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 Study and Examination Plan (Chapter 6).

Upon graduation, students in this program will receive a Bachelor of Science (BSc) degree with a scope of 180 ECTS (for specifics see Chapter 6 of this handbook).

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1 Program Overview

1.1 Concept

1.1.1 The Jacobs University Educational Concept

Jacobs University aims to educate students for both an academic and a professional career by emphasizing four core objectives: academic quality, self-development/personal growth, internationality and the ability to succeed in the working world (employability). Hence, study programs at Jacobs University offer a comprehensive, structured approach to prepare students for graduate education as well as career success by combining disciplinary depth and interdisciplinary breadth with supplemental skills education and extra-curricular elements.

In this context, it is Jacobs University's aim to educate talented young people from all over the world, regardless of nationality, religion, and material circumstances, to become citizens of the world who are able to take responsible roles for the democratic, peaceful, and sustainable development of the societies in which they live. This is achieved through a high-quality teaching as well as manageable study loads and supportive study conditions. Study programs and related study abroad programs convey academic knowledge as well as the ability to interact positively with other individuals and groups in culturally diverse environments. The ability to succeed in the working world is a core objective for all study programs at Jacobs University, both in terms of actual disciplinary subject matter and also to the social skills and intercultural competence. Study-program-specific modules and additional specializations provide the necessary depth, interdisciplinary offerings and the minor option provide breadth while the university-wide general foundation and methods modules, mandatory German language requirements, and an extended internship period strengthen the employability of students. The concept of living and learning together on an international campus with many cultural and social activities supplements students' education. In addition, Jacobs University offers professional advising and counseling.

Jacobs University's educational concept is highly regarded both nationally and internationally. While the university has consistently achieved top marks over the last decade in Germany's most comprehensive and detailed university ranking by the Center for Higher Education (CHE), it has also been listed by the renowned Times Higher Education (THE) magazine as one of the top 300 universities worldwide in 2018. The THE ranking is considered as one of the most widely observed university rankings. It is based on five major indicators: research, teaching, research impact, international orientation, and the volume of research income from industry.

1.1.2 Program Concept

Robotics and intelligent systems are more and more present in everyday life. Artificial intelligence and Machine learning are at the forefront of today's interconnected society. Automation with some sort of embedded intelligence is now the norm rather than the exception. This program covers engineering methods and technologies that are relevant for freeing artificial mobile systems from permanent human supervision, to enable systems to perform autonomous intelligent operations. Application areas include the automotive and transport industries, robotics and automation, communication technologies, marine technology, and logistics. Hands-on experience with technical systems and methods is provided in first-class labs across the entire program.

During the first year, the foundations of the program are laid out, with programming courses, algorithms, and a comprehensive introduction to robotics and intelligent systems. The second year represents the core of the educational offering of the program, with courses focused on Robotics Systems (Robotics, Machine Learning), Automation and Control (Automation, Embedded Systems, Control Systems), and Intelligent Systems (Computer Vision, Artificial Intelligence). The RIS Lab and RIS project will complement the theoretical education, with use of both robotics simulators and real systems. During the third year, based on their specific interests and career goals, students can choose a variety of specialization courses to complement the core education in depth or breadth. Because robotics science is rooted in mathematics, students will take math methods modules covering calculus, linear algebra, probability theory, and numerical methods or discrete mathematics.

The job market for roboticists and experts in intelligent systems is increasing continuously, and all indications point to the growth of the sector in the near future. Because of the rapid changes in the field, it is important to focus the education on fundamental principles and in subfields of promising future relevance. Cross-disciplinary breadth and flexibility, as well as social and work organization skills are increasingly important. The minor option allows the combination of the education in robotics and intelligent systems with a different discipline, facilitating a cross-disciplinary specialization. The academic qualifications and personal profiles for academic and industrial careers differ. Jacobs University's Intelligent Mobile Systems program responds to the needs in both areas by offering a core Robotics and Intelligent Systems track designed for students who plan to join the industry, work in / found a start-up, or join graduate programs. A minor track allows students to obtain basic skills in specific application domains, which makes them well suited to work in specific industrial sectors.

1.2 Specific Advantages of Intelligent Mobile Systems at Jacobs University

- Intelligent Mobile Systems is positioned in the focus area Mobility. It has been designed with an interdisciplinary approach, incorporating concepts from various engineering disciplines such as Computer Science, Electrical Engineering, Mechanical Engineering, and Logistics.
- Although programs on Automation, Robotics, and Mechatronics exist in other universities, what makes Intelligent Mobile Systems 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, and Computer Vision.
- The Intelligent Mobile Systems program is geared toward 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. A mandatory internship during the summer before the fifth semester allows students to gain industrial experience and make contacts for potential future job opportunities.
- Cooperation with universities abroad allows ample choice for students interested in studying a semester abroad.
- The Robotics@Jacobs initiative is a unique program to bring undergraduate students close to robotics systems, working with a variety of platforms. State-of-the-art, high-end

equipment includes systems working in land, aerial, and marine domains, ranging from underwater robots to autonomous driving, and from humanoids to drones

- Based on their performance and interest, students can team up and participate in robotics competitions, e.g., the European Robotics League, receiving support and guidance from faculty members.
- Many faculty members have research groups that are well-funded by European Union (EU) and German Research Foundation (DFG) projects. Hence, ample opportunities exist for students to get involved and gain research experience.

1.3 Program-Specific Educational Aims

1.3.1 Qualification Aims

The main subject-specific qualification aim is to enable students to take up qualified employment in modern industries involving robotics, autonomous systems, machine learning, artificial intelligence, or to enter related graduate programs. Graduates of the Intelligent Mobile Systems program have obtained the following competencies:

- Robotics and Intelligent Systems competence

Graduates are able to design and develop autonomous systems in a given application scenario, addressing both electrical engineering and computer science aspects. They can analyze, structure, and properly address complex problems. Graduates have the ability to construct and maintain complex robotics systems using a structured, analytic, and creative approach.

- Communication competence

Graduates are able to communicate subject-specific topics convincingly in both spoken and written form to fellow roboticists, experts in intelligent systems, industrial or academic colleagues, as well as to current and potential customers.

- Teamwork and project management competence

Graduates are able to work effectively in a team and to organize workflows in complex development efforts. They are familiar with tools that support the development, testing, and maintenance of complex intelligent systems and they can take design decisions in a constructive way.

- Learning competence

Graduates have acquired a solid foundation enabling them to learn effectively and to stay up to date with the latest developments in the fast-changing field of robotics and intelligent systems.

- Personal and professional competence

Graduates are able to develop a professional profile, justify professional decisions on the basis of theoretical and methodical knowledge, and critically on reflect their behavior, also with respect to its consequences for society.

During the design of the program, national guidelines published by the Gesellschaft für Informatik (GI) (GI: Empfehlungen für Bachelor- und Masterprogramme im Studienfach Informatik an Hochschulen, July 2016) and international guidelines published jointly by the

Association for Computing Machinery (ACM) and the Institute of Electrical and Electronics Engineers (IEEE) (ACM/IEEE: Computer Science Curricula 2013, December 2013) have been consulted.

1.3.2 Intended Learning Outcomes

By the end of the program, students will be able to

- demonstrate knowledge of kinematics and dynamics of multibody systems;
- design and develop linear and nonlinear control systems;
- design basic electronic 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 that are part of intelligent mobile systems;
- design robotics systems and program them using popular robotics software frameworks;
- use academic or scientific methods as appropriate in the field of Robotics and Intelligent Systems such as defining research questions, justifying methods, collecting, assessing and interpreting relevant information, and drawing scientifically founded conclusions that consider social, scientific, and ethical insights;
- develop and advance solutions to problems and arguments in their subject area and defend these in discussions with specialists and non-specialists;
- engage ethically with the academic, professional, and wider communities and to actively contribute to a sustainable future, reflecting and respecting different views;
- take responsibility for their own learning, personal, and professional development and role in society, evaluating critical feedback and self-analysis;
- apply their knowledge and understanding to a professional context;
- work effectively in a diverse team and take responsibility in a team;
- adhere to and defend ethical, scientific, and professional standards.

1.4 Career Options

Career options include areas such as research and development or management tracks in the 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 options that are covered in the program.

The Intelligent Mobile Systems program matches scientific content with real-world use cases. This is a strength of the Jacobs offering, to introduce students to real-world applications.

Field trips to and participation in robotics competitions significantly contribute to bringing students closer to the market and to real challenges, in addition to being an excellent opportunity for professional networking.

Companies which hired recent graduates of the IMS program include Cambio CarSharing Deutschland, Daimler AG, Klöckner Desma GmbH, Objective Software GmbH, and Ubimax.

Several graduate programs have offered a position to IMS students, including the Master in Artificial Intelligence, offered by Universita' della Svizzera Italiana (Switzerland), the Erasmus Mundus Joint Master Degree on Advanced Robotics, offered by Centrale Nantes (France), University of Genoa (Italy), Warsaw University of Technology (Poland), and Jaume I University (Spain), as well as the Master in Robotics, offered by Heriot-Watt University (Scotland, UK).

The Career Services Center (CSC) as well as the Jacobs Alumni Office help students in their career development. The CSC provides students with high-quality training and coaching in CV creation, cover letter formulation, interview preparation, effective presenting, business etiquette, and employer research, as well as in many other aspects, thus helping students to identify and follow up rewarding careers upon graduation from Jacobs University. Furthermore, the Alumni Office helps students to establish a long-lasting and worldwide network that represents an important asset when exploring job options in academia, industry, and elsewhere.

1.5 Admission Requirements

Admission to Jacobs University is selective and based on a candidate's school and/or university achievements, recommendations, self-presentation, and performance on required standardized tests. Students admitted to Jacobs University demonstrate exceptional academic achievements, intellectual creativity, and the desire and motivation to make a difference in the world.

The following documents need to be submitted with the application:

- Recommendation Letter
- Official or certified copies of high school/university transcripts
- Educational History Form
- Standardized test results (SAT/ACT/TestAS) if applicable
- ZeeMee electronic resume (optional)
- Language proficiency test results (TOEFL, IELTS or equivalent)

German language proficiency is not required, instead all applicants need to submit proof of English proficiency.

For any student who has acquired the right to study at a university in the country where she/he has acquired the higher education entrance qualification Jacobs University accepts the common international university entrance tests as a replacement for the entrance examination. Applicants who have a subject-related entrance qualification (fachgebundene Hochschulreife) may be admitted only to respective study programs.

For more detailed information visit:

https://www.jacobs-university.de/study/undergraduate/application-information

1.6 More Information and Contact

For more information please contact the study program chair:

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or visit our website: https://www.jacobs-university.de/ris/

2 The Curricular Structure

2.1 General

The curricular structure provides multiple elements for enhancing employability, interdisciplinarity, and internationality. The unique Jacobs Track, offered across all undergraduate study programs, provides comprehensive tailor-made modules designed to achieve and foster career competency. Additionally, a mandatory internship of at least two months after the second year of study and the possibility to study abroad for one semester give students the opportunity to gain insight into the professional world, apply their intercultural competences and reflect on their roles and ambitions for employment and in a globalized society.

All undergraduate programs at Jacobs University are based on a coherently modularized structure, which provides students with an extensive and flexible choice of study plans to meet the educational aims of their major as well as minor study interests and complete their studies within the regular period.

The framework policies and procedures regulating undergraduate study programs at Jacobs University can be found on the website (https://www.jacobs-university.de/academic-policies).

2.2 The Jacobs University 3C Model

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

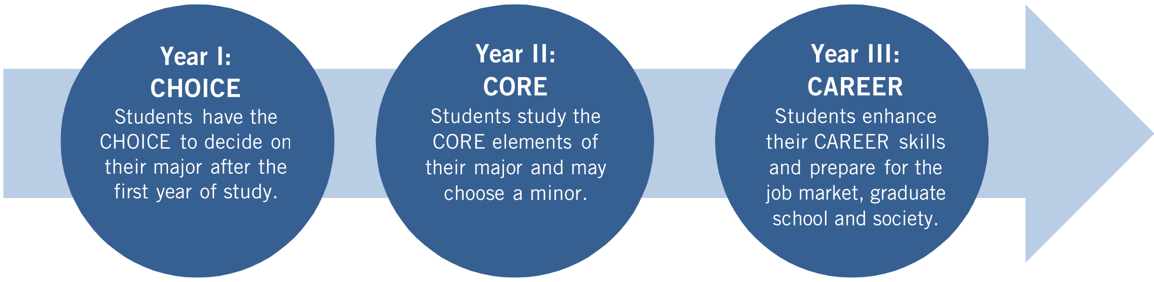

Figure 1: The Jacobs University 3C-Model

2.2.1 Year 1 – CHOICE

The first study year is characterized by a university-specific offering of disciplinary education that builds on and expands upon the students' entrance qualifications. Students select introductory modules for a total of 45 CP from the CHOICE area of a variety of study programs, of which 15-30 CP will be from their intended major. A unique feature of our curriculum structure allows students to select their major freely upon entering Jacobs University. The Academic Advising Coordinator offers curricular counseling to all Bachelor students independently of their major, while Academic Advisors support students in their decision-making regarding their major study program as contact persons from the faculty.

To pursue Intelligent Mobile Systems as a major, the following CHOICE modules (22.5 CP) need to be taken as mandatory modules:

- CHOICE Module: Introduction to Robotics and Intelligent Systems (7.5 CP)
- CHOICE Module: Programming in C and C++ (7.5 CP)
- CHOICE Module: Algorithms and Data Structures (7.5 CP)

The *Introduction to Robotics and Intelligent Systems* module lays the foundation for intelligent systems, the core of the program. *Programming in C and C++* and *Algorithms and Data Structures* introduce students to imperative and object-oriented programming and basic algorithms and data structures.

The remaining CHOICE modules (22.5 CP) can be selected in the first year of studies according to interest, and with the aim to allow a change of major until the beginning of the second year, when the major choice becomes fixed (see 2.2.1.1 below).

2.2.1.1 Major Change Option

Students can still change to another major at the beginning of their second year of studies if they have taken the corresponding mandatory CHOICE modules in their first year of studies. All students must participate in a seminar on the major change options in the O-Week and consult their Academic Advisor in the first year of studies prior to changing their major.

Intelligent Mobile Systems students that would like to retain an option for a major change after the first year are strongly recommended to register for the CHOICE modules of one of the following study programs in their first year. The module descriptions can be found in the respective Study Program Handbook.

- Computer Science (CS)
  CHOICE Module: Introduction to Computer Science (7.5 CP)

- Electrical and Computer Engineering (ECE)
  CHOICE Module: General Electrical Engineering I (7.5 CP)
  CHOICE Module: General Electrical Engineering II (7.5 CP)
  CHOICE: Module: Classical Physics (7.5 CP)

- Earth and Environmental Sciences (EES)
  CHOICE Module: General Earth and Environmental Science (7.5 CP)
  CHOICE Module: General Geology (7.5 CP)

- Physics (Phys)
  CHOICE Module: Classical Physics (7.5 CP)
  CHOICE Module: Modern Physics (7.5 CP)

- Psychology

CHOICE Module: Essentials of Cognitive Psychology (7.5 CP)
CHOICE Module: Essentials of Social Psychology (7.5 CP)

- International Relations: Politics and History (IRPH)
  CHOICE Module: Introduction to International Relations Theory (7.5 CP)
  CHOICE Module: Introduction to Modern European History (7.5 CP)

2.2.2 Year 2 – CORE

In their second year, students take a total of 45 CP from a selection of in-depth, discipline-specific CORE modules. Building on the introductory CHOICE modules and applying the methods and skills acquired so far (see 2.3.1), these modules aim to expand the students' critical understanding of the key theories, principles, and methods in their major for the current state of knowledge and best practice.

To pursue Intelligent Mobile Systems as a major, 45 CP from the following mandatory and mandatory elective CORE modules need to be taken:

- CORE Module: Robotics (m, 5 CP)
- CORE Module: Machine Learning (m, 5 CP)
- CORE Module: RIS Lab (me, 5CP)
- CORE Module: Automation (me, 5 CP)
- CORE Module: Embedded Systems (me, 5 CP)
- CORE Module: Control Systems (me, 5 CP)
- CORE Module: Computer Vision (me, 5CP)
- CORE Module: Artificial Intelligence (m, 5CP)
- CORE Module: RIS Project (m, 5CP)

Students who aim to pursue a minor can substitute 15 CP of the mandatory elective modules with CORE modules from a second field of studies.

2.2.2.1 Minor Option

Intelligent Mobile Systems students can take CORE modules (or more advanced Specialization modules) from a second discipline, which allows them to incorporate a minor study track into their undergraduate education, within the 180 CP required for a bachelor's degree. The educational aims of a minor are to broaden the students' knowledge and skills, support the critical reflection of statements in complex contexts, foster an interdisciplinary approach to problem-solving, and to develop an individual academic and professional profile in line with students' strengths and interests. This extra qualification will be highlighted in the transcript.

The Academic Advising Coordinator, Academic Advisor, and the Study Program Chair of the minor study program support students in the realization of their minor selection; the consultation with the Academic Advisor is mandatory when choosing a minor.

As a rule, this requires Intelligent Mobile Systems students to

- select two CHOICE modules (15 CP) from the desired minor program in the first year and

- substitute three of the mandatory elective Intelligent Mobile Systems CORE modules (15 CP) in the second year with the default minor CORE modules of the minor study program.

The requirements for the specific minors are described in the handbook of the study program offering the minor (Chapter 3.2) and are marked in the respective Study and Examination Plans. For an overview of accessible minors, please check the Major/Minor Combination Matrix, which is published at the beginning of each academic year.

2.2.3 Year 3 – CAREER

During their third year, students prepare and make decisions about their career path after graduation. To explore available choices and to gain professional experience, students undertake a mandatory summer internship. The third year of studies allows IMS students to take Specialization modules within their discipline, but also focuses on the responsibility of students beyond their discipline (see Jacobs Track).

The 5th semester also opens a mobility window for a diverse range of study abroad options. Finally, the 6th semester is dedicated to fostering the students' research experience by involving them in an extended Bachelor thesis project.

2.2.3.1 Internship / Start-up and Career Skills Module

As a core element of Jacobs University's employability approach students are required to engage in a mandatory two-month internship of 15 CP that will usually be completed during the summer between the second and third years of study. This gives students the opportunity to gain first-hand practical experience in a professional environment, apply their knowledge and understanding in a professional context, reflect on the relevance of their major to employment and society, reflect on their own role in employment and society, and find a professional orientation. The internship can also establish valuable contacts for the students' Bachelor's thesis project, for the selection of a Master program graduate school or further employment after graduation. This module is complemented by career advising and several career skills workshops throughout all six semesters that prepare students for the transition from student life to professional life. As an alternative to the full-time internship, students interested in setting up their own company can apply for a start-up option to focus on developing of their business plans.

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

2.2.3.2 Specialization Modules

In the third year of their studies, students take 15 CP from major-specific or major-related, advanced Specialization modules to consolidate their knowledge and to be exposed to state-of-the-art research in the areas of their interest. This curricular component is offered as a portfolio of modules, from which students can make free selections during their 5th and 6th semester. The default specialization module size is 5 CP, with smaller 2.5 CP modules being possible as justified exceptions.

To pursue Intelligent Mobile Systems as a major, at least 15 CP from the following mandatory elective Specialization modules need to be taken:

Specialization Modules offered inside Intelligent Mobile Systems

- Specialization: Human Computer Interaction (5 CP)
- Specialization: Marine Robotics (5 CP)
- Specialization: Optimization (5 CP)

Modules from Computer Sciences

- Specialization: Distributed Algorithms (5 CP)
- Specialization Computer Graphics (5 CP)
- Specialization: Web Application Development (5 CP)
- CORE Module: Software Engineering (7.5 CP)
- CORE Module: Databases and Web Services (7.5 CP)

Modules from Electrical and Computer Engineering

- Specialization: Digital Design (5 CP)
- CORE Module: PCB design and measurement automation (5 CP)
- CORE Module: Information Theory (5 CP)

Modules from Mathematics

- Specialization from MATH: Stochastic Processes (5 CP)
- Specialization from MATH: Stochastic Methods Lab (7.5 CP)

Modules from Industrial Engineering and Management

- CORE Module Operations Research (5 CP)

Available for IMS students minoring in the respective study program that meet the pre-requisites / co-requisites[1]

- Specialization: Image Processing (5 CP)
- Specialization: Automata, Computability, and Complexity (7.5 CP)
- Specialization: Computer Networks (5 CP)
- Specialization: Electronics (5 CP)
- Specialization: Digital Signal Processing (7.5 CP)
- Specialization: Signals and Systems (7.5 CP)
- Specialization: Industry 4.0 and Blockchain Technologies (5 CP)
- Specialization: Process Modeling and Simulation (5CP)
- Specialization: Operating Systems (7.5 CP)

In case of students pursuing a minor, the CORE modules of the Intelligent Mobile Systems program which are substituted for the minor modules are also eligible Specialization Modules.

[1] For module descriptions, see the respective handbook offering the modules.

2.2.3.3 Study Abroad

Students have the opportunity to study abroad for a semester to extend their knowledge and abilities, broaden their horizons and reflect on their values and behavior in a different context as well as on their role in a global society. For a semester abroad (usually the 5th semester), modules related to the major with a workload equivalent to 22.5 CP must be completed. Modules recognized as study abroad CP need to be pre-approved according to Jacobs University study abroad procedures. Several exchange programs allow students to directly enroll 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 that include Erasmus study abroad funding.

For further information, please contact the International Office (https://www.jacobs-university.de/study/international-office).

