Structure

3 Appendix 1a/1b: Mandatory Module and Examination Plans for World Track and Campus Track

Jacobs University Bremen reserves the right to substitute courses by replacements and/or reduce the number of mandatory/mandatory elective courses offered.

4 Appendix 2: Course Data for Program-Specific CHOICE and CORE Courses

All course data stated in the appendix is based on the previous study year and subject to change.

Appendix 1a - Mandatory Module and Examination Plan for World Track

Intelligent Mobile Systems – World Track

Matriculation Fall 2018

	Program-Specific Modules	Type	Status[1]	Semester	Credits		Jacobs Track Modules (General Education)	Type	Status[1]	Semester	Credits
Year 1 - CHOICE					**45**						**20**
Take the mandatory CHOICE module listed below, this is a requirement for the IMS program.											
CH09-IntroIMS	**Module: Introduction to Intelligent Mobile Systems**		**m**		**15**		**JT-ME-MethodsMath**	**Module: Methods / Mathematics**		**m**		**7,5**
CH09-320103	General Intelligent Mobile Systems I	Lecture	m	1	5		JT-ME-120103	Calculus I	Lecture	m	1	2,5
CH09-320113	Introduction to Intelligent Mobile Systems Lab I	Lab	m	1	2,5		JT-ME-120104	Calculus II	Lecture	m	1	2,5
CH09-320104	General Intelligent Mobile Systems II	Lecture	m	2	5		JT-ME-120122	Foundations of Linear Algebra I	Lecture	m	2	2,5
CH09-320114	Introduction to Intelligent Mobile Systems Lab II	Lab	m	2	2,5		**JT-SK-Skills**	**Module: Skills**		**m**		**5**
							JT-SK-320111	Programming in C I	Lecture	m	1	2,5
	Module: CHOICE (own selection)		**e**	**1/2**	**30**		JT-SK-320112	Programming in C II	Lecture	m	2	2,5
Students take two further CHOICE modules from those offered for all other study programs. [2]							**JT-TA-TriArea**	**Module: Triangle Area**		**m**		**2,5**
								Take one course from the triangle (BUSINESS, TECHNOLOGY & INNOVATION, SOCIETAL CONTEXT) area. Each counts 2,5 ECTS [3]		me	1/2	2,5
							JT-LA-Language	**Module: Language**		**m**		**5**
								Take two German courses (2,5 ECTS each). Native German speakers take courses in another offered language	Seminar	me	1/2	5
							CA01-CarAdv	**Career Advising**[4]		**m**		
Year 2 - CORE					**45**							**20**
Take all three modules or replace one with a CORE module from a different study program. [2]												
CO22-IntelSys	**Module: Intelligent Systems**		**me**		**15**		**JT-ME-MethodsMath**	**Module: Methods / Mathematics**		**m**		**7,5**
CO22-320671	Computer Vision	Lecture	m	3	5		JT-ME-120201	Elements of Probability	Lecture	m	3	2,5
CO22-320311	Robotics	Lecture	m	4	5		JT-ME-120113	Foundations of Linear Algebra II	Lecture	m	3	2,5
CO22-320372	Machine Learning	Lecture	m	4	5		JT-ME-120202	Numerical Methods I	Lecture	m	4	2,5
CO23-AutoControl	**Module: Automation and Control**		**me**		**15**		**JT-TA-TriArea**	**Module: Triangle Area**		**m**		**7,5**
CO23-320301	Control Systems	Lecture	m	3	5			Take three courses from the triangle (BUSINESS, TECHNOLOGY & INNOVATION, SOCIETAL CONTEXT) area. Each counts 2,5 ECTS [3]		me	3/4	7,5
CO26-300312	Embedded Systems Lab	Lab	m	3	5							
CO23-320203	Automation	Lecture	m	4	5							
CO24-PlanOpt	**Module: Planning and Optimization**		**me**		**15**		**JT-LA-Language**	**Module: Language**		**m**		**5**
CO29-080202	Operations Research	Lecture	m	3	5			Take two German courses (2,5 ECTS each). Native German speakers take courses in another offered language	Seminar	me	3/4	5
CO24-300491	Optimization	Lecture	m	4	5							
CO24-320521	Artificial Intelligence	Lecture	m	3	5		**CA01-CarAdv**	**Career Advising**[4]		**m**		
Year 3 - CAREER					**45**							**5**
CA02 / CA03	**Module: Internship / Study Abroad**		**m**	**5**	**20**		**JT-TA-TriArea**	**Module: Triangle Area**		**m**		**5**
								Take two courses from the triangle (BUSINESS, TECHNOLOGY & INNOVATION, SOCIETAL CONTEXT) area. Each counts 2,5 ECTS [3]		me	6	5
CA09-IMS	**Module: Project/Thesis IMS**		**m**		**15**		**CA01-CarAdv**	**Career Advising**[4]		**m**		
CA09-320303	Project IMS		m	6	5							
CA09-320304	Thesis IMS		m	6	10							
CA-S-IMS	**Module: Specialization Area IMS**		**m**		**10**							
	Take 10 ECTS of specialization courses [2]		me	5/6	10							
Total ECTS												**180**

