



JACOBS
UNIVERSITY



Study Program Handbook

Intelligent Mobile Systems

Bachelor of Science

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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

Knowledge and Understanding

After finishing this program, the student will have knowledge and understanding of

- Kinematics and dynamics of multi-body systems
- Linear and nonlinear control systems
- Basic electronics, operational principles of motors and drives

- Machine Learning algorithms and techniques for pattern-recognition, classification, and decision-making under uncertainty
- Computer Vision algorithms for inferring 3D information from camera images, and for object recognition and localization
- Robotic manipulators and mobile robots
- Simultaneous Localization and Mapping (SLAM) algorithms
- Motion planning techniques in robotics
- Relevant sensors, signal-processing, and probabilistic estimation techniques
- Analytical and numerical optimization in continuous and discrete domains

Ability

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

- Model common mechanical and electrical systems which are part of intelligent mobile systems
- Design control systems and tune their performance
- Design and program image-processing and computer-vision algorithms
- Select and implement classification and pattern recognition algorithms for real-world problems
- Design robots 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
- Work in a team to develop and integrate different components into a functioning system

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 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 possess the ability to acquire knowledge rapidly, to assess information and to evaluate new concepts critically;
- graduates have communicative competences which allow them to present themselves and their ideas and to negotiate successfully;

- graduates are familiar with business-related processes and management skills and are able to manage projects efficiently and independently.

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 in negotiating and mediating between different points of view;
- graduates can rely on basic civic knowledge and have an understanding for ethical reasoning; students are familiar with the requirements for taking on responsibility.

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 coordinator:

Dr. Kaustubh Pathak
Professor of Electrical Engineering and Computer Science
Email: k.pathak@jacobs-university.de
Telephone: +49 421 200-3512

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:

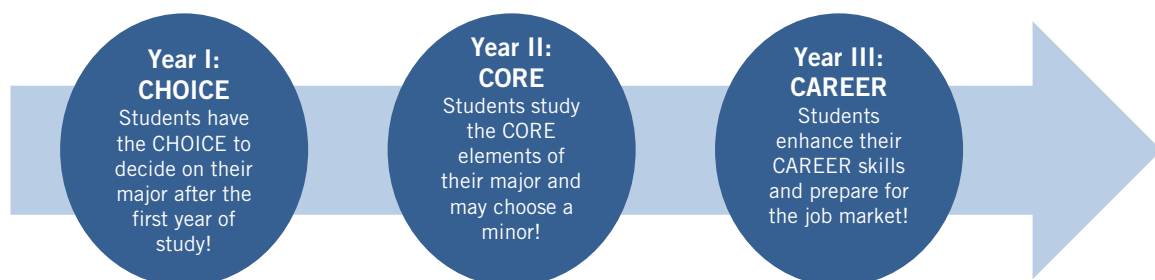


Figure 1: The Jacobs University 3C-Model

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 University's 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. For more 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 Union's 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.

All students attend a mandatory set of career skills courses and events throughout their studies. These equip them with necessary skills for their 5th semester and their future career.

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

2.4.1 Content

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 Mobile 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:

- Advanced Machine Perception
- Advanced Control
- Advanced Digital Design
- Wireless Localization
- Autonomous Systems
- Advanced Robotics
- Model Order Reduction
- Embedded Systems Design Lab
- Advanced Digital Design
- Operating Systems
- Computer Networks
- Computer Architecture
- Transportation and Storage Systems
- Modeling Dynamics in Industrial Systems