IMS students that wish to pursue a study abroad in their 5th semester are required to select their modules at the study abroad partners such that they can be used to substitute between 10-15 CP of major-specific Specialization modules and between 5-15 CP of modules equivalent to the non-disciplinary Big Questions modules or the Community Impact Project (see Jacobs Track). In their 6th semester, according to the study plan, returning study-abroad students complete the Bachelor Thesis/Seminar module (see next section), they take any missing Specialization modules to reach the required 15 CP in this area, and they take any missing Big Questions modules to reach 15 CP in this area. Study abroad students are allowed to substitute the 5 CP Community Impact Project (see Jacobs Track below) with 5 CP of Big Questions modules.

2.2.3.4 Bachelor Thesis/Seminar Module

This module is a mandatory graduation requirement for all undergraduate students. It consists of two module components in the major study program guided by a Jacobs faculty member: the Bachelor Thesis (12 CP) and a Seminar (3 CP). The title of the thesis will appear on the students' transcripts.

Within this module, students apply the knowledge skills, and methods they have acquired in their major discipline 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.

With their Bachelor Thesis students demonstrate mastery of the contents and methods of their major-specific research field. Furthermore, students 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 the original development of their own ideas. With the permission of a Jacobs Faculty Supervisor, the Bachelor Thesis can also have an interdisciplinary nature. In the seminar, students present and discuss their theses in a course environment and reflect on their theoretical or experimental approach and conduct. They learn to present their chosen research topics concisely and comprehensively in front of an audience and to explain their methods, solutions, and results to both specialists and non-specialists.

2.3 The Jacobs Track

The Jacobs Track, an integral part of all undergraduate study programs, is another important feature of Jacobs University's educational model. The Jacobs Track runs parallel to the disciplinary CHOICE, CORE, and CAREER modules across all study years and is an integral part of all undergraduate study programs. It reflects a university-wide commitment to an in-depth training in scientific methods, fosters an interdisciplinary approach, raises awareness of global challenges and societal responsibility, enhances employability, and equips students with augmented skills desirable in the general field of study. Additionally, it integrates (German) language and culture modules.

2.3.1 Methods and Skills Modules

Methods and skills such as mathematics, statistics, programming, data handling, presentation skills, academic writing, and scientific and experimental skills are offered to all students as part of the Methods and Skills area in their curriculum. The modules that are specifically assigned to each study programs equip students with transferable academic skills. They convey and practice specific methods that are indispensable for each students' chosen study program. Students are required to take 20 CP in the Methods and Skills area. The size of all Methods and Skills modules is 5 CP.

To pursue Intelligent Mobile Systems as a major, the following Methods and Skills modules (15 CP) need to be taken as mandatory modules:

- Methods: Calculus and Elements of Linear Algebra I (5 CP)
- Methods: Calculus and Elements of Linear Algebra II (5 CP)
- Methods: Probability and Random Processes (5 CP)

For the remaining 5 CP, IMS students can choose between the Methods module[2]

- Methods: Numerical Methods (5 CP)

and the Mathematics CORE module:

- CORE Module: Discrete Mathematics (5 CP).

2.3.2 Big Questions Modules

The modules in the Big Questions area (10 CP) intend to broaden students' horizons with applied problem solving between and beyond their chosen disciplines. The offerings in this area comprise problem-solving oriented modules that tackle global challenges from the perspectives of different disciplinary backgrounds that allow, in particular, a reflection of acquired disciplinary knowledge in economic, societal, technological, and/or ecological contexts. Working together with students from different disciplines and cultural backgrounds, these modules cross the boundaries of traditional academic disciplines.

Students are required to take 10 CP from modules in the Area. This curricular component is offered as a portfolio of modules, from which students can make free selections during their 5th and 6th semester with the aim of being exposed to the full spectrum of economic, societal,

[2] Students who take a minor must choose Numerical Methods.

technological, and/or ecological contexts. The size of Big Questions Modules is either 2.5 or 5 CP.

2.3.3 Community Impact Project

In their 5th semester students are required to take a 5 CP Community Impact Project (CIP) module. Students engage in on-campus or off-campus activities that challenge their social responsibility, i.e., they typically work on major-related projects that make a difference in the community life on campus, in the campus neighborhood, Bremen, or on a cross-regional level. The project is supervised by a faculty coordinator and mentors.

Study abroad students are allowed to substitute the 5-CP Community Impact Project with 5 CP of Big Questions modules.

2.3.4 Language Modules

Communication skills and foreign language abilities foster students' intercultural awareness and enhance their employability in an increasingly globalized and interconnected world. Jacobs University supports its students in acquiring and improving these skills by offering a variety of language modules at all proficiency levels. Emphasis is put on fostering the German language skills of international students as they are an important prerequisite for non-native students to learn about, explore, and eventually integrate into their host country and its professional environment. Students who meet the required German proficiency level (e.g., native speakers) are required to select modules in any other modern foreign language offered (Chinese, French or Spanish). Hence, acquiring 10 CP in language modules, with German mandatory for non-native speakers, is a requirement for all students. This curricular component is offered as a four-semester sequence of foreign language modules. The size of the Language Modules is 2.5 CP.

3 Intelligent Mobile Systems as a Minor

3.1 Qualification Aims

Students obtaining a minor in Intelligent Mobile Systems learn the basic principles of intelligent systems, including elements of both hardware and software. They obtain an understanding of how current robotics systems are designed and function. Upon completion of the minor, they will have obtained sufficient knowledge about robotics and intelligent systems concepts such that they can effectively work together with professional roboticists and experts in intelligent systems. Students obtaining a minor in Intelligent Mobile Systems can help to drive and advise on the automation processes, which are at the forefront of industrial interest currently and are expected to remain so for the foreseeable future.

3.1.1 Intended Learning Outcomes

With a minor in Intelligent Mobile Systems, students will be able to

- develop solutions to problems in the automation, robotics, and intelligent systems domains in close collaboration with professionals;
- design and develop software of moderate complexity for robotics and intelligent systems;

- design and develop basic algorithms and techniques for pattern-recognition, classification, and decision-making under uncertainty.

3.2 Module Requirements

A minor in Intelligent Mobile Systems requires 30 CP. The default option to obtain a minor in Intelligent Mobile Systems is marked in the Study and Examination Plan. It includes the following CHOICE and CORE modules:

- CHOICE Module: Programming in C and C++ (7.5 CP)
- CHOICE Module: Introduction to Robotics and Intelligent Systems (7.5 CP)
- CORE Module: Robotics (5 CP)
- CORE Module: Machine Learning (5 CP)
- CORE Module: RIS Lab (5 CP)

Upon consultation with the Academic Advisor and the IMS Study Program Chair, individual CORE modules from the default minor can be replaced by other advanced modules (CORE or Specialization) from the IMS major.

3.3 Degree

After successful completion, the minor in Intelligent Mobile Systems will be listed on the final transcript under PROGRAM OF STUDY and BA/BSc – [name of the major] as "(Minor: Intelligent Mobile Systems)."

4 Intelligent Mobile Systems Undergraduate Program Regulations

4.1 Scope of these Regulations

The regulations in this handbook are valid for all students who entered the Intelligent Mobile Systems undergraduate program at Jacobs University in Fall 2019. In case of a conflict between the regulations in this handbook and the general Policies for Bachelor Studies, the latter shall applies (see http://www.jacobs-university.de/academic-policies).

In exceptional cases, certain necessary deviations from the regulations of this study handbook might occur during the course of study (e.g., change of the semester sequence, assessment type, or the teaching mode of courses). Jacobs University Bremen reserves therefore the right to modify the regulations of the program handbook.

4.2 Degree

Upon successful completion of the study program, students are awarded a Bachelor of Science degree in Intelligent Mobile Systems.

4.3 Graduation Requirements

To graduate, students need to obtain 180 CP. In addition, the following graduation requirements apply:

Students need to complete all mandatory components of the program, as indicated in the Study and Examination Plan in Chapter 6 of this handbook.

5 Schematic Study Plan for Intelligent Mobile Systems

Figure 2 shows schematically the sequence and types of modules required for the study program. A more detailed description, including the assessment types, is given in the Study and Examination Plans in the following section.

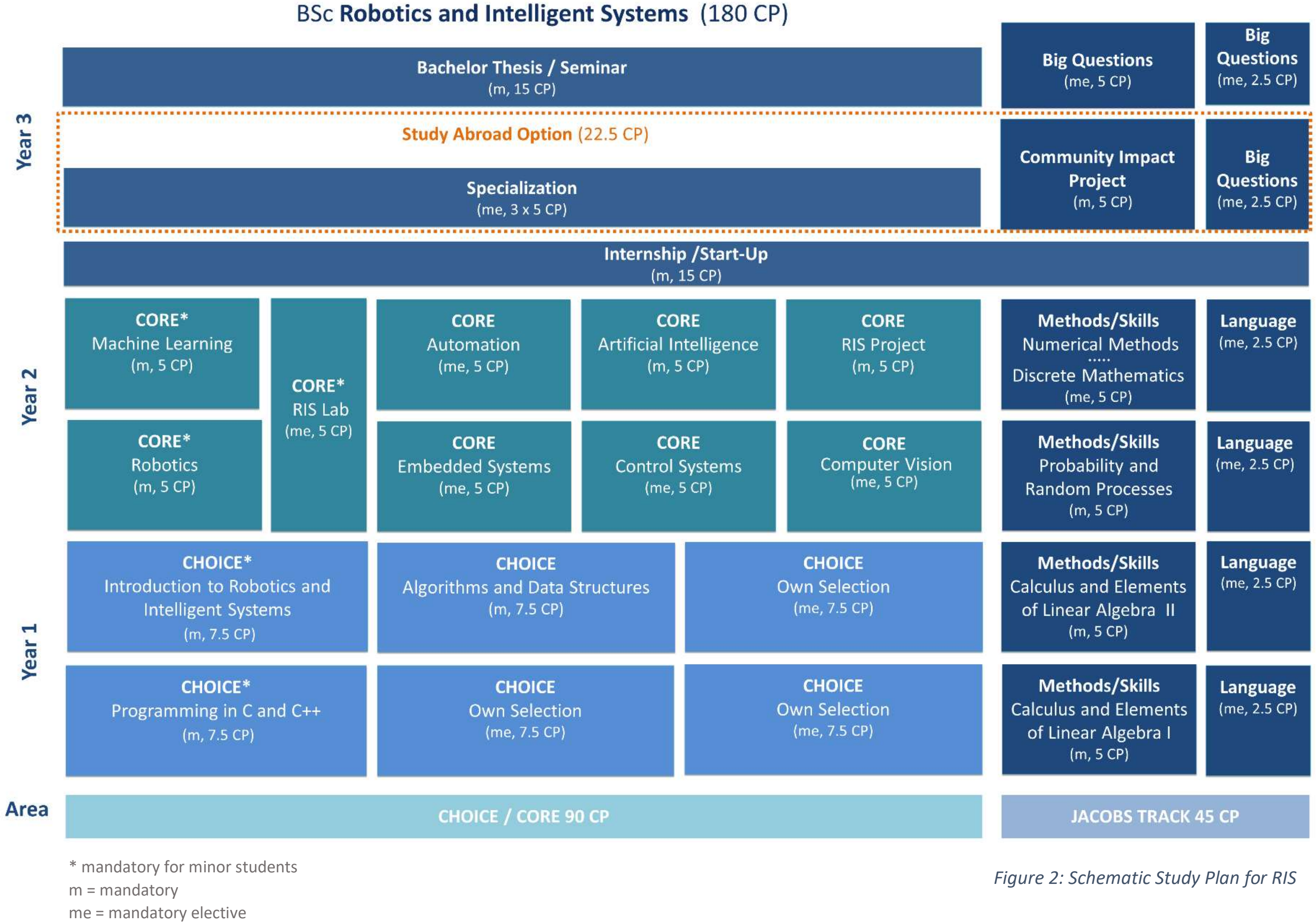

Figure 2: Schematic Study Plan for RIS

6 Study and Examination Plan

Intelligent Mobile Systems (IMS) BSc

Matriculation Fall 2019

	Program-Specific Modules	Type	Assessment	Period	Status¹	Sem.	CP
Year 1 - CHOICE *Take the mandatory CHOICE modules listed below*							**45**
							15
CH-220	**Module: Introduction to Robotics and Intelligent Systems (default minor)**				m	2	7.5
CH-220-A	Introduction to Robotics and Intelligent Systems	Lecture	Written examination	Examination period			5
CH-220-B	Intro to RIS - lab	Lab					2.5
CH-231	**Module: Algorithms and Data Structures**				m	2	7.5
CH-231-A	Algorithms and Data Structures	Lecture	Written examination	Examination period			
							7.5
CH-230	**Module: Programming in C and C++ (default minor)**				m	1	7.5
CH-230-A	Programming in C and C++	Lecture	Written examination	Examination period			2.5
CH-230-B	Programming in C and C++ Tutorial	Tutorial					5
	Unit: CHOICE (own selection)					1/2	22.5
Take three further CHOICE modules from those offered for all other study programs.²							
Year 2 - CORE *Take all CORE modules listed below or replace mandatory elective ("me") modules with suitable CORE modules from other study program*							**45**
	Unit: Robotics (default minor)						**15**
CO-540	**Module: Robotics**				m	3	5
CO-540-A	Robotics	Lecture	Written examination	Examination period			
CO-541	**Module: Machine Learning**				m	4	5
CO-541-A	Machine Learning	Lecture	Written examination	Examination period			
CO-542	**Module: RIS Lab**				me	3-4	5
CO-542-A	RIS Lab 1	Lab	Lab Report	During the semester		3	2.5
CO-542-B	RIS Lab 2	Lab	Lab Report			4	2.5
	Unit: Automation and Control						**15**
CO-543	**Automation**				me	4	5
CO-543-A	Automation	Lecture	Written examination	Examination period			
CO-544	**Module: Embedded Systems**				me	3	5
CO-544-A	Embedded Systems	Lecture/Lab	Project	During the semester			
CO-545	**Module: Control Systems**				me	3	5
CO-545-A	Control Systems	Lecture	Written examination	Examination period			
	Unit: Intelligent Systems						**15**
CO-546	**Module: Computer Vision**				me	3	5
CO-546-A	Computer Vision	Lecture/Lab	Written examination	Examination period			
CO-547	**Module: Artificial Intelligence**				m	4	5
CO-547-A	Artificial Intelligence	Lecture	Written examination	Examination period			
CO-548	**Module: RIS project**				m	4	5
CO-548-A	RIS project	Project/Lab	Report / Presentation	During the semester			
Year 3 - CAREER							**45**
CA-INT-900	**Module: Summer Internship**				m	4/5	15
CA-INT-900-0	Summer Internship	Internship	Report/Business Plan	During the 5th Semester			
CA-RIS-800	**Module: Thesis / Seminar IMS**				m	6	15
CA-RIS-800-T	Thesis IMS	Thesis	Thesis and Presentation	15th of May			12
CA-RIS-800-S	Seminar IMS	Seminar		During the semester			3
	Unit: Specialization				m	5/6	15
Take a total of 15 CP of specialization modules							
CA-S-RIS-801	Marine Robotics	Lecture/Lab	Oral examination	Examination period	me	6	5
CS-S-RIS-802	Human-Computer Interaction	Lecture	Written examination	Examination period	me	5	5
CS-S-RIS-803	Optimisation	Lecture	Written examination	Examination period	me	6	5
CA-S-xxx	Specialization elective (from CS, ECE, Math, IEM study programs)³	Various	Various	Various	me	5/6	5

	Jacobs Track Modules (General Education)	Type	Assessment	Period	Status¹	Sem.	CP
Year 1							**15**
	Unit: Methods / Skills						**10**
JTMS-MAT-09	**Module: Calculus and Elements of Linear Algebra I**				m	1	5
JTMS-09	Calculus and Linear Algebra I	Lecture	Written examination	Examination period			5
Module Code	**Module: Calculus and Elements of Linear Algebra II**				m	2	5
JTMS-10	Calculus and Linear Algebra II	Lecture	Written examination	Examination period			5
	Unit: Language						**5**
	German is default language. Native German speakers take modules in another offered language.						
Module Code	**Module: Language 1**				m	1	2.5
JTLA-xxx	Language 1	Seminar	Various	Various	me		2.5
Module Code	**Module: Language 2**				m	2	2.5
JTLA-xxx	Language 2	Seminar	Various	Various	me		2.5
Year 2							**15**
	Unit: Methods / Skills						**10**
JTMS-MAT-12	**Module: Probability and Random Processes**				m	3	5
JTMS-12	Probability and Random Processes	Lecture	Written examination	Examination period			5
Take one of the two listed mandatory elective methods modules:							
JTMS-MAT-13	**Module: Numerical Methods⁴**				me	4	5
JTMS-13	Numerical Methods	Lecture	Written examination	Examination period			5
CO-501	**Module: Discrete Mathematics**				me	4	5
CO-501-A	Discrete Mathematics	Lecture	Written examination	Examination period			5
	Unit: Language						**5**
	German is default language. Native German speakers take modules in another offered language.						
Module Code	**Module: Language 3**				m	3	2.5
JTLA-xxx	Language 3	Seminar	Various	Various	me		2.5
Module Code	**Module: Language 4**				m	4	2.5
JTLA-xxx	Language 4	Seminar	Various	Various	me		2.5
Year 3							**15**
	Unit: Big Questions						**10**
JTBQ-BQ	**Module: Big Questions**				m	5/6	
Take a total of 10 CP of Big Questions modules with each 2.5 or 5 CP		Lecture	Various	Various	me		10
	Unit: Community Impact Project						**5**
JTCI-CI-950	**Module: Community Impact Project**				m	5	5
JTCI-950	Community Impact Project	Project	Project	Examination period			

Total CP **180**

¹ Status (m = mandatory, 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 study program handbooks.
³ For details please see the program handbook
⁴ If you take minor in Math, you must choose Numerical methods module

Figure 3: Study and Examination Plan

7 Module Descriptions

7.1 Introduction to Robotics and Intelligent Systems

<table>
<tr><td colspan="3">Module Name
Introduction to Robotics and Intelligent Systems</td><td>Module Code
CH-220</td><td>Level (type)
Year 1
(CHOICE)</td><td>CP
7.5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CH-220-A</td><td colspan="3">Introduction to Robotics and Intelligent Systems - Lecture</td><td>Lecture</td><td>5</td></tr>
<tr><td>CH-220-B</td><td colspan="3">Introduction to Robotics and Intelligent Systems - Lab</td><td>Lab</td><td>2.5</td></tr>
<tr><td>Module Coordinator

Francesco Maurelli</td><td colspan="3">Program Affiliation

• Intelligent Mobile Systems (IMS)</td><td colspan="2">Mandatory Status

Mandatory for IMS
Mandatory for CS
Mandatory elective for ECE and Physics</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites
☒ None

Co-requisites
☒ None

Knowledge, Abilities, or Skills
None</td><td>Frequency

Annually
(Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lecture (35 hours)
• Lab (17.5 hours)
• Private study (115 hours)
• Exam preparation (20 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

187.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Review basic linear algebra concepts, vector and matrix operations.</td></tr>
<tr><td colspan="6">Content and Educational Aims

This module represents an initial introduction to robotics and intelligent systems, starting from the basics of mathematics and physics applied to simple robotics scenarios. It will cover transformation matrices and quaternions for reference systems. Students will then learn about particle kinematics, rigid bodies, and the basics of trajectory planning. The second part of the module offers an introduction to the 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. The concepts covered include time and frequency response, stability, and steady-state errors. This part culminates with a discussion on P, PI, PD, and PID controllers. The lab is designed to guide students through practical hands-on work with various components of intelligent systems. It will focus on the interfacing of a microcontroller with commonly used sensors and actuators.</td></tr>
</table>

Intended Learning Outcomes By the end of this module, successful students will be able to • compute 3D transformations; • understand and apply kinematics laws; • apply trajectory planning techniques; • model common mechanical and electrical systems; • understand and apply the unilateral Laplace transform and its inverse; • explore linear systems and tune their behavior; • program the open-source electronic prototyping platform Arduino; • interface Arduino to several different sensors and actuators.
Indicative Literature R. V. Roy, Advanced Engineering Dynamics. R. V. Roy, 2015. R. N. Jazar, Theory of Applied Robotics. Springer, 2010. N.S. Nise, Control Systems Engineering. Wiley, 2010.
Usability and Relationship to other Modules • Mandatory for a major in IMS and CS. • Mandatory for a minor in IMS. • Mandatory elective for a major in ECE and Physics. • This module is the foundation of the CORE modules in the following years.
Examination Type: Module Examination Assessment Type: Written examination — Duration: 120 min, Weight: 100% Scope: All intended learning outcomes of the module Module achievement: Lab report

7.2 Algorithms and Data Structures

Module Name Algorithms and Data Structures			***Module Code*** CH-231	***Level (type)*** Year 1 (CHOICE)	***CP*** 7.5
Module Components					
Number	*Name*			*Type*	*CP*
CH-231-A	Algorithms and Data Structures			Lecture	7.5
Module Coordinator Kinga Lipskoch	***Program Affiliation*** • Computer Science (CS)			***Mandatory Status*** Mandatory for CS and IMS	
Entry Requirements			***Frequency*** Annually (Spring)	***Forms of Learning and Teaching*** • Class attendance (52.5 hours) • Independent study (115 hours) • Exam preparation (20 hours)	
Pre-requisites ☒ Programming in C and C++	*Co-requisites* ☒ None	*Knowledge, Abilities, or Skills*	***Duration*** 1 semester	***Workload*** 187.5 hours	

Recommendations for Preparation

Students should refresh their knowledge of the C and C++ programming language and be able to solve simple programming problems in C and C++. Students are expected to have a working programming environment.

Content and Educational Aims

Algorithms and data structures are the core of computer science. An algorithm is an effective description for calculations using a finite list of instructions that can be executed by a computer. A data structure is a concept for organizing data in a computer such that data can be used efficiently. This introductory module allows students to learn about fundamental algorithms for solving problems efficiently. It introduces basic algorithmic concepts; fundamental data structures for efficiently storing, accessing, and modifying data; and techniques that can be used for the analysis of algorithms and data structures with respect to their computational and memory complexities. The presented concepts and techniques form the basis of almost all computer programs.