[1] Status (m = mandatory, e = elective, me = mandatory elective)

[2] For a full listing of all CHOICE / CORE / CAREER / Jacobs Track modules please consult the **CampusNet online catalogue** and / or the module handbook (on our website).

[3] You are required to take six Triangle Area courses in total. Select two from each of the three triangle areas (BUSINESS, TECHNOLOGY & INNOVATION, SOCIETAL CONTEXT).

[4] Mandatory component of the Jacobs University's Counseling and Advising Scheme.

Appendix 1b - Mandatory Module and Examination Plan for Campus Track

Intelligent Mobile Systems – Campus Track

Matriculation Fall 2018

	Program-Specific Modules	Type	Status[1]	Semester	Credits		Jacobs Track Modules (General Education)	Type	Status[1]	Semester	Credits
Year 1 - CHOICE					**45**						**20**
Take the mandatory CHOICE module listed below, this is a requirement for the IMS program.											
CH09-IntroIMS	**Module: Introduction to Intelligent Mobile Systems**		**m**		**15**		**JT-ME-MethodsMath**	**Module: Methods / Mathematics**		**m**		**7,5**
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CH09-320104	General Intelligent Mobile Systems II	Lecture	m	2	5		JT-ME-120122	Foundations of Linear Algebra I	Lecture	m	2	2,5
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							JT-SK-320111	Programming in C I	Lecture	m	1	2,5
	Module: CHOICE (own selection)		**e**	**1/2**	**30**		JT-SK-320112	Programming in C II	Lecture	m	2	2,5
Students take two further CHOICE modules from those offered for all other study programs. [2]							**JT-TA-TriArea**	**Module: Triangle Area**		**m**		**2,5**
								Take one course from the triangle (BUSINESS, TECHNOLOGY & INNOVATION, SOCIETAL CONTEXT) area. Each counts 2,5 ECTS [3]		me	1/2	2,5
							JT-LA-Language	**Module: Language**		**m**		**5**
								Take two German courses (2,5 ECTS each). Native German speakers take courses in another offered language	Seminar	me	1/2	5
							CA01-CarAdv	**Career Advising**[4]		**m**		
Year 2 - CORE					**45**							**20**
Take all three modules or replace one with a CORE module from a different study program. [2]												
CO22-IntelSys	**Module: Intelligent Systems**		**me**		**15**		**JT-ME-MethodsMath**	**Module: Methods / Mathematics**		**m**		**7,5**
CO22-320671	Computer Vision	Lecture	m	3	5		JT-ME-120201	Elements of Probability	Lecture	m	3	2,5
CO22-320311	Robotics	Lecture	m	4	5		JT-ME-120113	Foundations of Linear Algebra II	Lecture	m	3	2,5
CO22-320372	Machine Learning	Lecture	m	4	5		JT-ME-120202	Numerical Methods I	Lecture	m	4	2,5
CO23-AutoControl	**Module: Automation and Control**		**me**		**15**		**JT-TA-TriArea**	**Module: Triangle Area**		**m**		**7,5**
CO23-320301	Control Systems	Lecture	m	3	5			Take three courses from the triangle (BUSINESS, TECHNOLOGY & INNOVATION, SOCIETAL CONTEXT) area. Each counts 2,5 ECTS [3]		me	3/4	7,5
CO26-300312	Embedded Systems Lab	Lab	m	3	5							
CO23-320203	Automation	Lecture	m	4	5							
CO24-PlanOpt	**Module: Planning and Optimization**		**me**		**15**		**JT-LA-Language**	**Module: Language**		**m**		**5**
CO29-080202	Operations Research	Lecture	m	3	5			Take two German courses (2,5 ECTS each). Native German speakers take courses in another offered language	Seminar	me	3/4	5
CO24-300491	Optimization	Lecture	m	4	5							
CO24-320521	Artificial Intelligence	Lecture	m	3	5		**CA01-CarAdv**	**Career Advising**[4]		**m**		
Year 3 - CAREER					**45**							**5**
COXX	**Module: Additional (4th) CORE module**		**m**	**5/6**	**15**		**JT-TA-TriArea**	**Module: Triangle Area**		**m**		**5**
								Take two courses from the triangle (BUSINESS, TECHNOLOGY & INNOVATION, SOCIETAL CONTEXT) area. Each counts 2,5 ECTS [3]		me	5	5
CA09-IMS	**Module: Project/Thesis IMS**		**m**		**15**		**CA01-CarAdv**	**Career Advising**[4]		**m**		
CA09-320303	Project IMS		m	5	5							
CA09-320304	Thesis IMS		m	6	10							
CA-S-IMS	**Module: Specialization Area IMS**		**m**		**15**							
	Take 15 ECTS of specialization courses [2]		me	5/6	15							
Total ECTS												**180**