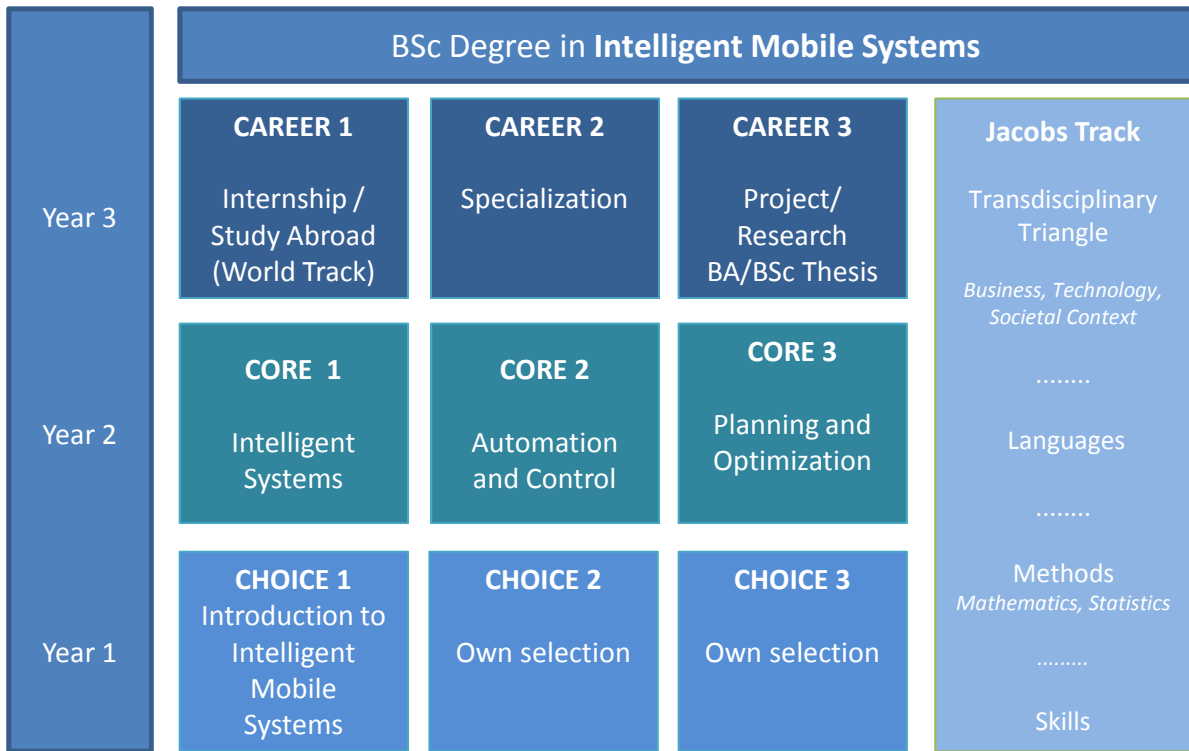
2. Campus Track

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

2.4.2 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 2: Intelligent Mobile Systems Module Structure

3 Appendix 1a/1b: Mandatory Course 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

Appendix 1a - Mandatory Course Plan for World Track

Program-Specific Modules						Jacobs Track Modules (General Education)								
Type	Status ¹	Semester	Credits	Type	Status ¹	Semester	Credits	Type	Status ¹	Semester	Credits			
Year 1 - CHOICE						Year 1 - CHOICE					45	20		
<i>Take the mandatory CHOICE module listed below, this is a requirement for the IMS program.</i>														
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: CHOICE (own selection)						e	1/2	30	Module: Skills			m	5	
<i>Students take two further CHOICE modules from those offered for all other study programs. ²</i>														
Year 2 - CORE						Year 2 - CORE					45	20		
<i>Take all three modules or replace one with a CORE module from a different study program. ²</i>														
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	4	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						
CO26-300312	Embedded Systems Lab	Lab	m	4	5			JT-LA-Language						
CO23-320203	Automation	Lecture	m	4	5			Module: Language			m	5		
CO24-PlanOpt	Module: Planning and Optimization			me			15	Take two German courses (2,5 ECTS each). Native German speakers take courses in another offered language						
CO29-080202	Operations Research	Lecture	m	3	5			me						
CO24-300491	Optimization	Lecture	m	4	5			3/4						
CO24-320521	Autonomous Systems	Lecture	m	3	5			5						
Year 3 - CAREER						Year 3 - CAREER					45	5		
CA02 / CA03	Module: Internship / Study Abroad			m			5	20	JT-TA-TriArea	Module: Triangle Area			m	5
CA01-CarSkills	Module: Career Skills			m										
CA09-IMS	Module: Project/Thesis IMS			m			15	Take two courses from the triangle (BUSINESS, TECHNOLOGY & INNOVATION, SOCIETAL CONTEXT) area. Each counts 2,5 ECTS ³						
CA09-320303	Project IMS	m	m	6	5			me						
CA09-320304	Thesis IMS	m	m	6	10			6						
CA-S-IMS	Module: Specialization Area IMS			m			10							
Take four specialization courses (2,5 ECTS each) ²						me	5/6	10				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).

Appendix 1b - Mandatory Course Plan for Campus Track

Program-Specific Modules						Jacobs Track Modules (General Education)						
	Type	Status ¹	Semester	Credits		Type	Status ¹	Semester	Credits			
Year 1 - CHOICE						Year 1 - CHOICE						
45						20						
<i>Take the mandatory CHOICE module listed below, this is a requirement for the IMS program.</i>												
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							
Module: CHOICE (own selection)			e	1/2	30	JT-SK-Skills	Module: Skills		m	5		
<i>Students take two further CHOICE modules from those offered for all other study programs.²</i>						JT-SK-320111	Programming in C I	Lecture	m	1	2,5	
						JT-SK-320112	Programming in C II	Lecture	m	2	2,5	
						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).			Seminar	me	1/2	5
						Native German speakers take courses in another offered language						
Year 2 - CORE						Year 2 - CORE						
45						20						
<i>Take all three modules or replace one with a CORE module from a different study program.²</i>												
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	4	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	4	5							
CO23-320203	Automation	Lecture	m	4	5	JT-LA-Language	Module: Language		m	5		
CO24-PlanOpt	Module: Planning and Optimization		me	15		Take two German courses (2,5 ECTS each).			Seminar	me	3/4	5
CO29-080202	Operations Research	Lecture	m	3	5	Native German speakers take courses in another offered language						
CO24-300491	Optimization	Lecture	m	4	5							
CO24-320521	Autonomous Systems	Lecture	m	3	5							
Year 3 - CAREER						Year 3 - CAREER						
45						5						
COXX	Module: Additional (4th) CORE module		m	5/6	15	JT-TA-TriArea	Module: Triangle Area		m	5		
CA01-CarSkills	Module: Career Skills		m			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								
CA09-320303	Project IMS		m	5	5							
CA09-320304	Thesis IMS		m	6	10							
CA-S-IMS	Module: Specialization Area IMS		m	15								
Take six specialization courses (2,5 ECTS each) ²			me	5/6	15							
Total ECTS						Total ECTS						
180						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).