Intended Learning Outcomes

By the end of this module, students will be able to

- explain asymptotic (time and memory) complexities and respective notations;
- able to prove asymptotic complexities of algorithms;
- illustrate basic data structures such as arrays, lists, queues, stacks, trees, and hash tables;
- describe algorithmic design concepts and apply them to new problems;
- explain basic algorithms (sorting, searching, graph algorithms, computational geometry) and their complexities;
- summarize and apply C++ templates and generic data structures provided by the standard C++ template library.

Indicative Literature

Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein: Introduction to Algorithms, 3rd edition, MIT Press, 2009.

Donald E. Knuth: The Art of Computer Programming: Fundamental Algorithms, volume 1, 3rd edition, Addison Wesley Longman Publishing, 1997.

Usability and Relationship to other Modules

- Mandatory for a major in CS and IMS
- Mandatory for a minor in CS
- Pre-requisite for the following CORE modules:
  - Databases and Web Services
  - Software Engineering
  - Legal and Ethical Aspects of Computer Science
  - Computer Graphics
  - Distributed Algorithms
- Familiarity with basic algorithms and data structures is fundamental for almost all advanced modules in computer science. This module additionally introduces advanced concepts of the C++ programming language that are needed in advanced programming-oriented modules in the 2nd and 3rd years of the CS and IMS programs.

Examination Type: Module Examination

Assessment Type: Written examination — Duration: 120 min, Weight: 100%

Scope: All intended learning outcomes of the module

7.3 Programming C and C++

Module Name	***Module Code***	***Level (type)***	***CP***
Programming in C and C++	CH-230	Year 1 (CHOICE)	7.5

Module Components

Number	*Name*	*Type*	*CP*
CH-230-A	Programming in C and C++ - Lecture	Lecture	2.5
CH-230-B	Programming in C and C++ - Tutorial	Tutorial	5

Module Coordinator	***Program Affiliation***	***Mandatory Status***
Kinga Lipskoch	• Computer Science (CS)	Mandatory for CS, IMS, and ECE

Entry Requirements			***Frequency***	***Forms of Learning and Teaching***
Pre-requisites	*Co-requisites*	*Knowledge, Abilities, or Skills*	Annually (Fall)	• Lecture attendance (17,5 hours) • Tutorial attendance (35 hours) • Independent study (115 hours) • Exam preparation (20 hours)
☒ None	☒ None		***Duration*** 1 semester	***Workload*** 187.5 hours

Recommendations for Preparation

It is recommended that students install a suitable programming environment on their notebooks. It is recommended to install a Linux system such as Ubuntu, which comes with open-source compilers such as gcc and g++ and editors such as vim or emacs. Alternatively, the open-source Code: Blocks integrated development environment can be installed to solve programming problems.

Content and Educational Aims

This course offers an introduction to programming using the programming languages C and C++. After a short overview of the program development cycle (editing, preprocessing, compiling, linking, executing), the module presents the basics of C programming. Fundamental imperative programming concepts such as variables, loops, and function calls are introduced in a hands-on manner. Afterwards, basic data structures such as multidimensional arrays, structures, and pointers are introduced and dynamically allocated multidimensional arrays and linked lists and trees are used for solving simple practical problems. The relationships between pointers and arrays, pointers and structures, and pointers and functions are described, and they are illustrated using examples that also introduce recursive functions, file handling, and dynamic memory allocation.

The module then introduces basic concepts of object-oriented programming languages using the programming language C++ in a hands-on manner. Concepts such as classes and objects, data abstractions, and information hiding are introduced. C++ mechanisms for defining and using objects, methods, and operators are introduced and the relevance of constructors, copy constructors, and destructors for dynamically created objects is explained. Finally, concepts such as inheritance, polymorphism, virtual functions, and overloading are introduced. The learned concepts are applied by solving programming problems.

Intended Learning Outcomes

By the end of this module, students will be able to

- explain basic concepts of imperative programming languages such as variables, assignments, loops, and function calls;
- write, test, and debug programs in the procedural programming language C using basic C library functions;
- demonstrate how to use pointers to create dynamically allocated data structures such as linked lists;
- explain the relationship between pointers and arrays;
- illustrate basic object-oriented programming concepts such as objects, classes, information hiding, and inheritance;
- give original examples of function and operator overloading and polymorphism;
- write, test, and debug programs in the object-oriented programming language C++.

Indicative Literature

Brian Kernighan, Dennis Ritchie: The C Programming Language, 2nd edition, Prentice Hall Professional Technical Reference, 1988.

Steve Oualline: Practical C Programming, 3rd edition, O'Reilly Media, 1997.

Bruce Eckel: Thinking in C++: Introduction to Standard C++, Prentice Hall, 2000.

Bruce Eckel, Chuck Allison: Thinking in C++: Practical Programming, Prentice Hall, 2004.

Bjarne Stroustrup: The C++ Programming Language, 4th edition, Addison Wesley, 2013.

Michael Dawson: Beginning C++ Through Game Programming, 4th edition, Delmar Learning, 2014.

Usability and Relationship to other Modules

- Mandatory for a major in CS, IMS, and ECE
- Mandatory for a minor in CS and IMS
- Pre-requisite for the CHOICE module Algorithms and Data Structures
- Elective for all other undergraduate study programs
- This module introduces the programming languages C and C++ and several other modules build on this foundation. Certain features of C++ such as templates and generic data structures and an overview of the standard template library will be covered in the Algorithms and Data Structures module.

Examination Type: Module Examinations

Assessment type: Written examination

Duration:120 min
Weight: 100%

Scope: All theoretical intended learning outcomes of the module

Module achievement: 50% of the assignments correctly solved.

7.4 Robotics

Module Name		Module Code	Level (type)	CP
Robotics		CO-540	Year 2 (CORE)	5

Module Components			
Number	*Name*	*Type*	*CP*
CO-540-A	Robotics	Lecture	5

Module Coordinator	Program Affiliation	Mandatory Status
Andreas Birk	• Intelligent Mobile Systems (IMS)	Mandatory for IMS Mandatory elective for CS

Entry Requirements			Frequency	Forms of Learning and Teaching
Pre-requisites	*Co-requisites*	*Knowledge, Abilities, or Skills*	Annually (Fall)	• Class attendance (35 hours) • Private study (70 hours) • Exam preparation (20 hours)
☒ Programming in C/C++ ☒ Introduction to IMS	☒ None		**Duration** 1 semester	**Workload** 125 hours

Recommendations for Preparation

Revise content of the pre-requisite modules.

Content and Educational Aims

Robotics is an area that is driven by dreams from science fiction and the reality of engineering. The module intends to provide an understanding of the formal foundations of this area as well as its technological state of the art and future directions. The course accordingly gives an introduction to the core algorithmic, mathematical, and engineering concepts and methods of robotics. This includes concepts and methods that are used for well-established tools of factory automation, especially in the form of robot-arms, as well as increasingly relevant intelligent mobile systems such as autonomous cars or autonomous transport systems.

Intended Learning Outcomes

By the end of this module, students should be able to

- outline and explain the history, general developments, and application areas of robotics;
- apply the concepts and methods to describe space and motions therein including homogeneous coordinates and transforms as well as quaternions;
- use the spatial concepts and methods for the forward kinematics (FK) of robot-arms;
- explain basic concepts of simple actuators, including electrical motors and gear systems;
- apply concepts and methods to derive the inverse kinematics of robot-arms and related systems such as legs in analytical and numerical forms;
- apply concepts and methods of wheeled locomotion including FK and IK of the differential and of the omni-directional drive;
- use basic concepts and methods of dynamics;
- Explain and use core concepts and methods of global localization, e.g., multilateration and multidimensional scaling;
- use the basic concepts and methods of error propagation estimation in the context of relative localization with dead-reckoning;
- outline and compare the basic concepts and methods of mapping.

Indicative Literature

J. J. Craig, Introduction to robotics - Mechanics and control, Prentice Hall, 2005.
G. Dudek and M. Jenkin, Computational Principles of Mobile Robotics, Cambridge University Press, 2000.
R. Siegwart and I. R. Nourbakhsh, Introduction to Autonomous Mobile Robots, The MIT Press, 2004.
S. Thrun, W. Burgard, and D. Fox, Probabilistic Robotics, MIT Press, 2005.
H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki, and S. Thrun, Principles of Robot Motion, MIT Press, 2005.

Usability and Relationship to other Modules

- Mandatory for a major in IMS
- Mandatory for a minor in IMS
- This module serves as a third Year Specialization module for CS major students.
- This module gives an introduction to Robotics, which is a core discipline of IMS and an important area of possible future employment.

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of the module

7.5 Machine Learning

<table>
<tr><td colspan="2">Module Name
Machine Learning</td><td>Module Code
CO-541</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td>Number</td><td colspan="2">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-541-A</td><td colspan="2">Machine Learning</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

N.N.</td><td colspan="2">Program Affiliation
Intelligent Mobile Systems (IMS)</td><td colspan="2">Mandatory Status

Mandatory for IMS
Mandatory elective for CS</td></tr>
<tr><td colspan="2" rowspan="2">Entry Requirements

Pre-requisites | Co-requisites | Knowledge, Abilities, or Skills
☒ None | ☒None |</td><td>Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching
Class attendance (35 hours)
Private study (70 hours)
Exam preparation (20 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="5">Recommendations for Preparation

None</td></tr>
<tr><td colspan="5">Content and Educational Aims

Machine learning (ML) concerns algorithms that 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, which is 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; this is 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 that are common to all of these formalisms and algorithms. The lectures introduce such fundamental concepts and illustrate them with a choice of elementary model formalisms (linear classifiers and regressors, radial basis function networks, clustering, online adaptive filters, neural networks, or hidden Markov models). Furthermore, the lectures also (re-)introduce required mathematical material from probability theory and linear algebra.</td></tr>
<tr><td colspan="5">Intended Learning Outcomes

By the end of this module, students should be able to
understand the notion of probability spaces and random variables;
understand basic linear modeling and estimation techniques;
understand the fundamental nature of the “curse of dimensionality;”
understand the fundamental nature of the bias-variance problem and standard coping strategies;
use elementary classification learning methods (linear discrimination, radial basis function networks, multilayer perceptrons);
implement an end-to-end learning suite, including feature extraction and objective function optimization with regularization based on cross-validation.</td></tr>
<tr><td colspan="5">Indicative Literature

T. Hastie, R. Tibshirani, J. Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction, 2nd edition, Springer, 2008.</td></tr>
</table>

S. Shalev-Shwartz, Shai Ben-David: Understanding Machine Learning, Cambridge University Press, 2014.

C. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.

T.M. Mitchell, Machine Learning, Mc Graw Hill India, 2017.

Usability and Relationship to other Modules

- Mandatory for a major in IMS
- Mandatory for a minor in IMS
- This module serves as a third Year Specialization module for CS major students.
- This module gives a thorough introduction to the basics of machine learning. It complements the Artificial Intelligence module.

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of the module

7.6 RIS Lab

Module Name RIS Lab			*Module Code* CO-542	*Level (type)* Year 2 (CORE)	*CP* *5*
Module Components					
Number	*Name*			*Type*	*CP*
CO-542-A	RIS Lab I			Lecture/lab	2.5
CO-542-B	RIS Lab II			Lecture/lab	2.5
Module Coordinator Francesco Maurelli	***Program Affiliation*** • Intelligent Mobile Systems (IMS)			***Mandatory Status*** Mandatory elective for IMS	
Entry Requirements *Pre-requisites* ☒ Introduction to RIS ☒ Programming in C/C++	*Co-requisites* ☒ None	*Knowledge, Abilities, or Skills*	***Frequency*** Annually (Fall)	***Forms of Learning and Teaching*** • Class attendance (35 hours) • Private study (70 hours) • Report preparation (20 hours)	
			Duration 2 semesters	***Workload*** 125 hours	

Recommendations for Preparation

None

Content and Educational Aims

RIS Lab I focuses on robotics middleware such as the Robot Operating System (ROS). Building on the programming class and on the introductory course, it presents ways in which different units of a robotic system can share information. The work will be mainly in simulation, using the ROS Gazebo package or similar.

RIS Lab II focuses on the analysis and the design of linear control systems. Students learn to use MATLAB and Simulink tools to investigate the system behavior and to study its time and frequency response. They also learn how to design feedback controls, and to interpret and take care of steady-state errors.

Students are also introduced to and practice technical and scientific writing skills in preparation for their thesis.

Intended Learning Outcomes

By the end of this module, students should be able to

1. describe robotics software architecture;
2. correctly use available libraries and packages;
3. create new packages and functionalities in a robotics simulator;
4. create an electromechanical model of a brushed DC motor in Simulink and study its properties;
5. design and tune PID controllers for motor-speed control and for servo control;
6. present and justify their work appropriately in accordance with scientific standards.

Indicative Literature

A. Koubaa, Robot Operating System (ROS), The Complete Reference Vol 1, Springer, 2018.

Usability and Relationship to other Modules

- Mandatory elective for a major in IMS
- Mandatory for a minor in IMS

- The first part is a pre-requisite for the RIS project, which will use robotics middleware with real robotics systems.

Examination Type: Module Component Examination

Module Component 1: Lab 1

Assessment Type: Final Report for RIS Lab I
Length: approx. 10 pages
Weight: 50%

Scope: Intended learning outcomes of RIS Lab I - 1, 2, 3, 6.

Module Component 2: Lab 2

Assessment Type: Final Report for RIS Lab II
Length: approx. 10 pages
Weight: 50%

Scope: Intended learning outcomes of RIS Lab II - 4, 5, 6.

Completion: To pass this module, both module component examinations have to be passed with at least 45%.

7.7 Automation

Module Name	***Module Code***	***Level (type)***	***CP***
Automation	CO-543	Year 2 (CORE)	*5*

Module Components

Number	*Name*	*Type*	*CP*
CO-543-A	Automation	Lecture	5

Module Coordinator	***Program Affiliation***	***Mandatory Status***
Dr. Szymon Krupinski	• Intelligent Mobile Systems (IMS)	Mandatory elective for IMS

Entry Requirements			***Frequency***	***Forms of Learning and Teaching***
Pre-requisites	*Co-requisites*	*Knowledge, Abilities, or Skills*	Annually (Spring)	• Lectures (30 hours) • Lab (5 hours) • Private study (70 hours) • Exam preparation (20 hours)
☒ Programming C/C++ ☒ Introduction to RIS	☒ None	• Understanding of the basics of electronics • Calculus • basic C/C++/Python • basic MATLAB/Simulink or SciLab	***Duration*** 1 semester	***Workload*** 125 hours

Recommendations for Preparation

Review material of Embedded Systems Lab.

Content and Educational Aims

Automation is the application of science and technology to control mechanical systems, including situations in which this proposed solution duplicates the skills of a human operator or even exceeds them. Industrial automation concentrates on solutions in 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 an industrial performance and setting, along with the concomitant focus on robustness and efficiency under factory conditions.
The topics covered in this course include: an introduction to sensors and their scientific principles; filtering, data fusion and estimation; types of actuators and details about the operation of industrial motors and drives; an introduction to programmable logic controllers (PLCs); their hierarchy and different PLC programming paradigms; and artificial intelligence (AI) concepts used in automation, such as state machines and sensor data processing.

Intended Learning Outcomes

By the end of this module, students should be able to

- explain the characteristics and principles of a number of industrial sensors and electric motors, comment on their overall parameters such as accuracy and precision, and outline the reasons for the calibration process;
- apply this knowledge to translate simple machine specifications into an automation problem in terms of sensing, actuation, and processing strategy at the conceptual level, including an educated selection of sensors and drives;
- apply a family of filtering and estimation techniques covered in the lectures to systems similar to those used in the examples; recall the analysis of their stability and duplicate it in the case of the presented system;
- apply the state machine concept to simple processes and routines;
- explain the strengths, principles, and programming paradigms of PLCs;

- recall the currently used concept in organizing a factory-wide automation pyramid and understand the working of at least one automation communication protocol in detail;
- combine the skills mentioned above in proposing solutions to simple industrial problem examples.
.

Indicative Literature

N. Zuech, Handbook of Intelligent Sensors for Industrial Automation, Addison-Wesley, 1992.
A. Hughes, Electric Motors and Drives, 3rd edition, 2006.
K. Collins, PLC Programming for Industrial Automation, 2007.

Usability and Relationship to other Modules

- Mandatory elective for IMS
- A portion of the knowledge is complementary with the Control Systems course
- The robotics course completes the information given in this course with respect to mobile machinery.

Examination Type: Module Examination

Assessment Type: Written examination — Duration: 150 min
Weight: 100%

Scope: The course material excluding programming skills.

The exam will provide a number of multiple choice of true/false questions, where students will be expected to recall facts and principles covered in the class.
Sample problems will be given, similar to those given in class, where the students will be expected to duplicate the calculations and choice principles explained in the class.
An open-ended question will test their understanding of the entire concepts such as calibration or state machine.

7.8 Embedded Systems

<table>
<tr><td colspan="2">Module Name
Embedded Systems</td><td>Module Code
CO-544</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td>Number</td><td colspan="2">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-544-A</td><td colspan="2">Embedded Systems</td><td>Lecture/Lab</td><td>5</td></tr>
<tr><td>Module Coordinator

Fangning Hu</td><td colspan="2">Program Affiliation

• Intelligent Mobile Systems (IMS)</td><td colspan="2">Mandatory Status

Mandatory elective for IMS</td></tr>
<tr><td colspan="2" rowspan="2">Entry Requirements

Pre-requisites: ☒ Programming in C/C++
Co-requisites: ☒ None
Knowledge, Abilities, or Skills</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching

• Lecture/Lab (35 hours)
• Private study (90 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="5">Recommendations for Preparation

Revising programming in C and the binary number systems.</td></tr>
<tr><td colspan="5">Content and Educational 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 is becoming increasingly popular with its use in smartphones, tablets, and various forms of embedded systems, owing to its small size and low power consumption. The course provides a sound introduction to these nearly 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, and I/O interface; the concepts of working registers, interrupt vectors, and program counters; necessary programming tools such as embedded C and assembler, as well as several implementation problems such as 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.</td></tr>
<tr><td colspan="5">Intended Learning Outcomes

By the end of this module, students should be able to

• describe the architecture of a microcontroller;
• understand the datasheet of a microcontroller;
• program a microcontroller to read/control sensors/actuators, process interrupters, generate PWM, and perform AD/DA conversion;
• design a solution for an embedded application by microcontroller.</td></tr>
<tr><td colspan="5">Indicative Literature

Online resources and manuals provided by the Instructor of Records.

M. Michalkiewics et. al, AVR C Runtime Library, http://savannah.nongnu.org/projects/avr-libc/, accessed 3 March 2020.</td></tr>
</table>

Usability and Relationship to other Modules • Mandatory elective for a major in IMS • This module introduces the architecture of an AVR/ARM-based microcontroller and how to program it. It could also serve as a specialization course for students from Electrical and Computer Engineering and Computer Science.
Examination Type: Module Examination Assessment Type: Project Duration: 180 min Weight: 100% Scope: All intended learning outcomes of the module

7.9 Control Systems

Module Name			Module Code	Level (type)	CP
Control Systems			CO-545	Year 2 (CORE)	*5*

Module Components

Number	*Name*	*Type*	*CP*
CO-545-A	Control Systems	Lecture	5

Module Coordinator	***Program Affiliation***	***Mandatory Status***
Mathias Bode	• Intelligent Mobile Systems (IMS)	Mandatory Elective for IMS

Entry Requirements			***Frequency***	***Forms of Learning and Teaching***
Pre-requisites	*Co-requisites*	*Knowledge, Abilities, or Skills*	Annually (Fall)	• Lecture (35 hours) • Private study (90 hours)
☒ Calc+LA I/II, ☒ Intro to RIS	☒ None	• Transfer functions • Laplace transforms	***Duration*** 1 semester	***Workload*** 125 hours

Recommendations for Preparation

Revise calculus, linear algebra, Laplace transforms, and obtain the course textbook in advance of the first class. Please see course pages for details.

Content and Educational Aims

This course offers a systematic walk through the fundamentals of control theory for linear systems. Building on the introduction to RIS course, 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 of 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.

Intended Learning Outcomes

By the end of this course, successful students will be able to

- understand and apply fundamental concepts from linear control theory;
-
- reduce larger block diagrams;
- use various methods (Routh table, root locus, Nyquist) to analyze systems for stability;
- find the steady-state errors for various standard input signals;
- understand and quantify the sensitivity of steady-state errors with regard to parameter deviations;
- design lead and lag compensators to improve the system response.

Indicative Literature

N.S. Nise: Control Systems Engineering, John Wiley & Sons, 2010.

Usability and Relationship to other Modules This module introduces the students to the field of automatic control and is strongly related to the embedded systems, automation, and robotics modules. However, it also helps to better understand how systems in general, be they mechanical, electrical, biological, or even social, such as smart cities, can be maintained under stable conditions and with desired response characteristics.
Examination Type: Module Examination Assessment Type: Written examination — Duration: 120 min, Weight: 100% Scope: All intended learning outcomes of the module

7.10 Computer Vision

<table>
<tr><td colspan="2">Module Name
Computer Vision</td><td>Module Code
CO-546</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td>Number</td><td colspan="2">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-546-A</td><td colspan="2">Computer Vision</td><td>Lecture/lab</td><td>5</td></tr>
<tr><td>Module Coordinator

Francesco Maurelli</td><td colspan="2">Program Affiliation

• Intelligent Mobile Systems (IMS)</td><td colspan="2">Mandatory Status

Mandatory elective for IMS
Mandatory elective for CS</td></tr>
<tr><td colspan="2" rowspan="2">Entry Requirements

Pre-requisites: ☒ Intro to RIS; ☒ Programming in C/C++
Co-requisites: ☒ None
Knowledge, Abilities, or Skills: • Basic knowledge of robotics middleware (RIS Lab I)</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching

• Class attendance (35 hours)
• Private study (70 hours)
• Exam preparation (20 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
</table>

Recommendations for Preparation

Refresh basic programming skills in MATLAB and/or Python

Content and Educational Aims

Computer Vision algorithms are used in a variety of real-world applications that include 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, and an introduction to object-recognition.