[1] Status (m = mandatory, e = elective, me = mandatory elective)

[2] For a full listing of all CHOICE / CORE / CAREER / Jacobs Track modules please consult the **CampusNet online catalogue** and / or the module handbook (on our website).

[3] You are required to take six Triangle Area courses in total. Select two from each of the three triangle areas (BUSINESS, TECHNOLOGY & INNOVATION, SOCIETAL CONTEXT).

[4] Mandatory component of the Jacobs University's Counseling and Advising Scheme.

Appendix 2 - Course Data

Course Name	***Course No***	***ECTS***
General Intelligent Mobile Systems I	CH09-320103	5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CH09-IntroIMS Introduction to Intelligent Mobile Systems	Contact Time: 35,00 Private Study: 90,00	Bachelor 1st Year CHOICE

Course Description / Content / Aims

This course teaches the essentials of spatial geometry, kinematics, and modeling in the context of intelligent mobile systems. The course starts with a review of 3D vectors and their products, and then covers 3D rotation representations, including the Direction Cosines Matrix (DCM), Euler angle sequences, axis-angle, quaternions, and the exponential mapping. Subsequently, general 3D transforms are studied with applications to the specification and visualization of robot geometry. In parallel, students also learn to use Matlab for symbolic algebra and programming. The last part of the course deals with particle and rigid body kinematics using the general screw-theory formulation. In kinematics, there is an emphasis on examples relevant to automobiles and to other common mobile platforms.

Methods of Assessment

Name	Weighting
Active Participation	5%
Final Exam	20%
Home Work	60%
Midterm Exam	15%

Course Name	***Course No***	***ECTS***
General Intelligent Mobile Systems II	CH09-320104	5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CH09-IntroIMS Introduction to Intelligent Mobile Systems	Contact Time: 35,00 Private Study: 90,00	Bachelor 1st Year CHOICE

Course Description / Content / Aims

The course offers an introduction to modeling, and design of linear control systems in terms of ordinary differential equations (ODEs). Students learn how to analyze and solve systems of ODEs using state and frequency space methods. Concepts covered include time and frequency response, stability, and steady-state errors. The first part of the course culminates with the detailed design of the famous PID controller.

Methods of Assessment

Name	Weighting
Final Exam	30%
Midterm Exam	30%
Test/ Reports	40%

Appendix 2 - Course Data

Course Name	***Course No***	***ECTS***
Introduction to Intelligent Mobile Systems Lab I	CH09-320113	2,5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CH09-IntroIMS Introduction to Intelligent Mobile Systems	Contact Time: 25,50 Private Study: 37,00	Bachelor 1st Year CHOICE

Course Description / Content / Aims

This lab accompanies the lecture course “General Intelligent Mobile Systems 1.” Employing a high-level systems approach, the lab teaches the student how to interface a microcontroller to commonly used sensors and actuators. A comprehensive introduction to programming the popular open-source Arduino board is given in the lab. It is recommended that this lab is taken after a lab on programming in C.

Methods of Assessment

Name	Weighting
Final Project	20%
Oral Quizz(es)	80%

Course Name	***Course No***	***ECTS***
Introduction to Intelligent Mobile Systems Lab II	CH09-320114	2,5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CH09-IntroIMS Introduction to Intelligent Mobile Systems	Contact Time: 25,50 Private Study: 37,00	Bachelor 1st Year CHOICE

Course Description / Content / Aims

This laboratory course offers intense practical experience in the analysis and the design of linear control systems. Students learn how to use Matlab and Simulink tools to investigate the system behavior and to study its time and frequency response. They learn how to design feedback controls, and to interpret and take care of steady-state erros. The lab is a strongly interactive course. Students need to prepare for the sessions and evaluate their results in written reports.