Intended Learning Outcomes

By the end of this module, students should be able

- describe image formation and camera models;
- calibrate cameras;
- compute image histograms, and basic image processing;
- discriminate among visual features (e.g., corner, edge, blob);
- Properly use computer vision libraries;
- implement computer vision applications.

Indicative Literature

D.A. Forsyth and J. Ponce, Computer Vision: A Modern Approach. 2nd edition, 2011.

R. Szeliski, Computer Vision: Algorithms and Applications, Springer, http://szeliski.org/Book, 2010.

Ma et al., An Invitation to 3 D Vision: From Images to Geometric Models, Springer, 2004.

Usability and Relationship to other Modules

- Giving the foundation of computer vision, this module is important for RIS project and for advanced specialization courses.
- Mandatory elective for a major in IMS.
- This module serves as a third year Specialization module for CS major students.

Examination Type: Module Examination

Assessment Type: Written examination	Duration: 120 min Weight: 100%
Scope: All intended learning outcomes of the module	
Module achievements: 50% if the assignments correctly solved	

7.11 Artificial Intelligence

Module Name			***Module Code***	***Level (type)***	***CP***
Artificial Intelligence			CO-547	Year 2 (CORE)	*5*
Module Components					
Number	*Name*			*Type*	*CP*
CO-547-A	Artificial Intelligence			Lecture	5
Module Coordinator Andreas Birk	***Program Affiliation*** • Intelligent Mobile Systems (IMS)			***Mandatory Status*** Mandatory for IMS Mandatory elective for CS	
Entry Requirements			***Frequency*** Annually (Spring)	***Forms of Learning and Teaching*** • Class attendance (35 hours) • Private study (70 hours) • Exam preparation (20 hours)	
Pre-requisites ☒ Programming in C/C++ ☒ Introduction to RIS	*Co-requisites* ☒ None	*Knowledge, Abilities, or Skills*	***Duration*** 1 semester	***Workload*** 125 hours	
Recommendations for Preparation Revise content of the pre-requisite modules.					

Content and Educational Aims

Artificial Intelligence (AI) is an important subdiscipline of Computer Science that deals with technologies to automate the performance of tasks 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 module 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 such as intelligent mobile robots or autonomous cars.

Intended Learning Outcomes

By the end of this module, students should be able to

- outline and explain the history, general developments, and application areas of AI;
- apply the basic concepts and methods of behavior-oriented AI;
- use concepts and methods of search algorithms for problem-solving;
- explain the basic concepts of path-planning as an application example for domain-specific search;
- apply basic path-planning algorithms and to compare their relations to general search algorithms;
- write and explain concepts of propositional and first-order logic;
- use logic representations and inference for basic examples of artificial planning systems.

Indicative Literature

S. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, Prentice Hall, 2009.

S. M. LaValle, Planning Algorithms. Cambridge University Press, 2006.

J.-C. Latombe, Robot Motion Planning, Springer, 1991.

Usability and Relationship to other Modules

- This module gives an introduction to Artificial Intelligence (AI) excluding the aspects of machine learning (ML), which are covered in a dedicated module that complements this one.
- Mandatory for a major in IMS
- This module serves as a third year Specialization module for CS major students.

Examination Type: Module Examination Assessment Type: Written examination — Duration: 120 min Weight: 100% Scope: All intended learning outcomes of the module

7.12 RIS Project

<table>
<tr><td colspan="4">Module Name
RIS Project</td><td>Module Code
CO-548</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5</td></tr>
<tr><td colspan="7">Module Components</td></tr>
<tr><td>Number</td><td colspan="4">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-548-A</td><td colspan="4">RIS Project</td><td>Lecture/lab</td><td>5</td></tr>
<tr><td>Module Coordinator

Francesco Maurelli</td><td colspan="4">Program Affiliation

• Intelligent Mobile Systems (IMS)</td><td colspan="2">Mandatory Status

Mandatory for IMS</td></tr>
<tr><td colspan="4" rowspan="2">Entry Requirements

Pre-requisites | Co-requisites | Knowledge, Abilities, or Skills

☒ Intro to RIS
☒ Programming in C/C++

☒ None

• Basic knowledge of robotics middleware (RIS Lab I)</td><td>Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching

• Class attendance (35 hours)
• Private study (70 hours)
• Report preparation (20 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="7">Recommendations for Preparation

None</td></tr>
<tr><td colspan="7">Content and Educational Aims

The aim of RIS project is to use real robotics systems (e.g., Duckietown for autonomous driving) to design and implement a project that is related to one or more modules of the IMS program. Students will work in groups and will choose a scenario to focus on, involving a combination of robotics, computer vision, machine learning, artificial intelligence, and control systems competences. The lecture part of the module will focus on the transition from work in simulation to work with real robotics systems, including basic health and safety procedures.</td></tr>
<tr><td colspan="7">Intended Learning Outcomes

By the end of this module, students should be able to
1. apply available libraries to real robotics systems;
2. develop new robotics functionalities;
3. integrate new functionalities in robotics systems;
4. design and plan a project over several weeks;
5. work in a team, overcoming challenges;
6. present scientific results in an adequate manner.</td></tr>
<tr><td colspan="7">Indicative Literature

Not specified</td></tr>
<tr><td colspan="7">Usability and Relationship to other Modules

• This module represents a glue among various different core modules, focusing on the design and implementation of a project with real robotics systems. It is pivotal for advanced courses in the third year and lays the foundation for the competence skills required for the thesis.</td></tr>
<tr><td colspan="7">Examination Type: Module Examination</td></tr>
</table>

Assessment Component 1: Report Scope: Intended learning outcomes of the lecture 1, 2, 3, 4, 5).	Length: approx. 15 pages Weight: 75%
Assessment Component 2: Presentation Scope: Intended learning outcomes of the lab 4, 5, 6.	Duration: approx. 15 min Weight: 25%
Completion: This module is passed with an assessment-component weighted average grade of 45% or higher.	

7.13 Marine Robotics

Module Name Marine Robotics			**_Module Code_** CA-S-RIS-801	**_Level (type)_** Year 3 (Specialization)	**_CP_** _5_
Module Components					
Number	_Name_			_Type_	_CP_
CA-RIS-801	Marine Robotics			Lecture/lab	5
Module Coordinator Francesco Maurelli	**_Program Affiliation_** • Intelligent Mobile Systems (IMS)			**_Mandatory Status_** Mandatory Elective for IMS Elective for CS	
Entry Requirements _Pre-requisites_ ☒ Intro to RIS ☒ Programming in C/C++	_Co-requisites_ ☒ None	_Knowledge, Abilities, or Skills_ • Basic knowledge of robotics middleware (RIS Lab I)	**_Frequency_** Annually (Spring)	**_Forms of Learning and Teaching_** • Class attendance (35 hours) • Private study (70 hours) • Exam preparation (20 hours)	
			Duration 1 semester	**_Workload_** 125 hours	

Recommendations for Preparation

None

Content and Educational Aims

Marine robotics currently plays a key role in the exploitation of marine resources (offshore), conservation of marine environments (environment assessment), and security applications (harbor protection). The European Commission has estimated that the economic impact of the "blue" economy, which considers all activities linked to the sea, is worth more than €400 billion annually, with more than €150 billion in activities directly related to marine activities.

This module builds on the CORE courses of the second year with a specialization on (intelligent) marine robotics, studying the typical environmental constraints, technical solutions, and current trends.

The topics covered by this module include ROV and AUV operations, underwater acoustic, underwater sensing, navigation, communication, and multivehicle cooperation.

The module will have a practical component, with the possibility of visiting nearby institutions and participating in field excursions.

Intended Learning Outcomes

By the end of this module, students should be able to

- understand the challenges in the marine domain for robotics systems;
- analyze the functioning of acoustic devices for robot autonomy;
- develop advanced functionalities for a marine robot in a simulation;
- develop advanced functionalities for a marine robot in the field.

Indicative Literature

L. Jaulin et. al, Marine Robotics and Applications , Springer, 2018.

S. W. Moore, Underwater Robotics: Science, Design & Fabrication, 2010.

B. Siciliano O. Khatib, Springer Handbook of Robotics, Springer, 2008.

Usability and Relationship to other Modules • This module is a robotics-oriented specialization course, with the possibility to work with real robots.
Examination Type: Module Examination Assessment Type: Oral examination Duration: approx. 15 min Weight: 100% Scope: All intended learning outcomes of the module

7.14 Human Computer Interaction

Module Name Human Computer Interaction	***Module Code*** CA-S-RIS-802	***Level (type)*** Year 3 (CAREER-Specialization)	***CP*** 5

Module Components

Number	*Name*	*Type*	*CP*
CA-RIS-802	Human Computer Interaction	Lecture	5

Module Coordinator	***Program Affiliation***	***Mandatory Status***
Sergey Kosov	• Intelligent Mobile Systems (IMS)	Mandatory elective for IMS and CS

Entry Requirements			***Frequency***	***Forms of Learning and Teaching***
Pre-requisites	*Co-requisites*	*Knowledge, Abilities, or Skills*	Annually (Fall)	• Class attendance (35 hours) • Private study (70 hours) • Exam preparation (20 hours)
☒ None	☒ None	• None	***Duration*** 1 semester	***Workload*** 125 hours

Recommendations for Preparation

None

Content and Educational Aims

Computer systems often interact with human beings. The design of a good human–computer interface is often crucial for the acceptance and the success of a software system. Human–computer interface designs have to satisfy several requirements such as usability, learnability, efficiency, accessibility, and safety. The module discusses the evolution of human–computer interaction models and introduces design principles for graphical user interfaces and other types of interaction (e.g., visual, voice, gesture). Human–computer interaction designs are often evaluated using prototypes or mockups that can be given to test candidates to evaluate the effectiveness of the design. The module introduces evaluation strategies as well as tools and techniques that can be used to prototype human–computer interfaces.

Intended Learning Outcomes

By the end of this module, students should be able to

- explain the evolution of human–computer interaction models;
- design and implement simple graphical user interfaces;
- explain ergonomic principles guiding the design of user interfaces;
- illustrate different types of interaction (e.g., visual, voice, gestures) and their usability aspects;
- evaluate aspects of and tradeoffs between usability, learnability, efficiency, and safety;
- apply scientific methods to evaluate interfaces with respect to their usability and other desirable properties;
- use prototyping tools that can be employed to create mockups of user interfaces during the early stages of a software project.

Indicative Literature

Not specified

Usability and Relationship to other Modules

- Students with a strong interest in graphical user interfaces are encouraged to also select the Computer Graphics specialization module, which introduces methods and technologies for creating computer graphics and animations.
- Mandatory elective third year Specialization module for CS and IMS major students.

Examination Type: Module Examination

Assessment Type: Written examination	Duration: 120 min Weight: 100%
Scope: All intended learning outcomes of the module	

7.15 Optimization

Module Name	***Module Code***	***Level (type)***	***CP***
Optimization	CA-RIS-803	Year 3 (CAREER-Specialization)	*5*

Module Components

Number	*Name*	*Type*	*CP*
CA-S-RIS-803	Optimization	Lecture	5

Module Coordinator	***Program Affiliation***	***Mandatory Status***
Mathias Bode	• Intelligent Mobile Systems (IMS)	Mandatory elective for IMS

Entry Requirements			***Frequency***	***Forms of Learning and Teaching***
Pre-requisites	*Co-requisites*	*Knowledge, Abilities, or Skills*	Annually (Spring)	• Lecture (35 hours) • Private study (90 hours)
☒ Calc+LA I/II	☒ None	•	***Duration***	***Workload***
			1 semester	125 hours

Recommendations for Preparation

Revise calculus and linear algebra from your first year.

Content and Educational 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 placed on duality, in particular, in the case of semidefinite programming. The last part of the course is devoted to deterministic and probabilistic search methods, introducing the ideas of genetic algorithms. The course provides a wide variety of examples, including applications in electronics, decision-making, machine learning, and optimal control.

Intended Learning Outcomes

By the end of this course, successful students will be able to

1. apply classical search techniques;
2. apply and understand the Lagrange formalism;
3. phrase optimization problems in terms of suitable standard types, and address them accordingly;
4. solve optimization problems by means of dedicated software packages.

Indicative Literature

S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004.

J. Brinkhuis & V. Tikhomiriv, Optimization: Insights and Applications, Princeton University Press, 2005.

Usability and Relationship to other Modules

- This module builds on the first year Calc/LA modules and prepares the students for more challenging optimization aspects, which will be relevant in many third year projects, particularly in the fields of machine learning, robotics, control, and communication.

Examination Type: Module Examination

Type: Written examination

Duration: 120 min
Weight: 100%

Scope: Intended Learning Outcomes 1–3

Intended Learning Outcome 4 will be assessed through non graded tasks during the lecture.

7.16 Distributed Algorithms

<table>
<tr><td colspan="3">Module Name
Distributed Algorithms</td><td>Module Code
CA-S-CS-803</td><td>Level (type)
Year 3 (Specialization)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CF</td></tr>
<tr><td>CA-CS-803</td><td colspan="3">Distributed Algorithms</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

Kinga Lipskoch</td><td colspan="3">Program Affiliation

• Computer Science (CS)</td><td colspan="2">Mandatory Status

Mandatory elective for CS and IMS.</td></tr>
<tr><td rowspan="2">Entry Requirements

Pre-requisites

☒ Algorithms and Data Structures</td><td rowspan="2">

Co-requisites

☒ None</td><td rowspan="2">

Knowledge, Abilities, or Skills</td><td>Frequency

Annually (Fall or Spring)</td><td colspan="2">Forms of Learning and Teaching

• Class attendance (35 hours)
• Private study (70 hours)
• Exam preparation (20 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

None</td></tr>
<tr><td colspan="6">Content and Educational Aims

Distributed algorithms are the foundation of modern distributed computing systems. They are characterized by a lack of knowledge of a global state, a lack of knowledge of a global time, and inherent non-determinism in their execution. The course introduces basic distributed algorithms using an abstract formal model, which is centered on the notion of a transition system. The topics covered are logical clocks, distributed snapshots, mutual exclusion algorithms, wave algorithms, election algorithms, reliable broadcast algorithms, and distributed consensus algorithms. Process algebras are introduced as another formalism to describe distributed and concurrent systems.

The distributed algorithms introduced in this module form the foundation of computing systems that have to be scalable and fault-tolerant, e.g., large-scale distributed non-standard databases or distributed file systems. The course is recommended for students interested in the design of scalable distributed computing systems.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes

By the end of this module, students will be able to

• describe and analyze distributed algorithms using formal methods such as transition systems;
• explain different algorithms to solve election problems;
• illustrate the limitations of time to order events and how logical clocks and vector clocks overcome these limitations;
• apply distributed algorithms to produce consistent snapshots of distributed computations;
• describe the differences among wave algorithms for different topologies;
• analyze and implement distributed consensus algorithms such as Paxos and Raft;
• use a process algebra such as communicating sequential processes or π-calculus to model distributed algorithms.</td></tr>
<tr><td colspan="6">Indicative Literature

Maarten van Steen, Andrew S. Tanenbaum: Distributed Systems, 3rd edition, Pearson Education, 2017.</td></tr>
</table>

Nancy A. Lynch: Distributed Algorithms, Morgan Kaufmann, 1996.

Usability and Relationship to other Modules

- Mandatory elective 3rd Specialization module for CS and IMS major students.

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of the module

7.17 Computer Graphics

<table>
<tr><td colspan="2">Module Name
Computer Graphics</td><td>Module Code
CA-S-CS-801</td><td>Level (type)
Year 3
(CAREER - Specialization)</td><td>CP
5</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td>Number</td><td colspan="2">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CA-CS-801</td><td colspan="2">Computer Graphics</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

Sergey Kosov</td><td colspan="2">Program Affiliation
Computer Science (CS)</td><td colspan="2">Mandatory Status

Mandatory elective for CS and IMS</td></tr>
<tr><td colspan="2" rowspan="2">Entry Requirements

Pre-requisites: ☒ Algorithms and Data Structures
Co-requisites: ☒ None
Knowledge, Abilities, or Skills</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching
Class attendance (35 hours)
Private study (70 hours)
Exam preparation (20 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="5">Recommendations for Preparation

None</td></tr>
<tr><td colspan="5">Content and Educational Aims

This module deals with the digital synthesis and manipulation of visual content. The creation process of computer graphics spans from the creation of a three-dimensional (3D) scene to displaying or storing it digitally. Prominent tasks in computer graphics are geometry processing, rendering, and animation. Geometry processing is concerned with object representations such as surfaces and their modeling. Rendering is concerned with transforming a model of the virtual world into a set of pixels by applying models of light propagation and sampling algorithms. Animation is concerned with descriptions of objects that move or deform over time. This is an introductory module covering the concepts and techniques of 3D (interactive) computer graphics. It covers mathematical foundations, basic algorithms and principles, and some advanced methods and concepts. An introduction to the implementation of simple programs using a mainstream computer graphics library completes this module.</td></tr>
<tr><td colspan="5">Intended Learning Outcomes

By the end of this module, students will be able to
construct 3D geometry representations;
apply 3D transformations;
understand the algorithms and optimizations applied by graphics rendering systems;
explain the stages of modern computer graphics programmable pipelines
implement simple computer graphics applications using graphics frameworks such as OpenGL;
illustrate the techniques used to create animations.</td></tr>
<tr><td colspan="5">Indicative Literature

John Hughes, Andries van Dam, Morgan McGuire, David F. Sklar, James D. Foley, Steven K. Feiner, Kurt Akeley, Computer Graphics - Principles and Practice, 3rd edition, Addison-Wesley, 2013.

Peter Shirley, Steve Marschner, Fundamentals of Computer Graphics, 4th edition, Taylor and Francis Ltd, 2016.</td></tr>
</table>

Matt Pharr, Wenzel Jakob, Greg Humphreys, Physically Based Rendering: From Theory to Implementation, 3rd edition, Morgan Kaufmann, 2016.

Usability and Relationship to other Modules

- Mandatory elective for a major in CS.
- Serves as a 3rd year specialization module for IMS major students.
- Students with a strong interest in graphical user interfaces are encouraged to also select the Human–Computer Interaction specialization module, which discusses among other things how computer graphics can be used as a component of interactive graphical user interfaces.

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of the module

7.18 Software Engineering

Module Name Software Engineering		***Module Code*** CO-561	***Level (type)*** Year 2 (CORE)	***CP*** 7.5
Module Component				
Number	*Name*		*Type*	*CP*
CO-561-A	Software Engineering		Lecture	2.5
CO-561-B	Software Engineering Project		Project	5
Module Coordinator Peter Baumann	***Program Affiliation*** • Computer Science (CS)		***Mandatory Status*** Mandatory for CS Mandatory elective for IMS	
Entry Requirements *Pre-requisites* ☒ Algorithms and Data Structures	*Co-requisites* ☒ None	*Knowledge, Abilities, or Skills*	***Frequency*** Annually (Spring)	***Forms of Learning and Teaching*** • Class attendance (35 hours) • Independent study (10 hours) • Development work (132.5 hours) • Exam preparation (10 hours)
		Duration 1 semester	***Workload*** 187.5 hours	

Recommendations for Preparation

Students are expected to be able to develop software using an object-oriented programming language such as C++, and they should have access to a Linux system and associated software development tools.

Content and Educational Aims

This module is an introduction to software engineering and object-oriented software design. The lecture focuses on software quality and the methods to achieve and maintain it in environments of "multi-person construction of multi-version software." Based on their pre-existing knowledge of an object-oriented programming language, students are familiarized with software architectures, design patterns and frameworks, software components and middleware, Unified Modeling Language (UML)-based modelling, and validation by testing. Furthermore, the course addresses the more organizational topics of project management and version control.

The lectures are accompanied by a software project in which students have to develop a software solution to a given problem. The problem is described from the viewpoint of a customer and students working in teams have to execute a whole software project lifecycle. The teams have to create a suitable software architecture and software design, implement the components, and integrate the components. The teams have to ensure that basic quality requirements for the solution and the components are defined and satisfied. The students produce various artifacts such as design documents, source code, test cases and user documentation. All artifacts need to be maintained in a version control system and the commits should allow the instructor and other team members to track in a meaningful way the changes and who has been contributing them.

Intended Learning Outcomes

By the end of this module, students will be able to

- understand and apply object-oriented design patterns;
- read and write UML diagrams;
- contrast the benefits and drawbacks of different software development models;
- design and plan a larger software project involving a team development effort;
- translate requirements formulated by a customer into computer science terminology;
- evaluate the applicability of different software engineering models for a given software development project;
- assess the quality of a software design and its implementation;
- apply tools that assist in the various stages of a software development process;
- work effectively in a team toward the goals of the team.

Indicative Literature

Ian Sommerville: Software Engineering, Pearson, 2010.

Roger Pressman: Software Engineering – a Practitioner's Approach, McGraw-Hill, 2014.

Usability and Relationship to other Modules

- Mandatory for a major in CS
- Mandatory for a minor in CS
- Serves as mandatory elective 3rd year Specialization module for IMS major students.
- Pre-requisite for the CORE module Image Processing

Examination Type: Module Component Examinations

Module Component 1: Lecture

Assessment Type: Written examination
Duration: 60 min
Weight: 33%

Scope: The first three intended learning outcomes of the module (the lecture module component)

Module Component 2: Project

Assessment Type: Project
Weight: 66%

Scope: The remaining intended learning outcomes of the module (the project module component)

Completion: To pass this module, the examination of each module component has to be passed with at least 45%.

7.19 Databases and Web Services

<table>
<tr><td colspan="2">Module Name
Databases and Web Services</td><td>Module Code
CO-560</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td>Number</td><td colspan="2">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-560-A</td><td colspan="2">Databases and Web Services</td><td>Lecture</td><td>5</td></tr>
<tr><td>CO-560-B</td><td colspan="2">Databases and Web Services - Project</td><td>Project</td><td>2.5</td></tr>
<tr><td>Module Coordinator

Peter Baumann</td><td colspan="2">Program Affiliation
Computer Science (CS)</td><td colspan="2">Mandatory Status

Mandatory for CS
Mandatory elective for IMS</td></tr>
<tr><td rowspan="2">Entry Requirements

Pre-requisites

☒ Algorithms and Data Structures</td><td rowspan="2">Co-requisites

☒ None</td><td rowspan="2">Knowledge, Abilities, or Skills</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching
Class attendance (35 hours)
Project (97.5hours)
Independent Studies (35 hours)
Exam preparation (20 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

187.5 hours</td></tr>
<tr><td colspan="5">Recommendations for Preparation

Working knowledge of basic data structures, such as trees, is required as well as familiarity with an object-oriented programming language such as C++. Basic knowledge of algebra is useful. For the project work, students benefit from having basic hands-on skills using Linux and, ideally, basic knowledge of a scripting language such as Python (the official Python documentation is available on https://docs.python.org/).</td></tr>
<tr><td colspan="5">Content and Educational Aims

This module offers a combined introduction to databases and web services. The database part starts with database design using the Entity Relationship (ER) and Unified Modeling Language (UML) models, followed by relational databases and querying them through SQL, relational design theory, indexing, query processing, transaction management, and NoSQL/Big Data databases. In the web services part, the topics addressed include markup languages, three-tier application architectures, and web services. Security aspects are addressed from both perspectives.

A hands-on group project complements the theoretical aspects: on a self-chosen topic, students implement the core of a web-accessible information system using Python (or a similar language), MySQL, and Linux, guided through homework assignments.</td></tr>
</table>

Intended Learning Outcomes

By the end of this module, students will be able to

- read and write ER and UML diagrams;
- design and normalize data models for relational databases;
- write SQL queries and understand their evaluation by a database server;
- explain the concept of transactions and how to use transactions in application design;
- use web application frameworks to create dynamic websites;
- describe the differences of selected NoSQL data models and make a requirement-driven choice;
- restate three-tier architectures and their components;
- discuss the principles and basic mechanisms of reactive website design;
- summarize the security and privacy issues in the context of databases and web services.

Indicative Literature

Hector Garcia-Molina, Jeffrey D. Ullman, Jennifer D. Widom: Database Systems: The Complete Book. 2nd edition, Pearson, 2008.

Ragu Ramakrishnan: Database Management Systems. 3rd edition, McGraw Hill, 2003.

James Lee: Open Source Web Development with LAMP. Pearson, 2003.

Usability and Relationship to other Modules

- Mandatory for a major in CS
- Mandatory for a minor in CS
- Serves as a mandatory elective specialization module for IMS major students.
- Pre-requisite for the CORE module Secure and Dependable Systems
- This module introduces components that are widely used by modern applications and information systems. Students can apply their knowledge in the software engineering module. This module serves as a default advanced level minor module.

Examination Type: Module Component Examinations

Module Component 1: Lecture

Assessment Type: Written examination Duration: 120 min

Weight: 67%

Scope: All intended learning outcomes of the excluding the practical aspects

Module Component 2: Project

Assessment Type: Project

Weight: 33%

Scope: All practical aspects of the intended learning outcomes

Completion: To pass this module, the examination of each module component has to be passed with at least 45%.

7.20 Digital Design

Module Name Digital Design			**_Module Code_** CA-S-ECE-803	**_Level (type)_** Year 3 (CAREER - Specialization)	**_CP_** _5_
Module Components					
Number	_Name_			_Type_	_CP_
CA-ECE-803	Digital Design			Lecture/Lab	5
Module Coordinator Fangning Hu	**_Program Affiliation_** • Electrical and Computer Engineering (ECE)			**_Mandatory Status_** Mandatory elective for ECE, IMS, CS	
Entry Requirements _Pre-requisites_ ☒ None	_Co-requisites_ ☒ None	_Knowledge, Abilities, or Skills_	**_Frequency_** Annually (Fall)	**_Forms of Learning and Teaching_** • Lecture/Lab (35 hours) • Private study (90 hours)	
			Duration 1 semester	**_Workload_** 125 hours	

Recommendations for Preparation

Students may prepare themselves with books like "Brent E. Nelson, Designing Digital Systems, 2005" and "Pong P. Chu, RTL Hardware Design Using VHDL, A John Wiley & Sons, Inc, Publication, 2006"

Content and Educational Aims

The current trend of digital system design is towards hardware description languages (HDLs) that allow compact description of very complex hardware constructs. The module provides a sound introduction to basic components of a digital system such as logic gates, multiplexers, decoders, flip-flops and registers as well as VHDLs such as types, signals, sequential and concurrent statements. Methods and principle of designing complex digital systems such as finite state machines, hierarchical design, pipelined design, RTL design methodology and parameterized design will also be introduced. Students will learn VHDL for programming FPGA boards to realize small digital systems in hardware (i.e. on FPGA boards). Such digital systems could be adders, multiplexers, control units, multipliers, asynchronous serial communication modules (UART). At the end of the module, the students should be able to design a simple digital system by VHDL on an FPGA board.

Intended Learning Outcomes

By the end of this module, students will be able to

- understand the principle of digital system design based on standard building blocks and components;
- design a complex digital system;
- understand the limitations of a given hardware platform (here FPGAs), modify algorithms where necessary, and structure them suitably in order to optimize performance and complexity;
- use a typical development system;
- program in VHDL;
- program an FPGA board.

Indicative Literature

Brent E. Nelson, *Designing Digital Systems with SystemVerilog*, 2018, ISBN-13: 978-1980926290 Pong P. Chu, *RTL Hardware Design Using VHDL*, Wiley-IEEE Press, 2006, ISBN-13: 978-0471720928
Usability and Relationship to other Modules • This module introduces how to design digital systems and how to realize them on a FPGA board which could also serve as a specialization module for students from Computer Science and Robotics and Intelligent Systems. • Mandatory elective 3rd year Specialization module for ECE, CS and IMS major students.
Examination Type: Module Examination Assessment Type: written examination   Duration: 120 min Scope: All intended learning outcomes of the module   Weight: 100%

7.21 PCB Design and Measurement Automation

<table>
<tr><td colspan="3">Module Name
PCB Design and Measurement Automation</td><td>Module Code
CO-527</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5.0</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-527-A</td><td colspan="3">PCB Design and Measurement Automation</td><td>Lab</td><td>5.0</td></tr>
<tr><td>Module Coordinator

Prof. Dr.-Ing. Werner Henkel</td><td colspan="3">Program Affiliation

- Electrical and Computer Engineering (ECE)</td><td colspan="2">Mandatory Status

Mandatory for ECE
Mandatory elective for IMS</td></tr>
<tr><td rowspan="2">Entry Requirements

Pre-requisites

☒ General Electrical Engineering I
☒ General Electrical Engineering II

OR

Introduction to RIS (IMS)</td><td rowspan="2">

Co-requisites

☒ None</td><td rowspan="2">

Knowledge, Abilities, or Skills

• Knowledge of Fourier series and transforms
• Basic knowledge of electronics compo-nents and circuits
• Matlab</td><td>Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lab (59.5 hours)
• Private Study (65.5 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Download material from corresponding Web pages and get to know the tasks and how the tools and equipment works.</td></tr>
<tr><td colspan="6">Content and Educational Aims
The module (lab) covers mainly two aspects that are seen to be important for employability. One share of the lab deals with measurement automation. Similar tasks, one also finds in industrial automation or monitoring, sometimes using the same tools. Students will learn to use Matlab and Labview for measurement automation tasks. In there, students will also get acquainted with more advanced measurement equipment, like high-end digital scopes, network, and spectrum analyzers. The students will measure standard telephone cables in their properties, which will require a treatment of transmission line theory and transformers/baluns. These theoretical aspects will also be covered.

The second major aspect handled in the lab makes students aware that electrical/electronic components have non-ideal behaviors, e.g., that a capacitor can act as an inductor in some frequency range. It makes students also aware of the problems in selecting the right component for a certain function inside a circuit, caring not just for the frequency range and the variation of properties with frequency, but also power, current, and voltage limits.
Then, a typical circuit design path will be taught, starting from schematics to placement of components and routing. Important aspects of printed circuit board design are treated, like how analog and digital power supplies have to be realized, how mass connections should look like, what measures have to be taken to block unwanted signal coupling is avoided, e.g., blocking capacitors, star-like power supply wiring.

Students also practice scientific writing in line with scientific writing rules as a preparation for their BSc thesis.</td></tr>
</table>

Intended Learning Outcomes

By the end of this module, students should be able to

1. use vector network analyzers, spectrum analyzers, and more advanced digital scopes;
2. learn how to program with LabVIEW;
3. remotely control measurement equipment using Matlab or LabVIEW;
4. describe principles of remote control;
5. know transmission line theory and how transformers/baluns are modeled;
6. measure and determine line parameters;
7. taking non-ideal behavior of passive and active components into account and be able to select components according to their parameters and limitations;
8. design printed circuit boards (PCB) with typical tools and a typical design cycle consisting of schematics, placement, and routing;
9. design analog and digital power routes, shielding ground connections, use measures to block unwanted ingress and coupling;
10. organize work contributions of group members in the lab and in reporting;
11. write reports in line with scientific writing rules as a preparation for their BSc thesis.

Usability and Relationship to other Modules

- This module builds on previous electronics knowledge and rounds this knowledge up with the final PCB design.
- Having learned to use Matlab in earlier modules, mostly for signal processing tasks, this module shows another application and provides a view into graphical programming as another option which they have seen earlier in the form of Simulink
- The module prepares students for a thesis with PCB design aspects.
- Mandatory for major in ECE.
- Serves as a mandatory elective 3rd year Specialization module for IMS major students.

Indicative Literature

Hank Zumbahlen Ed., *Basic Linear Design*, Analog Devices, 2007.

Walt Jung Ed., *Op Amp Applications*, Analog Devices, 2005.

Tim Williams, *The Circuit Designer's Companion*, 3rd ed., Newnes, 2012.

National Instruments, *LabVIEW, Getting Started with LabVIEW*, 2007.

Examination Type: Module Examination

Assessment Component 1: Written examination — Duration: 120 min, Weight: 50%

Scope: Intended learning outcomes of the lecture/theory component (4, 5, 7, 9).

Assessment Component 2: Lab reports — Length: 5-10 pages per experiment session, Weight: 50%

Scope: Intended learning outcomes of the lab (1-3, 6-11).

Completion: This module is passed with an assessment-component weighted average grade of 45% or higher.

7.22 Information Theory

<table>
<tr><td colspan="2">Module Name
Information Theory</td><td>Module Code
CO-525</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5.0</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td>Number</td><td colspan="2">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-525-A</td><td colspan="2">Information Theory</td><td>Lecture</td><td>5.0</td></tr>
<tr><td>Module Coordinator

Prof. Dr.-Ing. Werner Henkel</td><td colspan="2">Program Affiliation

- Electrical and Computer Engineering (ECE)</td><td colspan="2">Mandatory Status

Mandatory for ECE
Mandatory elective for CS and IMS</td></tr>
<tr><td colspan="2">Entry Requirements

Pre-requisites

☒ None

Co-requisites

☒ None

Knowledge, Abilities, or Skills

• Signals and Systems contents, such as DFT and convolution
• Notion of probability, combinatorics basics as taught in Methods module “Probability and Random Processes"</td><td>Frequency

Annually (Spring)

Duration

1 semester</td><td colspan="2">Forms of Learning and Teaching

• Lectures (35 hours)
• Private Study (90 hours)

Workload

125 hours</td></tr>
<tr><td colspan="5">Recommendations for Preparation

Some basic knowledge of communications and sound understanding of probability is recommended. Hence, it is strongly advised to take the methods and skills course Probability and Random Processes prior to this module. Nevertheless, probability basics will also be revised within the module.</td></tr>
<tr><td colspan="5">Content and Educational Aims

Information theory serves as the most important foundation for communication systems. The module provides an analytical framework for modeling and evaluating point-to-point and multi-point communication. After a short rehearsal of probability and random variables and some excursion to random number generation, the key concept of information content of a signal source and information capacity of a transmission medium are precisely defined, and their relationships to data compression algorithms and error control codes are examined in detail. The module aims to install an appreciation for the fundamental capabilities and limitations of information transmission schemes and to provide the mathematical tools for applying these ideas to a broad class of communications systems.
The module contains also a coverage of different source-coding algorithms like Huffman, Lempel-Ziv-(Welch), Shannon-Fano-Elias, Arithmetic Coding, Runlength Encoding, Move-to-Front transform, PPM, and Context Tree Weighting. In Channel coding, finite fields, some basic block and convolutional codes, and the concept of iterative decoding will be introduced. Aside from source and channel aspects, an introduction to security is given, including public-key cryptography. Information theory is a standard module in every communications-oriented Bachelor’s program.</td></tr>
<tr><td colspan="5">Intended Learning Outcomes
By the end of this module, students should be able to
• explain what is understood as the information content of data and the corresponding limits of data compression algorithms;
• design and apply fundamental algorithms in data compression;</td></tr>
</table>

- explain the information theoretic limits of data transmission;
- apply the mathematical basics of channel coding and cryptography;
- implement some channel coding schemes;
- differentiate the principles of encryption and authentication schemes and implement discussed procedures;

Indicative Literature

Thomas M. Cover, Joy A. Thomas, *Elements of Information Theory*, 2nd ed., Wiley, Sept. 2006.

David Salomon, *Data Compression, The Complete Reference*, 4th ed., Springer, 2007.

Usability and Relationship to other Modules

- Although not a mandatory prerequisite, this module is ideally taken before Coding Theory (CA-ECE-802)
- All communications-related modules are naturally based on information theory
- Students from Computer Science or related programs, also students taking Bio-informatics modules, profit from information-theoretic knowledge and source coding (compression) algorithms. Students from Computer Science would also be interested in the algebraic basics for error-correcting codes and cryptology, fields which area also introduced shortly.
- Mandatory for a major in ECE.
- Serves as a mandatory elective 3rd year Specialization module for CS and IMS major students.

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of the module.

7.23 Stochastic Processes

<table>
<tr><td colspan="3">Module Name

Stochastic Processes</td><td>Module Code

CA-S-MATH-803</td><td>Level (type)

Year 2/3 (Specialization)</td><td>CP

5.0</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CA-MATH-803</td><td colspan="3">Stochastic Processes</td><td>Lecture</td><td>5.0</td></tr>
<tr><td>Module Coordinator

K. Mallahi-Karai</td><td colspan="3">Program Affiliation

• Mathematics</td><td colspan="2">Mandatory Status

Mandatory elective for Mathematics and IMS</td></tr>
<tr><td rowspan="2">Entry Requirements

Pre-requisites

☒ “Applied Mathematics” or “Probability and Random Processes”</td><td rowspan="2">Co-requisites

☒None</td><td rowspan="2">Knowledge, Abilities, or Skills

• None beyond formal pre-requisites</td><td>Frequency

Biennially (Fall)</td><td colspan="2">Forms of Learning and Teaching

• Lectures (35 hours)
• Private study (90 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Review of Probability and Analysis I</td></tr>
<tr><td colspan="6">Content and Educational Aims

This module serves as an introduction to the theory of stochastic processes. It starts with a review of Kolmogorov axioms for probability spaces and continues by providing a rigorous treatment of topics such as the independence of events and Borel-Cantelli Lemma, Kolmogorov’s zero-one law, random variables, expected value and variance, the weak and strong laws of large numbers, and the Central limit theorem. More advanced topics that will follow include finite and countable state Markov chains, Galton-Watson trees, and the Wiener process. Several relevant applications that will be discussed are percolation on graphs, the application of Markov chains to sampling problems, and probabilistic methods in graph theory. The module also includes examples from mathematical finance.</td></tr>
</table>

Intended Learning Outcomes

By the end of the module, students will be able to

- demonstrate their mastery of basic stochastic methods;
- develop ability to use stochastic processes to model real-world problems, e.g. in finance;
- analyze the definition of basic probabilistic objects, and their numerical features;
- formulate and design methods and algorithms for solving applied problems based on ideas from stochastic processes.

Indicative Literature

R. Durrette (2019). Probability: Theory and Examples. Cambridge: Cambridge University Press.

A. Koralov and Ya. Sinai (2007). Theory of Probability and Random Processes, Berlin: Springer.

Usability and Relationship to other Modules

- This module is a specialization module in Mathematics to be taken in Semester 4 or 6.
- Serves as a mandatory elective 3rd year Specialization module for IMS major students.

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of this module

7.24 Stochastic Methods Lab

<table>
<tr><td colspan="3">Module Name
Stochastic Methods Lab</td><td>Module Code
CA-S-MATH-811</td><td>Level (type)
Year 2/3 (Specialization)</td><td>CP
7.5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CA-MATH-811</td><td colspan="3">Stochastic Methods Lab</td><td>Lecture with integrated Lab component</td><td>7.5</td></tr>
<tr><td>Module Coordinator

S. Petrat</td><td colspan="3">Program Affiliation

• Mathematics</td><td colspan="2">Mandatory Status

Mandatory elective for Mathematics and IMS</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒Calculus and Elements of Linear Algebra I and II

Co-requisites: ☒ None

Knowledge, Abilities, or Skills:
• Python programming as can be learned in the first-year module “Applied Mathematics” or any Programming in Python class
• Advanced Multivariable Calculus as taught in the first-year module “Applied Mathematics” is helpful, but not required.
• Analysis I is helpful, but not required.
•</td><td>Frequency

Biennially (Fall)</td><td colspan="2">Forms of Learning and Teaching

• Class sessions (52.5 hours)
• Private study (135 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

187.5 hours</td></tr>
</table>

Recommendations for Preparation

- Review the content of Calculus and Elements of Linear Algebra II
- Review Python programming
- Pre-install *Anaconda Python* on your own laptop and know how to edit and start simple Python programs in a Python IDE like *Spyder* (which comes bundled as part of *Anaconda Python*).

Content and Educational Aims

This module is a first hands-on introduction to stochastic modeling. Examples will mostly come from the area of Financial Mathematics, so that this module plays a central role in the education of students interested in Quantitative Finance and Mathematical Economics. The module is taught as an integrated lecture-lab, where short theoretical units are interspersed with interactive computation and computer experiments.

Topics include a short introduction to the basic notions of financial mathematics, binomial tree models, discrete Brownian paths, stochastic integrals and ODEs, Ito’s Lemma, Monte-Carlo methods, finite differences solutions, the Black-Scholes equation, and an introduction to time series analysis, parameter estimation, and calibration. Students will program and explore all basic techniques in a numerical programming environment and apply these algorithms to real data whenever possible.

Intended Learning Outcomes
By the end of the module, students will be able to

- apply fundamental concepts of deterministic and stochastic modeling;
- design, conduct, and interpret controlled in-silico scientific experiments;
- analyze the basic concepts of financial mathematics and their role in finance;
- write computer code for basic financial calculations, binomial trees, stochastic differential equations, stochastic integrals and time series analysis;
- compare their programs and predictions in the context of real data;
- demonstrate the usage of a version control system for collaboration and the submission of code and reports.

Indicative Literature

Y.-D. Lyuu (2002). Financial Engineering and Computation - Principles, Mathematics, Algorithms. Camridge: Cambridge University Press.
J.C. Hull (2015). Options, Futures and other Derivatives, 9th edition. New York: Pearson.
A. Etheridge (2002). A Course in Financial Calculus. Cambridge: Cambridge University Press.
D.J. Higham (2001). An Algorithmic Introduction to Numerical Simulation of Stochastic Differential Equations, SIAM Rev. 43(3):525-546.
D.J. Higham (2004). Black-Scholes Option Valuation for Scientific Computing Students, Computing in Science & Engineering 6(6):72-79.

Usability and Relationship to other Modules

- This module is part of the core education in Applied Mathematics
- It is also valuable for students in Physics, Computer Science, IMS, and ECE, either as part of a minor in Mathematics, or as an elective module.
- Serves as a mandatory elective 3rd year specialization module for IMS major students.

Examination Type: Module Examination

Assessment Type: Project (portfolio)

Weight: 100%

Scope: All intended learning outcomes of this module

7.25 Operations Research

Module Name		Module Code	Level (type)	CP
Operations Research		CO-583	Year 2 (CORE)	*5*
Module Components				
Number	*Name*		*Type*	*CP*
CO-583-A	Operations Research		Lecture	5

Module Coordinator	Program Affiliation	Mandatory Status
Prof. Dr. Marcel Oliver	• Industrial Engineering & Management (IEM)	Mandatory for IEM Mandatory elective for IMS

Entry Requirements			Frequency	Forms of Learning and Teaching
Pre-requisites	*Co-requisites*	*Knowledge, Abilities, or Skills*	Annually (Fall)	• Lectures (35 hours) • Private Study (90 hours)
☒ None	☒ None	• Basic spreadsheet software skills (e.g. MS Excel) • basic calculus and matrix algebra • basic knowledge in logistics	**Duration** 1 semester	**Workload** 125 hours

Recommendations for Preparation

Revise basic calculus, matrix algebra and spreadsheet software functions.