Methods of Assessment

Name	Weighting
Lab Performance	100%

Appendix 2 - Course Data

Course Name	***Course No***	***ECTS***
Robotics	CO22-320311	5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CO22-IntelSys Intelligent Systems	Contact Time: 35,00 Private Study: 90,00	Bachelor 2nd Year CORE

Course Description / Content / Aims

The course gives an introduction to robotics with a particular focus on (intelligent) mobile robots. The lecture covers the according core methods and technologies to enable autonomous or semi-autonomous operations of mobile platforms. Examples of related topics include

- actuators and their components, i.e., electrical motors, gears, feedback sensors
- locomotion, especially different drive units, their physical implementation and their kinematics
- robot control architectures
- localization sensors and methods
- range sensing and processing
- map representations
- core principles of Simultaneous Localization and Mapping (SLAM)
- sensor data registration
- place recognition
- obstacle avoidance and introduction to path-planning

Methods of Assessment

Name	Weighting
Final Exam	45%
Home Work	20%
Midterm Exam	35%

Course Name	***Course No***	***ECTS***
Machine Learning	CO22-320372	5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CO22-IntelSys Intelligent Systems	Contact Time: 35,00 Private Study: 90,00	Bachelor 2nd Year CORE

Course Description / Content / Aims

Machine learning (ML) is about algorithms which are fed with (large quantities of) real-world data, and which return a compressed "model" of the data. An example is the "world model" of a robot: the input data are sensor data streams, from which the robot learns a model of its environment -- needed, for instance, for navigation. Another example is a spoken language model: the input data are speech recordings, from which ML methods build a model of spoken English -- useful, for instance, in automated speech recognition systems. There exist many formalisms in which such models can be cast, and an equally large diversity of learning algorithms. However, there is a relatively small number of fundamental challenges which are common to all of these formalisms and algorithms. The lecture introduces such fundamental concepts and illustrates them with a choice of elementary model formalisms (linear classifiers and regressors, radial basis function networks, clustering, neural networks, hidden Markov models). Furthermore, the lecture also provides a refresher of required mathematical material from probability theory and linear algebra.

Methods of Assessment

Name	Weighting
Final Exam	100%

Appendix 2 - Course Data

Course Name	***Course No***	***ECTS***
Computer Vision	CO22-320671	5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CO22-IntelSys Intelligent Systems	Contact Time: 35,00 Private Study: 90,00	Bachelor 2nd Year CORE

Course Description / Content / Aims

Computer Vision algorithms are used in a variety of real-world applications, such as surveillance and object tracking, 3D model building (photogrammetry), and object recognition. Apart from their visual appeal, these algorithms also represent elegant applications of linear algebra and optimization techniques. Topics covered in this course include a recapitulation of relevant linear algebra, introduction to face-recognition, camera calibration, stitched panoramas, edge and blob visual features, structure from motion, color-spaces, segmentation, basic 3D point-cloud processing, and an introduction to object-recognition. It is assumed that the student can program in C and Matlab.

Methods of Assessment

Name	Weighting
Final Exam	20%
Home Work	60%
Midterm Exam	20%

Course Name	***Course No***	***ECTS***
Automation	CO23-320203	5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CO23-AutoControl Automation and Control	Contact Time: 35,00 Private Study: 90,00	Bachelor 2nd Year CORE

Course Description / Content / Aims

Automation is the application of technology to monitor and control the production and delivery of products and services. The field of Automation has considerable overlap with the fields of Control and Robotics. However, the distinguishing aspect is the emphasis on industrial application, along with the concomitant focus on robustness and efficiency under factory conditions.

Topics covered in this course include: an introduction to industrial sensors used in process control, operational principles of industrial motors and drives, an introduction to Programmable Logic Controllers (PLC), programming PLCs, fuzzy logic and controllers, and artificial intelligence (AI) concepts used in automation.

Appendix 2 - Course Data

Course Name	***Course No***	***ECTS***
Control Systems	CO23-320301	5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CO23-AutoControl Automation and Control	Contact Time: 35,00 Private Study: 90,00	Bachelor 2nd Year CORE

Course Description / Content / Aims

This course offers a systematic walk through the fundamentals of control theory for linear systems. Building on what has been done in General IMS II, new concepts, perspectives and skills will be introduced and discussed. In particular, this includes (different) state space representations, reduction techniques for larger block diagrams, the BIBO perspective on stability, the role of disturbances, and the related question of sensitivity. We will also study new approaches to improve the response a given system via lead and lag compensators including feedback techniques. The major new analytic tools will be the Nyquist plot and techniques based on it.