Content and Educational 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 finds optimal or near-optimal solutions to complex decision-making problems. Operations Research is concerned with determining the maximum (of profit, performance, or yield) or the minimum (of loss, risk, or cost) of some real-world objective. This module introduces students to the modelling of decision problems and the use of quantitative methods and techniques for effective decision-making.

Intended Learning Outcomes

By the end of this module, students will be able to

- calculate optimal or near-optimal solutions to complex decision-making problems using operations research methods;
- design mathematical models for business problems;
- apply techniques such as linear programming, dynamic programming or stochastic programming to solve business problems;
- resolve common network optimization problems such as transportation, shortest path, minimum spanning tree, and maximum flow problems.

Indicative Literature

Hillier, F. S. & Lieberman, G.J. (2009). Introduction to Operations Research. McGraw-Hill. New York, NY.

Usability and Relationship to other Modules • Pre-requisite for 3rd-year IEM Specialization modules and Thesis • Serves as a 3rd-year Specialization module for major students in IMS • Elective for all other undergraduate study programs.
Examination Type: Module Examination Assessment Type: Written examination Duration: 120 minutes Weight: 100 % Scope: All intended learning outcomes of the module.

7.26 Web Application Development

Module Name	***Module Code***	***Level (type)***	***CP***
Web Application Development	CA-S-CS-804	Year 3 (CAREER - Specialization)	5

Module Components

Number	*Name*	*Type*	*CP*
CA-CS-804-A	Web Application Development - Lecture	Lecture	2.5
CA-CS-804-B	Web Application Development - Project	Project	2.5

Module Coordinator	***Program Affiliation***	***Mandatory Status***
N.N.	• Computer Science (CS)	Mandatory elective for CS and Mandatory elective for IMS

Entry Requirements

Pre-requisites	*Co-requisites*	*Knowledge, Abilities, or Skills*
☒ *Databases and Web Services*	☒ None	

Frequency	***Forms of Learning and Teaching***
Annually (Spring)	• Class attendance (17.5 hours) • Private study (40 hours) • Project work (50 hours) • Exam preparation (17.5 hours)

Duration	***Workload***
1 semester	125 hours

Recommendations for Preparation

None

Content and Educational Aims

A web application is a client-server computer program where the client provides the user interface and the client side logic runs in a web browser or as an app running on a mobile device such as a smart phone or a tablet. A key characteristic is that more complex application logic and data storage is realized by a server offering a web application programming interface.

This module focuses on the client side of web application and introduces technologies that can be used to implement interactive user interfaces and client side logic. It builds on the module databases and web services, which covers the data storage components and server side logic of web applications.

This modules consists of a lecture and an associated project. The lecture component introduces programming languages and frameworks that are widely used for implementing the client side of web applications such as Java, Kotlin, Swift, JavaScript and frameworks built on top of them. In the project component, students develop web applications and test them on existing and openly accessible web services.

Intended Learning Outcomes

By the end of this module, students will be able to

- explain the document object model behind HTML and its relation to CSS;
- discuss the principles and basic mechanisms of reactive website design;
- analyze the interactions between web applications and web services.
- use languages such as Java, Kotlin, or Swift to implement mobile web applications;
- use web standards such as HTML, CSS, and JavaScript to implement web applications running in standard web browsers.

Indicative Literature

Stoyan Stefanov: JavaScript Patterns, O'Reilly Media, 2010.

Alexey Soshin: Hands-on Design Patterns with Kotlin, Packt Publishing, 2018.

Alex Banks, Eve Porcello: Learning React: Functional Web Development.with React and Flux, O'Reilly, 2017.

Usability and Relationship to other Modules

- Mandatory for a major in CS.
- Mandatory for a major in IMS.

Examination Type: Module Component Examinations

Module Component 1: Lecture

Assessment Type: Written examination — Duration: 120 min, Weight: 50%

Scope: First group of intended learning outcomes of the module

Module Component 2: Project

Assessment Type: Project — Weight: 50%

Scope: Second group of intended learning outcomes of the module

Completion: To pass this module, the examination of each module component has to be passed with at least 45%.

7.27 Internship / Startup and Career Skills

<table>
<tr><td colspan="3">Module Name
Internship / Startup and Career Skills</td><td>Module Code
CA-INT-900</td><td>Level (type)
Year 3
(CAREER)</td><td>CP
15</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CA-INT-900-0</td><td colspan="3">Internship</td><td>Internship</td><td>15</td></tr>
<tr><td>Module Coordinator

Predrag Tapavicki & Christin Klähn (CSC Organization); SPC / Faculty Startup Coordinator (Academic responsibility);</td><td colspan="3">Program Affiliation

• CAREER module for undergraduate study programs</td><td colspan="2">Mandatory Status

Mandatory for all undergraduate study programs except IEM</td></tr>
<tr><td>Entry Requirements

Pre-requisites

☒ at least 15 CP from CORE modules in the major</td><td>Co-requisites

☒ None</td><td>Knowledge, Abilities, or Skills

• Information provided on CSC pages (see below)
• Major specific knowledge and skills</td><td>Frequency

Annually (Spring/Fall)

Duration
1 semester</td><td colspan="2">Forms of Learning and Teaching

• Internship/Start-up
• Internship event
• Seminars, info-sessions, workshops and career events
• Self-study, readings, online tutorials

Workload

375 Hours consisting of:
• Internship (308 hours)
• Workshops (33 hours)
• Internship Event (2 hours)
• Self-study (32 hours)</td></tr>
<tr><td colspan="6">Recommendations for Preparation

• Reading the information in the menu sections titled “Internship Information,” “Career Events,” “Create Your Application,” and “Seminars & Workshops” at the Career Services Center website: https://jacobs-university.jobteaser.com/en/users/sign_in?back_to_after_login=%2F
• Completing all four online tutorials about job market preparation and the application process, which can be found here: https://jacobs-university.jobteaser.com/en/users/sign_in?back_to_after_login=%2F
• Participating in the internship events of earlier classes</td></tr>
<tr><td colspan="6">Content and Educational Aims
The aims of the internship module are reflection, application, orientation, and development: for students to reflect on their interests, knowledge, skills, their role in society, the relevance of their major subject to society, to apply these skills and this knowledge in real life whilst getting practical experience, to find a professional orientation, and to develop their personality and in their career. This module supports the programs’ aims of preparing students for gainful, qualified employment and the development of their personality.

The full-time internship must be related to the students’ major area of study and extends lasts a minimum of two consecutive months, normally scheduled just before the 5th semester, with the internship event and submission of the internship report in the 5th semester. Upon approval by the SPC and CSC, the internship may take place at other times, such as before teaching starts in the 3rd semester or after teaching finishes in the 6th semester. The Study</td></tr>
</table>

Program Coordinator or their faculty delegate approves the intended internship a priori by reviewing the tasks in either the Internship Contract or Internship Confirmation from the respective internship institution or company. Further regulations as set out in the Policies for Bachelor Studies apply.

Students will be gradually prepared for the internship in semesters 1 to 4 through a series of mandatory information sessions, seminars, and career events.
The purpose of the Career Services Information Sessions is to provide all students with basic facts about the job market in general, and especially in Germany and the EU, and services provided by the Career Services Center.
In the Career Skills Seminars, students will learn how to engage in the internship/job search, how to create a competitive application (CV, Cover Letter, etc.), and how to successfully conduct themselves at job interviews and/or assessment centers. In addition to these mandatory sections, students can customize their skill set regarding application challenges and their intended career path in elective seminars.
Finally, during the Career Events organized by the Career Services Center (e.g. the annual Jacobs Career Fair and single employer events on and off campus), students will have the opportunity to apply their acquired job market skills in an actual internship/job search situation and to gain their desired internship in a high-quality environment and with excellent employers.

As an alternative to the full-time internship, students can apply for the StartUp Option. Following the same schedule as the full-time internship, the StartUp Option allows students who are particularly interested in founding their own company to focus on the development of their business plan over a period of two consecutive months. Participation in the StartUp Option depends on a successful presentation of the student's initial StartUp idea. This presentation will be held at the beginning of the 4th semester. A jury of faculty members will judge the student's potential to realize their idea and approve the participation of the students. The StartUp Option is supervised by the Faculty StartUp Coordinator. At the end of StartUp Option, students submit their business plan. Further regulations as outlined in the Policies for Bachelor Studies apply.

The concluding Internship Event will be conducted within each study program (or a cluster of related study programs) and will formally conclude the module by providing students the opportunity to present on their internships and reflect on the lessons learned within their major area of study. The purpose of this event is not only to self-reflect on the whole internship process, but also to create a professional network within the academic community, especially by entering the Alumni Network after graduation. It is recommended that all three classes (years) of the same major are present at this event to enable networking between older and younger students and to create an educational environment for younger students to observe the "lessons learned" from the diverse internships of their elder fellow students.

Intended Learning Outcomes

By the end of this module, students should be able to

- describe the scope and the functions of the employment market and personal career development;
- apply professional, personal, and career-related skills for the modern labor market, including self-organization, initiative and responsibility, communication, intercultural sensitivity, team and leadership skills, etc.;
- independently manage their own career orientation processes by identifying personal interests, selecting appropriate internship locations or start-up opportunities, conducting interviews, succeeding at pitches or assessment centers, negotiating related employment, managing their funding or support conditions (such as salary, contract, funding, supplies, work space, etc.);
- apply specialist skills and knowledge acquired during their studies to solve problems in a professional environment and reflect on their relevance in employment and society;
- justify professional decisions based on theoretical knowledge and academic methods;
- reflect on their professional conduct in the context of the expectations of and consequences for employers and their society;
- reflect on and set their own targets for the further development of their knowledge, skills, interests, and values;
- establish and expand their contacts with potential employers or business partners, and possibly other students and alumni, to build their own professional network to create employment opportunities in the future;
- discuss observations and reflections in a professional network.

Indicative Literature

Not specified

Usability and Relationship to other Modules

- Mandatory for a major in BCCB, Chemistry, CS, EES, GEM, IBA, IRPH, Psychology, Math, MCCB, Physics, IMS, and ISS.
- This module applies skills and knowledge acquired in previous modules to a professional environment and provides an opportunity to reflect on their relevance in employment and society. It may lead to thesis topics.

Examination Type: Module Examination

Assessment Type: Internship Report or Business Plan and Reflection	Length: approx. 3.500 words
Scope: All intended learning outcomes	Weight: 100%

7.28 Bachelor Thesis and Seminar

<table>
<tr><td colspan="3">Module Name

Bachelor Thesis and Seminar</td><td>Module Code

CA-RIS-800</td><td>Level (type)

Year 3 (CAREER)</td><td>CP

15</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CA-RIS-800-T</td><td colspan="3">Thesis</td><td>Thesis</td><td>12</td></tr>
<tr><td>CA-RIS-800-S</td><td colspan="3">Thesis Seminar</td><td>Seminar</td><td>3</td></tr>
<tr><td>Module Coordinator

Study Program Chair</td><td colspan="3">Program Affiliation

• All undergraduate programs</td><td colspan="2">Mandatory Status

Mandatory for all undergraduate programs</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements</td><td>Frequency

Annually (Spring)</td><td colspan="2" rowspan="2">Forms of Learning and Teaching

• Self-study/lab work (350 hours)
• Seminars (25 hours)</td></tr>
<tr><td></td></tr>
<tr><td>Pre-requisites

☒ Students must be in their third year and have taken at least 30 CP from CORE modules in their major.</td><td>Co-requisites

☒ None</td><td>Knowledge, Abilities, or Skills

• comprehensive knowledge of the subject and deeper insight into the chosen topic;
• ability to plan and undertake work independently;
• skills to identify and critically review literature.</td><td>Duration

1 semester</td><td colspan="2">Workload

375 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

• Identify an area or a topic of interest and discuss this with your prospective supervisor in a timely manner.
• Create a research proposal including a research plan to ensure timely submission.
• Ensure you possess all required technical research skills or are able to acquire them on time.
• Review the University's Code of Academic Integrity and Guidelines to Ensure Good Academic Practice.</td></tr>
</table>

Content and Educational Aims

This module is a mandatory graduation requirement for all undergraduate students to demonstrate their ability to address a problem from their respective major subject independently using academic/scientific methods within a set time frame. Although supervised, this module requires students to be able to work independently and systematically and set their own goals in exchange for the opportunity to explore a topic that excites and interests them personally and that a faculty member is interested in supervising. Within this module, students apply their acquired knowledge about their major discipline and their learned skills and methods for conducting research, ranging from the identification of suitable (short-term) research projects, preparatory literature searches, the realization of discipline-specific research, and the documentation, discussion, interpretation, and communication of research results.

This module consists of two components, an independent thesis and an accompanying seminar. The thesis component must be supervised by a Jacobs University faculty member and requires short-term research work, the results of which must be documented in a comprehensive written thesis including an introduction, a justification of the methods, results, a discussion of the results, and a conclusion. The seminar provides students with the opportunity to practice their ability to present, discuss, and justify their and other students' approaches, methods, and results at various stages of their research in order to improve their academic writing, receive and reflect on formative feedback, and therefore grow personally and professionally.

Intended Learning Outcomes

On completion of this module, students should be able to

1. independently plan and organize advanced learning processes;
2. design and implement appropriate research methods, taking full account of the range of alternative techniques and approaches;
3. collect, assess, and interpret relevant information;
4. draw scientifically-founded conclusions that consider social, scientific, and ethical factors;
5. apply their knowledge and understanding to a context of their choice;
6. develop, formulate, and advance solutions to problems and debates within their subject area, and defend these through argument;
7. discuss information, ideas, problems, and solutions with specialists and non-specialists.

Indicative Literature

Justin Zobel, *Writing for Computer Science, 3rd edition,* Springer, 2015.

Usability and Relationship to other Modules

- This module builds on all previous modules in the undergraduate program. Students apply the knowledge, skills, and competencies they have acquired and practiced during their studies, including research methods and their ability to acquire additional skills independently as and if required.

Examination Type: Module Component Examinations

Module Component 1: Thesis
Assessment type: Thesis
Scope: All intended learning outcomes, mainly 1-6.
Weight: 80%

Length: approx. 10,000 – 14,000 words (25–35 pages), excluding front and back matter.

Module Component 2: Seminar
Assessment type: Presentation

Duration: approx. 15 to 30 minutes
Weight: 20%

Scope: The presentation focuses mainly on ILOs 6 and 7, but by nature of these ILOs it also touches on the others.

Completion: To pass this module, both module component examinations have to be passed with at least 45%.

Two separate assessments are justified by the size of this module and the fact that the justification of solutions to problems and arguments (ILO 6) and discussion (ILO 7) should at least have verbal elements. The weights of the types of assessments are commensurate with the sizes of the respective module components.

7.29 Jacobs Track Modules

7.29.1 Methods and Skills Modules

7.29.1.1 Calculus and Elements of Linear Algebra I

<table>
<tr><td colspan="3">Module Name
Calculus and Elements of Linear Algebra I</td><td>Module Code
JTMS-MAT-09</td><td>Level (type)
Year 1 (Methods)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>JTMS-09</td><td colspan="3">Calculus and Elements of Linear Algebra I</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

Marcel Oliver, Tobias Preußer</td><td colspan="3">Program Affiliation

• Jacobs Track – Methods and Skills</td><td colspan="2">Mandatory Status

Mandatory for CS, ECE, IMS, MATH and Physics
Mandatory elective for EES</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ None
Co-requisites: ☒ None
Knowledge, Abilities, or Skills
• Knowledge of Pre-Calculus at High School level (Functions, inverse functions, sets, real numbers, polynomials, rational functions, trigonometric functions, logarithm and exponential function, parametric equations, tangent lines, graphs, elementary methods for solving systems of linear and nonlinear equations)
• Knowledge of Analytic Geometry at High School level (vectors, lines, planes,</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching

• Lectures (35 hours)
• Private study (90 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
</table>

	reflection, rotation, translation, dot product, cross product, normal vector, polar coordinates) • Some familiarity with elementary Calculus (limits, derivative) is helpful, but not strictly required.		

Recommendations for Preparation

Review all of higher-level High School Mathematics, in particular the topics explicitly named in “Entry Requirements – Knowledge, Ability, or Skills” above.

Content and Educational Aims

This module is the first in a sequence introducing mathematical methods at the university level in a form relevant for study and research in the quantitative natural sciences, engineering, Computer Science, and Mathematics. The emphasis in these modules is on training operational skills and recognizing mathematical structures in a problem context. Mathematical rigor is used where appropriate. However, a full axiomatic treatment of the subject is provided in the first-year modules “Analysis I” and “Linear Algebra”.

The lecture comprises the following topics

- Brief review of number systems, elementary functions, and their graphs
- Brief introduction to complex numbers
- Limits for sequences and functions
- Continuity
- Derivatives
- Curve sketching and applications (isoperimetric problems, optimization, error propagation)
- Introduction to Integration and the Fundamental Theorem of Calculus
- Review of elementary analytic geometry
- Vector spaces, linear independence, bases, coordinates
- Matrices and matrix algebra
- Solving linear systems by Gauss elimination, structure of general solution
- Matrix inverse

Intended Learning Outcomes

By the end of the module, students will be able to

- apply the methods described in the content section of this module description to the extent that they can solve standard text-book problems reliably and with confidence;
- recognize the mathematical structures in an unfamiliar context and translate them into a mathematical problem statement;
- recognize common mathematical terminology used in textbooks and research papers in the quantitative sciences, engineering, and mathematics to the extent that they fall into the content categories covered in this module.

Indicative Literature

S.I. Grossman (2014). Calculus of one variable, 2nd edition. Cambridge: Academic Press.

S.A. Leduc (2003). Linear Algebra. Hoboken: Wiley.

K. Riley, M. Hobson, S. Bence (2006). Mathematical Methods for Physics and Engineering, third edition. Cambridge: Cambridge University Press.

Usability and Relationship to other Modules

- The module is a mandatory / mandatory elective module of the Methods and Skills area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- The module is followed by “Calculus and Elements of Linear Algebra II”. All students taking this module are expected to register for the follow-up module.

- A rigorous treatment of Calculus is provided in the module “Analysis I”. All students taking “Analysis I” are expected to either take this module or exceptionally satisfy the conditions for advanced placement as laid out in the Jacobs Academic Policies for Undergraduate Study.
- The second-semester module “Linear Algebra” will provide a complete proof-driven development of the theory of Linear Algebra. Students enrolling in “Linear Algebra” are expected to have taken this module; in particular, the module “Linear Algebra” will assume that students are proficient in the operational aspects of Gauss elimination, matrix inversion, and their elementary applications.
- This module is a prerequisite for the module “Applied Mathematics” which develops more advanced theoretical and practical mathematical tools essential for any physicist or mathematician.
- Mandatory for a major in CS, ECE, IMS, MATH and Physics
- Mandatory elective for a major in EES.
- Pre-requisite for Calculus and Elements of Linear Algebra II
- Elective for all other study programs.

Examination Type: Module Examination

Assessment type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of this module

7.29.1.2 Calculus and Elements of Linear Algebra II

<table>
<tr><td colspan="3">Module Name
Calculus and Elements of Linear Algebra II</td><td>Module Code
JTMS-MAT-10</td><td>Level (type)
Year 1 (Methods)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CF</td></tr>
<tr><td>JTMS-10</td><td colspan="3">Calculus and Elements of Linear Algebra II</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

Marcel Oliver, Tobias Preußer</td><td colspan="3">Program Affiliation

• Jacobs Track – Methods and Skills</td><td colspan="2">Mandatory Status

Mandatory for CS, ECE, MATH, Physics, IMS</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

<table><tr><td>Pre-requisites</td><td>Co-requisites</td><td>Knowledge, Abilities, or Skills</td></tr><tr><td>☒ Calculus and Elements of Linear Algebra I</td><td>☒ None</td><td>• None beyond formal pre-requisites</td></tr></table></td><td>JTMS-MAT-10Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lectures (35 hours)
• Private study (90 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Review the content of Calculus and Elements of Linear Algebra I</td></tr>
<tr><td colspan="6">Content and Educational Aims
This module is the second in a sequence introducing mathematical methods at the university level in a form relevant for study and research in the quantitative natural sciences, engineering, Computer Science, and Mathematics. The emphasis in these modules is on training operational skills and recognizing mathematical structures in a problem context. Mathematical rigor is used where appropriate. However, a full axiomatic treatment of the subject is provided in the first-year modules “Analysis I” and “Linear Algebra”.

The lecture comprises the following topics
• Directional derivatives, partial derivatives
• Linear maps
• The total derivative as a linear map
• Gradient and curl (elementary treatment only, for more advanced topics, in particular the connection to the Gauss and Stokes’ integral theorems, see module “Applied Mathematics”
• Optimization in several variables, Lagrange multipliers
• Elementary ordinary differential equations
• Eigenvalues and eigenvectors
• Hermitian and skew-Hermitian matrices
• First important example of eigendecompositions: Linear constant-coefficient ordinary differential equations
• Second important example of eigendecompositions: Fourier series
• Fourier integral transform
• Matrix factorizations: Singular value decomposition with applications, LU decomposition, QR decomposition</td></tr>
<tr><td colspan="6">Intended Learning Outcomes
By the end of the module, students will be able to
• apply the methods described in the content section of this module description to the extent that they can solve standard text-book problems reliably and with confidence;
• recognize the mathematical structures in an unfamiliar context and translate them into a mathematical problem statement;</td></tr>
</table>

- recognize common mathematical terminology used in textbooks and research papers in the quantitative sciences, engineering, and mathematics to the extent that they fall into the content categories covered in this module.

Indicative Literature

S.I. Grossman (2014). Calculus of one variable, 2nd edition. Cambridge: Academic Press.

S.A. Leduc (2003). Linear Algebra. Hoboken: Wiley.

K. Riley, M. Hobson, S. Bence (2006). Mathematical Methods for Physics and Engineering, third edition. Cambridge: Cambridge University Press.

Usability and Relationship to other Modules

- The module is a mandatory / mandatory elective module of the Methods and Skills area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- A more advanced treatment of multi-variable Calculus, in particular, its applications in Physics and Mathematics, is provided in the second-semester module “Applied Mathematics”. All students taking “Applied Mathematics” are expected to take this module as well as the module topics are closely synchronized.
- The second-semester module “Linear Algebra” provides a complete proof-driven development of the theory of Linear Algebra. Diagonalization is covered more abstractly, with particular emphasis on degenerate cases. The Jordan normal form is also covered in “Linear Algebra”, not in this module.
- Mandatory for CS, ECE, MATH, Physics and IMS.
- Elective for all other study programs.

Examination Type: Module Examination

Assessment type: Written examination — Duration: 120 min; Weight: 100%

Scope: All intended learning outcomes of this module

7.29.1.3 Probability and Random Processes

Module Name	***Module Code***	***Level (type)***	***CP***
Probability and Random Processes	JTMS-MAT-12	Year 2 (Methods)	*5*

Module Components

Number	*Name*	*Type*	*CP*
JTMS-12	Probability and random processes	Lecture	5

Module Coordinator	***Program Affiliation***	***Mandatory Status***
Marcel Oliver, Tobias Preußer	• Jacobs Track – Methods and Skills	Mandatory for CS, ECE, MATH, Physics, IMS Mandatory elective for EES

Entry Requirements

Pre-requisites	*Co-requisites*	*Knowledge, Abilities, or Skills*
☒ Calculus and Elements of Linear Algebra I & II	None	• Knowledge of calculus at the level of a first year calculus module (differentiation, integration with one and several variables, trigonometric functions, logarithms and exponential functions). • Knowledge of linear algebra at the level of a first year university module (eigenvalues and eigenvectors, diagonalization of matrices). • Some familiarity with elementary probability theory at the high school level.

Frequency	***Forms of Learning and Teaching***
Annually (Fall)	• Lectures (35 hours) • Private study (90 hours)
Duration	***Workload***
1 semester	125 hours

Recommendations for Preparation

Review all of the first year calculus and linear algebra modules as indicated in “Entry Requirements – Knowledge, Ability, or Skills” above.

Content and Educational Aims

This module aims to provide a basic knowledge of probability theory and random processes suitable for students in engineering, Computer Science, and Mathematics. The module provides students with basic skills needed for formulating real-world problems dealing with randomness and probability in mathematical language, and methods for applying a toolkit to solve these problems. Mathematical rigor is used where appropriate. A more advanced treatment of the subject is deferred to the third-year module *Stochastic Processes*.

The lecture comprises the following topics

- Brief review of number systems, elementary functions, and their graphs
- Outcomes, events and sample space.
- Combinatorial probability.
- Conditional probability and Bayes' formula.
- Binomials and Poisson-Approximation
- Random Variables, distribution and density functions.
- Independence of random variables.
- Conditional Distributions and Densities.
- Transformation of random variables.
- Joint distribution of random variables and their transformations.
- Expected Values and Moments, Covariance.
- High dimensional probability: Chebyshev and Chernoff bounds.
- Moment-Generating Functions and Characteristic Functions,
- The Central limit theorem.
- Random Vectors and Moments, Covariance matrix, Decorrelation.
- Multivariate normal distribution.
- Markov chains, stationary distributions.

Intended Learning Outcomes

By the end of the module, students will be able to

- command the methods described in the content section of this module description to the extent that they can solve standard text-book problems reliably and with confidence;
- recognize the probabilistic structures in an unfamiliar context and translate them into a mathematical problem statement;
- recognize common mathematical terminology used in textbooks and research papers in the quantitative sciences, engineering, and mathematics to the extent that they fall into the content categories covered in this module.

Indicative Literature

J. Hwang and J.K. Blitzstein (2019). Introduction to Probability, second edition. London: Chapman & Hall.

S. Ghahramani. Fundamentals of Probability with Stochastic Processes, fourth edition. Upper Saddle River: Prentice Hall.

Usability and Relationship to other Modules

- The module is a mandatory / mandatory elective module of the Methods and Skills area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students taking this module are expected to be familiar with basic tools from calculus and linear algebra.
- Mandatory for a major in CS, ECE, MATH, Physics and IMS.
- Mandatory elective for a major in EES (if pre-requisites are met).
- Elective for all other study programs.

Examination Type: Module Examination

Assessment type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of this module

7.29.1.4 Numerical Methods

<table>
<tr><td colspan="3">Module Name
Numerical Methods</td><td>Module Code
JTMS-MAT-13</td><td>Level (type)
Year 2 (Methods)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>JTMS-13</td><td colspan="3">Numerical Methods</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

Marcel Oliver, Tobias Preußer</td><td colspan="3">Program Affiliation

• Jacobs Track – Methods and Skills</td><td colspan="2">Mandatory Status

Mandatory for ECE, MATH, Physics
Mandatory elective for CS and IMS</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ None
Co-requisites: ☒ None
Knowledge, Abilities, or Skills
• Knowledge of Calculus (functions, inverse functions, sets, real numbers, sequences and limits, polynomials, rational functions, trigonometric functions, logarithm and exponential function, parametric equations, tangent lines, graphs, derivatives, anti-derivatives, elementary techniques for solving equations)
• Knowledge of Linear Algebra (vectors, matrices, lines, planes, n-dimensional Euclidean vector space, rotation, translation, dot product (scalar product), cross product, normal vector, eigenvalues, eigenvectors, elementary techniques for</td><td>Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lectures (35 hours)
• Private study (90 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
</table>

	solving systems of linear equations)		

Recommendations for Preparation

Taking Calculus and Elements of Linear Algebra II before taking this module is recommended, but not required. A thorough review of Calculus and Elements of Linear Algebra, with emphasis on the topics listed as “Knowledge, Abilities, or Skills” is recommended.

Content and Educational Aims

This module covers calculus-based numerical methods, in particular root finding, interpolation, approximation, numerical differentiation, numerical integration (quadrature), and a first introduction to the numerical solution of differential equations.

The lecture comprises the following topics

- number representations
- Gaussian elimination
- LU decomposition
- Cholesky decomposition
- iterative methods
- bisection method
- Newton’s method
- secant method
- polynomial interpolation
- Aitken’s algorithm
- Lagrange interpolation
- Newton interpolation
- Hermite interpolation
- Bezier curves
- De Casteljau’s algorithm
- piecewise interpolation
- Spline interpolation
- B-Splines
- Least-squares approximation
- polynomial regression
- difference schemes
- Richardson extrapolation
- Quadrature rules
- Monte Carlo integration
- time stepping schemes for ordinary differential equations
- Runge Kutta schemes
- finite difference method for partial differential equations

Intended Learning Outcomes

By the end of the module, students will be able to

- describe the basic principles of discretization used in the numerical treatment of continuous problems;
- command the methods described in the content section of this module description to the extent that they can solve standard text-book problems reliably and with confidence;
- recognize mathematical terminology used in textbooks and research papers on numerical methods in the quantitative sciences, engineering, and mathematics to the extent that they fall into the content categories covered in this module;
- implement simple numerical algorithms in a high-level programming language;
- understand the documentation of standard numerical library code and understand the potential limitations and caveats of such algorithms.

Indicative Literature

D. Kincaid and W. Cheney (1991). Numerical Analysis: Mathematics of Scientific Computing. Pacific Grove: Brooks/Cole Publishing.

W. Boehm and H. Prautzsch (1993). Numerical Methods. Natick: AK Peters.

Usability and Relationship to other Modules

- The module is a mandatory / mandatory elective module of the Methods and Skills area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- This module is a co-recommendation for the module "Applied Dynamical Systems Lab", in which the actual implementation in a high-level programming language of the learned methods will be covered.
- Mandatory for a major in ECE, MATH, and Physics.
- Mandatory elective for a major in CS and IMS.
- Elective for all other study programs.

Examination Type: Module Examination

Assessment type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of this module.

7.29.1.5 Discrete Mathematics

<table>
<tr><td colspan="3">Module Name
Discrete Mathematics</td><td>Module Code
CO-501</td><td>Level (type)
Year 2/3 (CORE)</td><td>CP
5.0</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-501-A</td><td colspan="3">Discrete Mathematics</td><td>Lecture</td><td>5.0</td></tr>
<tr><td>Module Coordinator
K. Mallahi-Karai</td><td colspan="3">Program Affiliation
• Mathematics</td><td colspan="2">Mandatory Status
Mandatory elective for Mathematics, CS, Physics and IMS</td></tr>
<tr><td rowspan="2" colspan="3">Entry Requirements
Pre-requisites: ☒ None
Co-requisites: ☒ None
Knowledge, Abilities, or Skills
• Basic university mathematics: can be acquired via the Methods Modules “Calculus and Elements of Linear Algebra I + II” or “Applied Calculus” and “Finite Mathematics”</td><td>Frequency
Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching
• Lectures (35 hours)
• Private Study (90 hours)</td></tr>
<tr><td>Duration
1 semester</td><td colspan="2">Workload
125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation
• Some basic familiarity with linear algebra is useful, but not technically required.
• It is recommended to have taken the Methods module: Calculus and Elements of Linear Algebra I + II</td></tr>
<tr><td colspan="6">Content and Educational Aims
This module is an introductory lecture in discrete mathematics. The lecture consists of two main components, enumerative combinatorics and graph theory. The lecutre emphasizes connections of discrete mathematics with other areas of mathematics such as linear algebra and basic probability, and outlines applications to areas of computer science, cryptography, etc. where employment of ideas from discrete mathematics has proven to be fruitful. The first part of the lecture—enumerative combinatorics—deals with several classical enumeration problems (Binomial coefficients, Stirling numbers), counting under group actions and generating function. The second half of the lecture—graph theory—includes a discussion of basic notions such as chromatic number, planarity, matchings in graphs, Ramsey theory, and expanders, and their applications.</td></tr>
</table>

Intended Learning Outcomes
By the end of the module, students will be able to

- demonstrate their mastery of basic tools in discrete mathematics.
- develop the ability to use discrete mathematics concepts (such as graphs) to model problems in computer science.
- analyze the definition of basic combinatorial objects such as graphs, permutations, partitions, etc.
- formulate and design methods sand algorithms for solving applied problems basic on concepts from discrete mathematics.

Indicative Literature

J.H. van Lint and R.M. Wilson (2001). A Course in Combinatorics, second edition. Cambridge: Cambridge University Press.

B. Bollobas (1998). Modern Graph Theory, Berlin: Springer.

Usability and Relationship to other Modules

- This module is a specialization / CORE module in Mathematics to be taken in Semester 4 or 6.
- This module is recommended for students pursuing a minor in Mathematics
- This module serves as a mandatory elective Methods and Skills module for CS, Physics and IMS
- This module is a good option as an elective module for students in IMS.

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of this module

7.29.1 Big Questions Modules

7.29.1.1 Water: The Most Precious Substance on Earth

Module Name Big Questions: Water: The Most Precious Substance on Earth	***Module Code*** JTBQ-02	***Level (type)*** Year 3 (Jacobs Track)	***CP*** 5

Module Components

Number	*Name*	*Type*	*CP*
JTBQ-02	Water: The Most Precious Substance on Earth	Lecture/Tutorial	5

Module Coordinator	***Program Affiliation***	***Mandatory Status***
M. Bau and D. Mosbach	• Big Questions Area: All undergraduate study programs except IEM	• Mandatory elective for students of all undergraduate study programs, except IEM

Entry Requirements

Pre-requisites	*Co-requisites*	*Knowledge, Abilities, or Skills*
☒ None	☒ None	• The ability and openness to engage in interdisciplinary issues of global relevance • Media literacy, critical thinking, and a proficient handling of data sources

Frequency	***Forms of Learning and Teaching***
Annually (part I: Fall; part II: Spring)	• Lectures (17.5 hours) • Project work (90 hours) • Private study (17.5 hours)

Duration	***Workload***
2 semesters	125 hours

Recommendations for Preparation

Critically following media coverage on the module's topics in question.

Content and Educational Aims

All "Big Questions" (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students' horizons with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.

Water is the basic prerequisite for life on our planet, but it has become a scarce resource and a valuable commodity. Water is of fundamental importance to the world's economy and global food supply, in addition to being a driving force behind geopolitical conflict. In this module, the profound impact of water on all aspects of human life will be addressed from very different perspectives: from the natural and environmental sciences and engineering, and from the social and cultural sciences.

Following topical lectures in the Fall semester, students will work on projects on the occasion of the World Water Day (March 22) in small teams comprised of students from various disciplines and with different cultural backgrounds. This teamwork will be accompanied by related tutorials.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, students will be able to

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- advance a knowledge-based opinion on the complex module topics: on the physio-chemical properties of water, its origin and history, on the importance of water as a resource, on physical and economic freshwater scarcity, on the risks of water pollution and the challenges faced by waste water treatment, on the concept of virtual water, on the bottled water industry, and on the cultural values and meanings of water;
- formulate coherent written and oral contributions (e.g., to panel discussions) on the topic;
- perform well-organized teamwork;
- present a self-designed project in a university-wide context.

Indicative Literature

Finney, John (2015). Water. A Very Short Introduction. Oxford: Oxford University Press.

Zetland, David (2011). The End of Abundance: Economic Solutions to Water Scarcity. California: Aguanomics Press.

United Nation (January 2016): Sustainable Development Goals. Retrieved from https://www.un.org/sustainabledevelopment/sustainable-development-goals

Usability and Relationship to other Modules

- This module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

Examination Type: Module Examination

Assessment Component 1: Written examination	Duration: 60 min Weight: 50%
Assessment Component 2: Team project	Weight: 50%

Scope: All intended learning outcomes of the module

Completion: This module is passed with an assessment-component weighted average grade of 45% or higher.

7.29.1.2 Ethics in Science and Technology

Module Name			**Module Code**	**Level (type)**	**CP**
Big Questions: Ethics in Science and Technology			JTBQ-03	Year 3 (Jacobs Track)	5.0
Module Components					
Number	*Name*			*Type*	*CP*
JTBQ-03	Ethics in Science and Technology			Lecture /Projects	5.0
Module Coordinator A. Lerchl	**Program Affiliation** • Big Questions Area: All undergraduate study programs, except IEM			**Mandatory Status** • Mandatory for Chemistry • Mandatory elective for students of all undergraduate study programs, except IEM	
Entry Requirements *Pre-requisites* ☒ None	*Co-requisites* ☒ None	*Knowledge, Abilities, or Skills* • The ability and openness to engage in interdisciplinary issues of global relevance • Media literacy, critical thinking, and a proficient handling of data sources		**Frequency** Each semester (Fall & Spring)	**Forms of Learning and Teaching** • Lectures (35 hours) • Project work (55 hours) • Private study (35 hours)
				Duration 1 semester	**Workload** 125 hours
Recommendations for Preparation Critically following media coverage of the scientific topics in question.					
Content and Educational Aims All “Big Questions” (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students’ horizons with applied problem solving that extends beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society. Ethics is an often neglected, yet essential part of science and technology. Our decisions about right and wrong influence the way in which our inventions and developments change the world. A wide array of examples will be presented and discussed, e.g., the foundation of ethics, individual vs. population ethics, artificial life, stem cells, animal rights, abortion, pre-implantation diagnostics, legal and illegal drugs, the pharmaceutical industry, gene modification, clinical trials and research with test persons, weapons of mass destruction, data fabrication, and scientific fraud.					

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, students will be able to

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- summarize and explain ethical principles;
- critically look at scientific results that seem too good to be true;
- apply the ethical concepts to virtually all areas of science and technology;
- discover the responsibilities of society and of the individual for ethical standards;
- understand and judge the ethical dilemmas in many areas of the daily life;
- discuss the ethics of gene modification at the level of cells and organisms;
- reflect on and evaluate clinical trials in relation to the Helsinki Declaration;
- distinguish and evaluate the ethical guidelines for studies with test persons;
- complete a self-designed project;
- overcome general teamwork problems;
- perform well-organized project work.

Indicative Literature

Not specified.

Usability and Relationship to other Modules

- Mandatory for Chemistry
- This module is a mandatory elective module in the Big Questions area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

Examination Type: Module Examination

Assessment Component 1: Written examination	Duration: 60 min Weight: 50%
Assessment Component 2: Team project	Weight: 50%

Scope: All intended learning outcomes of the module

Completion: This module is passed with an assessment-component weighted average grade of 45% or higher.

7.29.1.3 Global Health – Historical context and future challenges

Module Name	***Module Code***	***Level (type)***	***CP***
Big Questions: Global Health – Historical context and future challenges	JTBQ-04	Year 3 (Jacobs Track)	5

Module Components

Number	*Name*	*Type*	*CP*
JTBQ-04	Global Health – Historical context and future challenges	Lecture	5

Module Coordinator	***Program Affiliation***	***Mandatory Status***
A. M. Lisewski	• Big Questions Area: All undergraduate study programs, except IEM	• Mandatory elective for students of all undergraduate study programs, except IEM

Entry Requirements

Pre-requisites	*Co-requisites*	*Knowledge, Abilities, or Skills*	***Frequency***	***Forms of Learning and Teaching***
☒ None	☒ None	• The ability and openness to engage in interdisciplinary issues of global relevance • Media literacy, critical thinking, and a proficient handling of data sources	Annually (Spring)	• Lectures (35 hours) • Private study (90 hours)
			Duration	***Workload***
			1 semester	125 hours

Recommendations for Preparation

Critically following media coverage on the module's topics in question.

Content and Educational Aims

All "Big Questions" (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students' horizons with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.

This module gives a historical, societal, technical, scientific, and medical overview of the past and future milestones and challenges of global health. Particular focus is put on future global health issues in a world that is interconnected both through mobility and communication networks. This module presents the main milestones along the path to modern health systems, including the development of public hygiene, health monitoring and disease response, and health-related breakthroughs in science, technology, and the economy. Focus is given to pediatric, maternal, and adolescent health, as these are the areas most critical to the well-being of future generations. This module also provides key concepts in global health, epidemiology, and demographics, such as the connection between a society's economic level and its population's health status, measures of health status, demographic and epidemiologic transitions, and modern issues such as the growing fragmentation (at a personal level) of disease conditions and the resulting emergence of personalized medicine. Finally, attention is also given to less publicly prominent global health issues, such as re-emerging diseases, neglected tropical diseases, and complex humanitarian crises.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, students will be able to

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- explain the historical context of current global health surveillance, response systems, and institutions;
- discuss and evaluate the imminent and future challenges to public hygiene and response to disease outbreaks in the context of a global societal network.

Indicative Literature

Richard Skolnik (2015). Global Health 101 (Essential Public Health). Burlington: Jones and Bartlett Publishers, Inc.

Usability and Relationship to other Modules

- The module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

Examination Type: Module Examination

Assessment Type: Written examination	Duration: 60 min.
Scope: All intended learning outcomes of the module	Weight: 100%

7.29.1.4 Global Existential Risks

Module Name			***Module Code***	***Level (type)***	***CP***
Big Questions: Global Existential Risks			JTBQ-05	Year 3 (Jacobs Track)	2.5
Module Components					
Number	*Name*			*Type*	*CP*
JTBQ-05	Global Existential Risks			Lecture	2.5
Module Coordinator M. A. Lisewski	***Program Affiliation*** • Big Questions Area: All undergraduate study programs except IEM			***Mandatory Status*** • Mandatory elective for students of all undergraduate study programs except IEM	
Entry Requirements			***Frequency*** Annually (Spring)	***Forms of Learning and Teaching*** • Lectures (17.5 hours) • Private study (45 hours)	
Pre-requisites ☒ None	*Co-requisites* ☒ None	*Knowledge, Abilities, or Skills* • The ability and openness to engage in interdisciplinary issues of global relevance • Media literacy, critical thinking, and a proficient handling of data sources	***Duration*** 1 semester	***Workload*** 62.5 hours	

Recommendations for Preparation

Critically following media coverage on the module's topics in question.

Content and Educational Aims

All "Big Questions" (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students' horizons with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.
The more we develop science and technology, the more we also learn about catastrophic and, in the worst case, even existential global dangers that put the entire human civilization at risk of collapse. These doomsday scenarios therefore directly challenge humanity's journey through time as an overall continuous and sustainable process that progressively leads to a more complex but still largely stable human society. The module presents the main known varieties of existential risks, including, for example, astrophysical, planetary, biological, and technological events or critical transitions that have the capacity to severely damage or even eradicate earth-based human civilization as we know it. Furthermore, this module offers a description of the characteristic features of these risks in comparison to more conventional risks, such as natural disasters, and a classification of global existential risks based on parameters such as range, intensity, probability of occurrence, and imminence. Finally, this module reviews several hypothetical monitoring and early warning systems as well as analysis methods that could potentially be used in strategies, if not to eliminate, then at least to better understand and ideally to minimize imminent global existential risks. This interdisciplinary module will allow students to explore this topic across diverse subject fields.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, students will be able to • use their factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines; • explain the varieties of global existential risks; • discuss approaches to minimize these risks; • formulate coherent written and oral contributions on this topic.
Indicative Literature Nick Bostrom, Milan M. Cirkovic (eds.) (2011). Global Catastrophic Risk.Oxford: Oxford University Press. Murray Shanahan (2015). The Technological Singularity. Cambridge:The MIT Press. Martin Rees (2003) Our Final Hour. New York: Basic Books.
Usability and Relationship to other Modules • This module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules). • Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.
Examination Type: Module Examination Assessment Type: Written examination — Duration: 60 min. Scope: All intended learning outcomes of the module — Weight: 100%

7.29.1.5 Future - From Predictions and Visions to Preparations and Actions

<table>
<tr><td colspan="3">Module Name
Big Questions: Future: From Predictions and Visions to Preparations and Actions</td><td>Module Code
JTBQ-06</td><td>Level (type)
Year 3 (Jacobs Track)</td><td>CP
2.5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>JTBQ-06</td><td colspan="3">Future: From Predictions and Visions to Preparations and Actions</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>Module Coordinator

Joachim Vogt</td><td colspan="3">Program Affiliation
Big Questions Area: All undergraduate study programs, except IEM</td><td colspan="2">Mandatory Status
Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ None
Co-requisites: ☒ None
Knowledge, Abilities, or Skills
The ability and openness to engage in interdisciplinary issues of global relevance
Media literacy, critical thinking, and a proficient handling of data sources</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching
Lecture (17.5 hours)
Private study (45 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

62.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Critically following media coverage of the module’s topics in question.</td></tr>
<tr><td colspan="6">Content and Educational Aims

All “Big Questions” (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students’ horizons with applied problem solving that extend beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.
This module addresses selected topics related to the future as a general concept in science, technology, culture, literature, ecology, and economy, and it consists of three parts. The first part (Future Continuous) discusses forecasting methodologies rooted in the idea that key past and present processes are understood and continue to operate such that future developments can be predicted. General concepts covered in this context include determinism, uncertainty, evolution, and risk. Mathematical aspects of forecasting are also discussed. The second part (Future Perfect) deals with human visions of the future as reflected in the arts and literature, ranging from ideas of utopian societies and technological optimism to dystopian visions in science fiction. The third part (Future Now) concentrates on important current developments—such as trends in technology, scientific breakthroughs, the evolution of the Earth system, and climate change—and concludes with opportunities and challenges for present and future generations.</td></tr>
</table>

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, student should be able to

- use their factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- distinguish and qualify important approaches to forecasting and prediction;
- summarize the history of utopias, dystopias, and the ideas presented in classical science fiction;
- characterize current developments in technology, ecology, society, and their implications for the future.