Methods of Assessment

Name	Weighting
2 Exams	60%
Home Work	40%

Course Name	***Course No***	***ECTS***
Embedded Systems Lab	CO26-300312	5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CO23-AutoControl Automation and Control	Contact Time: 51,00 Private Study: 74,00	Bachelor 2nd Year CORE

Course Description / Content / Aims

Microcontrollers are core components of modern devices. Designed to handle sensor data and to control actuators, equipped with considerable computational power at relatively low cost and with limited power consumption, they are enablers of our rapidly growing technological environment, in particular, when it comes to mobile systems. We are going to use the AVR/ARM processor based on the RISC-architecture which becomes more and more popular used in smartphones, tablets and various forms of embedded systems due to its small size and low power consumption. The course provides a sound introduction to these almost ubiquitous devices and guides the students in an application-oriented manner through a series of design tasks. The list of topics includes the basic architecture of a microcontroller with its ALU, timer/counter, memory, I/O interface; the concepts of working registers, interrupt vectors, program counter etc.; necessary programming tools like embedded C, and assembler, as well as several implementation problems like reading/controlling various sensors/actuators, processing internal/external interrupts, generation of PWM signals, and AD/DA conversion. At the end of the course, students should be able to develop and implement their own solutions for typical applications on AVR/ARM based microcontrollers

Methods of Assessment

Name	Weighting
Examination	50%
Lab Performance	25%
Lab Reports	25%

Appendix 2 - Course Data

Course Name	***Course No***	***ECTS***
Optimization	CO24-300491	5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CO24-PlanOpt Planning and Optimization	Contact Time: 35,00 Private Study: 90,00	Bachelor 2nd Year CORE

Course Description / Content / Aims

Optimization is a key step in the design of systems and processes. The course starts with a review of multidimensional calculus applied to unconstrained problems. It then focuses on equality and inequality constrained cases from the perspective of the Lagrange formalism and introduces the KKT theorem for convex problems. Linear and quadratic programming methods are covered as important application oriented examples. Special emphasis is given to duality. The last part of the course is devoted to deterministic and probabilistic search methods introducing the ideas of genetic algorithms. The course comes with a wide variety of examples including applications in electronics, decision making, machine learning, and optimal control

Methods of Assessment

Name	Weighting
Final Exam	30%
Home Work	40%
Midterm Exam	30%

Course Name	***Course No***	***ECTS***
Artificial Intelligence	CO24-320331	5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CO24-PlanOpt Planning and Optimization	Contact Time: 35,00 Private Study: 90,00	CORE

Course Description / Content / Aims

Artificial intelligence is an important sub-discipline of Computer Science that deals with technologies to carry out tasks in an automated way that are usually associated with intelligence. AI methods have a significant application potential as there is an increasing interest and need to generate artificial systems that can carry out complex missions in unstructured environments without permanent human supervision. The course teaches a selection of the most important methods in AI. In addition to general purpose techniques and algorithms, it also includes aspects of methods that are especially targeted for physical systems like intelligent mobile robots or autonomous cars.

Methods of Assessment

Name	Weighting
Active Participation	10%
Final Exam	70%
Home Work	20%

Appendix 2 - Course Data

Course Name	***Course No***	***ECTS***
Operations Research	CO29-080202	5
Module Affiliation	***Workload (hrs / sem)***	***Level***
CO29-ProcessEng Process Engineering CO24-PlanOpt Planning and Optimization	Contact Time: 35,00 Private Study: 90,00	Bachelor 2nd Year CORE

Course Description / Content / Aims

Operations research is an interdisciplinary mathematical science that focuses on the effective use of technology by organizations. By employing techniques such as mathematical modeling, statistical analysis, and mathematical optimization, operations research ?nds optimal or near-optimal solutions to complex decision-making problems. Operations Research is concerned with determining the maximum (of pro?t, performance, or yield) or the minimum (of loss, risk, or cost) of some real-world objective. This course introduces students to modelling of decision problems and the use of quantitative methods and techniques for effective decision-making. Familiarity with a programming language (e.g., Python, C++, etc.) is desirable for this course.

Methods of Assessment

Name	Weighting
Final Exam	40%
Home Work	30%
Midterm Exam	30%