Indicative Literature

United Nations (2015, September) Millennium Development Goals. Retrieved from http://www.un.org/millenniumgoals.
United Nation (2016, January): Sustainable Development Goals. Retrieved from https://www.un.org/sustainabledevelopment/sustainable-development-goals
United Nations University. https://unu.edu.
US National Intelligence Council (2017). Global Trends. Retrieved from https://www.dni.gov/index.php/global-trends-home.
International Panel on Climate Change. Retrieved from https://www.ipcc.ch.
World Inequality Lab (2017, December). World Inequality Report 2018. Retrieved from https://wir2018.wid.world.
World Health Organization. Retrieved from http://www.who.int.
World Trade Organization. Retrieved from *https://www.wto.org*
Gapminder. Retrieved from https://www.gapminder.org.
World Bank. Retrieved from http://www.worldbank.org.

Usability and Relationship to other Modules

- This module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 60 min
Weight: 100%

Scope: All intended learning outcomes of the module

7.29.1.6 Climate Change

Module Name		Module Code	Level (type)	CP
Big Questions: Climate Change		JTBQ-07	Year 3 (Jacobs Track)	2.5
Module Components				
Number	*Name*		*Type*	*CP*
JTBQ-07	Climate Change		Lecture	2.5
Module Coordinator L. Thomsen/ V. Unnithan	**Program Affiliation** • Big Questions Area: All undergraduate study programs, except IEM		**Mandatory Status** • Mandatory elective for students of all undergraduate study programs, except IEM	
Entry Requirements *Pre-requisites* ☒ None	*Co-requisites* ☒ None	*Knowledge, Abilities, or Skills* • The ability and openness to engage in interdisciplinary issues of global relevance • Media literacy, critical thinking, and a proficient handling of data sources	**Frequency** Annually (Spring) **Duration** 1 semester	**Forms of Learning and Teaching** • Lecture (17.5 hours) • Private study (45 hours) **Workload** 62.5 hours

Recommendations for Preparation

Critically following media coverage of the module's topics in question.

Content and Educational Aims

All "Big Questions" (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students' horizon with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.
This module will give a brief introduction into the development of the atmosphere throughout Earth's history from the beginning of the geological record up to modern times, and will focus on geological, cosmogenic, and anthropogenic changes. Several major events in the evolution of the Earth that had a major impact on climate will be discussed, such as the evolution of an oxic atmosphere and ocean, the onset of early life, snowball Earth, and modern glaciation cycles. In the second part, the module will focus on the human impact on present climate change and global warming. Causes and consequences, including case studies and methods for studying climate change, will be presented and possibilities for climate mitigation (geo-engineering) and adapting our society to climate change (such as coastal protection and adaption of agricultural practices to more arid and hot conditions) will be discussed.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, students should be able to

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- advance a knowledge-based opinion on the complex module topics, including: impact of climate change on the natural environment over geological timescales and since the industrial revolution, and the policy framework in which environmental decisions are made internationally;
- work effectively in a team environment and undertake data interpretation;
- discuss approaches to minimize habitat destruction.

Indicative Literature

The course is based on a self-contained, detailed set of online lecture notes.

Ruddiman, William F. Earth's Climate (2001). Past and future. New York: Macmillan.

Usability and Relationship to other Modules

- This module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

Examination Type: Module Examination

Assessment Type: Written examination	Duration: 60 min.
Scope: All intended learning outcomes of the module	Weight: 100%

7.29.1.7 Extreme Natural Hazards, Disaster Risks, and Societal Impact

Module Name			**Module Code**	**Level (type)**	**CP**
Big Questions: Extreme Natural Hazards, Disaster Risks, and Societal Impact			JTBQ-08	Year 3 (Jacobs Track)	2.5
Module Components					
Number	*Name*			*Type*	*CP*
JTBQ-08	Extreme Natural Hazards: Disaster Risks, and Societal Impact			Lecture	2.5
Module Coordinator L. Thomsen	**Program Affiliation** • Big Questions Area: All undergraduate study programs, except IEM			**Mandatory Status** • Mandatory elective for students of all undergraduate study programs, except IEM	
Entry Requirements *Pre-requisites* ☒ None	*Co-requisites* ☒ None	*Knowledge, Abilities, or Skills* • The ability and openness to engage in interdisciplinary issues of global relevance • Media literacy, critical thinking, and a proficient handling of data sources	**Frequency** Annually (Fall) **Duration** 1 semester	**Forms of Learning and Teaching** • Lecture (17.5 hours) • Private study (45 hours) **Workload** 62.5 hours	
Recommendations for Preparation Critically following media coverage of the module’s topics in question.					

Content and Educational Aims

All “Big Questions” (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students’ horizons with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.
Extreme natural events increasingly dominate global headlines, and understanding their causes, risks, and impacts, as well as the costs of their mitigation, is essential to managing hazard risk and saving lives. This module presents a unique, interdisciplinary approach to disaster risk research, combining natural science and social science methodologies. It presents the risks of global hazards and natural disasters such as volcanoes, earthquakes, landslides, hurricanes, precipitation floods, and space weather, and provides real-world hazard and disaster case studies from Latin America, the Caribbean, Africa, the Middle East, Asia, and the Pacific.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, student should be able to

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- advance a knowledge-based opinion on the complex module topics, including how natural processes affect and interact with our civilization, especially those that create hazards and disasters;
- distinguish the methods scientists use to predict and assess the risk of natural disasters;

- discuss the social implications and policy framework in which decisions are made to manage natural disasters;
- work effectively in a team environment.

Indicative Literature

The course is based on a self-contained, detailed set of online lecture notes.

Ismail-Zadeh, Alik, et al., eds (2014). Extreme natural hazards, disaster risks and societal implications. In *Special Publications of the International Union of Geodesy and Geophysics Vol. 1.* Cambridge: Cambridge University Press.

Usability and Relationship to other Modules

- The module is a mandatory elective module of the Big Questions area, that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules)
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute such knowledge and competences to class discussions and activities.

Examination Type: Module Examination

Assessment Type: Written examination	Duration: 60 min.
Scope: All intended learning outcomes of the module	Weight: 100%

7.29.1.8 International Development Policy

<table>
<tr><td colspan="3">Module Name
Big Questions: International Development Policy</td><td>Module Code
JTBQ-09</td><td>Level (type)
Year 3 (Jacobs Track)</td><td>CP
2.5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>JTBQ-09</td><td colspan="3">Big Questions: International Development Policy</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>Module Coordinator

C. Knoop</td><td colspan="3">Program Affiliation

• Big Questions Area: All undergraduate study programs, except IEM</td><td colspan="2">Mandatory Status

• Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ None
Co-requisites: ☒ None
Knowledge, Abilities, or Skills:
• The ability and openness to engage in interdisciplinary issues of global relevance
• Media literacy, critical thinking, and a proficient handling of data sources</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching

• Lecture (17.5 hours)
• Presentations
• Private study (45 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

62.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Critically following media coverage of the module’s topics in question.</td></tr>
<tr><td colspan="6">Content and Educational Aims

All “Big Questions” (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students’ horizon with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.
We live in a world where still a large number of people still live in absolute poverty without access to basic needs and services, such as food, sanitation, health care, security, and proper education. This module provides an introduction to the basic elements of international development policy, with a focus on the relevant EU policies in this field and on the Sustainable Development Goals/SDGs of the United Nations. The students will not only learn about the tools applied in modern development policies, but also about the critical aspects of monitoring and evaluating the results of development policy. Module-related oral presentations and debates will enhance the students’ learning experience.</td></tr>
</table>

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, the student should be able to

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- breakdown the complexity of modern development policy;
- identify, explain, and evaluate the tools applied in development policy;
- formulate well-justified criticism of development policy;
- summarize and present a module-related topic in an appropriate verbal and visual form.

Indicative Literature

Francis Fukuyama (2006). The end of history and the last man. New York: Free Press.

Kingsbury, McKay, Hunt (2008). International Development.Issues and challenges. London: Palgrave.

A.Sumner, M.Tiwari (2009) After 2015: International Development Policy at a crossroad. New York: Palgrave Macmillan.

Graduate Institute of International Development, G. Carbonnier eds. (2001). International Development Policy: Energy and Development. New York:Palgrave Macmillan.

John Donald McNeil. International Development: Challenges and Controversy. Sentia Publishing,e-book.

Usability and Relationship to other Modules

- This module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

Examination Type: Module Examination

Assessment Type: Presentation — Duration: 10 minutes per student
Scope: All intended learning outcomes of the module — Weight: 100%

7.29.1.9 Sustainable Value Creation with Biotechnology. From Science to Business

<table>
<tr><td colspan="2">Module Name
Sustainable Value Creation with Biotechnology. From Science to Business.</td><td>Module Code
JTBQ-BQ-011</td><td>Level (type)
Year 3
(Jacobs Track)</td><td>CP
2.5</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td>Number</td><td colspan="2">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>JTBQ-011</td><td colspan="2">Sustainable Value Creation with Biotechnology. From Science to Business</td><td>Lecture - Tutorial</td><td>2.5</td></tr>
<tr><td>Module Coordinator
Marcelo Fernandez Lahore</td><td colspan="2">Program Affiliation
Jacobs Track - Big Questions</td><td colspan="2">Mandatory Status
Mandatory elective for students of all undergraduate study except IEM</td></tr>
<tr><td colspan="2" rowspan="2">Entry Requirements

Pre-requisites
☒ None

Co-requisites
☒ None

Knowledge, Abilities, or Skills
The ability and openness to engage in interdisciplinary issues on bio-based value creation
media literacy, critical thinking and a proficient handling of data sources</td><td>Frequency
Annually
(Spring)</td><td colspan="2">Forms of Learning and Teaching
Lecture and Tutorial (17.5 hours)
Private study (45 hours)</td></tr>
<tr><td>Duration
1 semester</td><td colspan="2">Workload
62.5 hours</td></tr>
<tr><td colspan="5">Recommendations for Preparation
https://www.ctsi.ucla.edu/researcher-resources/files/view/docs/EGBS4_Kolchinsky.pdf
https://link.springer.com/article/10.1057/jcb.2008.27
https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf</td></tr>
</table>

Content and Educational Aims

All “Big Questions” (BQ) modules deal with the economic, technological, societal and environmental contexts of the global issues and challenges of the coming decades. The BQ modules intend to raise awareness of those challenges and broaden the students’ horizon with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become an informed and responsible citizen in a global society.
This module has a particular focus on the role that Biotechnology and Biorefining is expected to play in social, economic and environmental contexts.

To deliver such a vision the module will prepare students to extract value form Biotechnology and associated activities. This will be done in the form of business cases that will be systematically developed by students alongside the development of the module. In this way, students will develop entrepreneurial skills while understanding basic business-related activities that are not always present in a technical curriculum. Case development will also provide students with the possibility of understanding the social, economic, environmental impact that Biotechnology and Biorefining can deliver in a Bio-Based Economy. The knowledge and skills gained through this module are in direct and indirect support of the UN 2030 Agenda for Sustainable Development: “Transforming our World”.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, the students should be able to

1. design and develop a Business Case based on the tools provided by modern Biotechnology;
2. explain the interplay between Science, Technology and Economics / Finance;
3. use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
4. work effectively in a team environment and undertake data interpretation and analysis;
5. discuss approaches to value creation in the context of Biotechnology and Sustainable Development;
6. explain the ethical implications of technological advance and implementation;
7. demonstrate presentation skills.

Indicative Literature

Springham, D., V. Moses & R.E. Cape (1999). Biotechnology – The Science and the Business. 2nd. Ed. Boca Raton: CRC Press.

Kornberg, Arthur (2002). The Golden Helix: Inside Biotech Ventures. Sausalito, CA: University Science Books.

UNESCO, Director-General. (2017). UNESCO moving forward the 2030 Agenda for Sustainable Development. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000247785

Usability and Relationship to other Modules

- The module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

Examination Type: Module Examination

Assessment Component 1: Term Paper	Length:1.500 – 3.000 words Weight: 75%
Scope: Intended learning outcomes of the module (1-6)	
Assessment Component 2: Presentation	Duration: 10-15 min. Weight: 25%
Scope: Intended learning outcomes of the module (2-7)	

7.29.1.10 Gender and Multiculturalism. Debates and Trends in Contemporary Societies

<table>
<tr><td colspan="2">Module Name
Big Questions: Gender and Multiculturalism. Debates and Trends in Contemporary Societies</td><td>Module Code
JT-BQ-013</td><td>Level (type)
Year 3 (Jacobs Track)</td><td>CP
5.0</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td>Number</td><td colspan="2">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>JT-BQ-013</td><td colspan="2">Gender and Multiculturalism: Debates and Trends in Contemporary Societies</td><td>Lecture</td><td>5.0</td></tr>
<tr><td>Module Coordinator

J. Price</td><td colspan="2">Program Affiliation

• Big Questions Area: All undergraduate study programs</td><td colspan="2">Mandatory Status

Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td colspan="2" rowspan="2">Entry Requirements

Pre-requisites
☒ None

Co-requisites
☒ None

Knowledge, Abilities, or Skills
• The ability and openness to engage in interdisciplinary issues of global relevance
• Media literacy, critical thinking and a proficient handling of data sources</td><td>Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lectures (35 hours)
• Private study (90 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="5">Recommendations for Preparation

Critical following of the media coverage on the module’s topics in question.</td></tr>
<tr><td colspan="5">Content and Educational Aims

All “Big Questions” (BQ) modules deal with the economic, technological, societal and environmental contexts of the global issues and challenges of the coming decades. The BQ modules intend to raise awareness of those challenges and broaden the students’ horizon with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules are relevant for every university graduate in order to become an informed and responsible citizen in a global society.
The objective of this module is to introduce and familiarize students with the current debates, trends and analytical frameworks pertaining how gender is socially constructed in different cultural zones. Through lectures, group discussions and reflecting upon cultural cases, students will familiarize themselves with the current trends and the different sides of ongoing cultural and political debates that shape cultural practices, policies and discourses. The module will zoom-in on topics such as: cultural identity; the social construction of gender; gender fluidity and its backlash; gender and human rights; multiculturalism as a perceived threat in plural societies, among others. Students will be provided with opportunities for reflection and to ultimately develop informed opinions concerning topics that are continue to define some of the most contested cultural debates of contemporary societies.</td></tr>
</table>

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, students will be able to

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- summarize and evaluate the current cultural, political and legal debates concerning the social construction of gender in contemporary societies;
- reflect and develop informed opinions concerning the current debates and trends that are shaping ideas of whether multiculturalism ideals are realistic in pluralist western societies, or whether multiculturalism is a failed project;
- identify, explain and evaluate the role that societal forces, such as religion, socio-economic, political and migratory factors play in the construction of gendered structures in contemporary societies
- develop a well-informed perspective concerning the interplay of science and culture in the debates around gender fluidity.
- deconstruct and reflect on the intersectionality between populist/nationalist discourses and gender discrimination
- reflect and propose societal strategies and initiatives that attempt to answer the big questions presented in this module regarding gendered and cross-culturally-based inequalities.

Indicative Literature

Moller Okin, S. (1999). Is Multiculturalism Bad for Women? New Jersey: Princeton University Press.

Connell, R. W. (2002). Gender. Cambridge: Polity Press.

Inglehart, Ronald and Pippa Norris (2003). Rising Tide: Gender Equality and Cultural Change Around the World. New York and Cambridge: Cambridge University Press.

Usability and Relationship to other Modules

- The module is a mandatory elective module of the Big Questions area, that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules)
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute such knowledge and competences to class discussions and activities.

Examination Type: Module Examination

Assessment Type: Written examination — Duration: 60 min. Weight: 100%

Scope: All intended learning outcomes of the module

7.29.1.11 Big Questions: The Challenge of Sustainable Energy

<table>
<tr><td colspan="2">Module Name
Big Questions: The Challenge of Sustainable Energy</td><td>Module Code
JTBQ-14</td><td>Level (type)
Year 3 (Jacobs Track)</td><td>CP
2.5</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td colspan="3">Number</td><td>Type</td><td>CP</td></tr>
<tr><td>JTBQ-14</td><td colspan="2">The Challenge of Sustainable Energy</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>Module Coordinator

K. Smith Stegen</td><td colspan="2">Program Affiliation

• Big Questions Area: All undergraduate study programs</td><td colspan="2">Mandatory Status

Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td colspan="2" rowspan="2">Entry Requirements

Pre-requisites: ☒ None
Co-requisites: ☒ None
Knowledge, Abilities, or Skills:
• Ability to read texts from a variety of disciplines</td><td>Frequency

Annually
(Fall or Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lectures and Group Exercises</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

62.5 hours</td></tr>
<tr><td colspan="5">Recommendations for Preparation

Reflect on their own behavior and habits with regard to sustainability.</td></tr>
<tr><td colspan="5">Content and Educational Aims

All “Big Questions” (BQ) modules deal with the economic, technological, societal and environmental contexts of the global issues and challenges of the coming decades. The BQ modules intend to raise awareness of those challenges and broaden the students’ horizon with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules are relevant for every university graduate in order to become an informed and responsible citizen in a global society.
How can wide-scale social, economic and political change be achieved? This module examines this question in the context of encouraging “sustainability”. To address global warming and environmental degradation, humans must adopt more sustainable lifestyles. Arguably, the most important change is the transition from conventional fuels to renewable sources of energy, particularly at the local, country and regional levels. The main challenge to achieving an “energy transition” stems from human behavior and not from a lack of technology or scientific expertise. This module thus examines energy transitions from the perspective of the social sciences, including political science, sociology, psychology, economics and management. To understand the drivers of and obstacles to technology transitions, students will learn the “Multi-Level Perspective”. Some of the key questions explored in this module include: What is meant by sustainability? Are renewable energies “sustainable”? How can a transition to renewable energies be encouraged? What are the main social, economic, and political challenges? How can these (potentially) be overcome? The aim of the course is to provide students with the tools for reflecting on energy transitions from multiple perspectives.</td></tr>
<tr><td colspan="5">Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, students will be able to

• articulate the history of the sustainability movement and the major debates;
• identify different types of renewable energies;
• explain the multi-level perspective (MLP), which models technology innovations and transitions;
• summarize the obstacles to energy transitions;
• compare a variety of policy mechanisms for encouraging renewable energies.</td></tr>
</table>

Usability and Relationship to other Modules	
• The module is a mandatory elective module of the Big Questions area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules). • For students interested in sustainability issues, this module complements a variety of modules from different programs, such as “International Resource Politics” (IRPH/ISS), “Environmental Science” (EES), “General Earth and Environmental Sciences” (EES), and “Renewable Energies” (Physics).	
Examination Type: Module Examination	
Assessment Type: Written Examination	Duration: 60 min Weight: 100%
Scope: All intended learning outcomes of the module	

7.29.1.12 Big Questions: State, Religion and Secularism

<table>
<tr><td colspan="3">Module Name
Big Questions: State, Religion and Secularism</td><td>Module Code
JTBQ-15</td><td>Level (type)
Year 3 (Jacobs Track)</td><td>CP
2.5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td colspan="4">Number</td><td>Type</td><td>CP</td></tr>
<tr><td>JTBQ-15</td><td colspan="3">State, religion and secularism</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>Module Coordinator

Manfred O. Hinz</td><td colspan="3">Program Affiliation

• Big Questions Area: All undergraduate study programs</td><td colspan="2">Mandatory Status

Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ None
Co-requisites: ☒ None
Knowledge, Abilities, or Skills:
• Ability to read texts from a variety of disciplines</td><td>Frequency

Annually
(Fall or Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lectures and Group Exercises</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

62.5 Hours</td></tr>
</table>

Recommendations for Preparation

Reflect on the situation and role in respective home-country

Content and Educational Aims

The relationship between state and religion has been a matter of concern in most if not all societies. Is religion above the state, or is it to the state to determine the place of religion? What does secularity mean? To what extent will religion accept secularity? Where does the idea of secularity come from? The course State, religion, secularism will search for answers to questions of this nature. After introducing to the topic and looking at some legal attempts to regulate the relationship between state and religion, the focus will be, on the one hand, on Christianity and secularity and, on Islam and secularity, on the other. Depending on the interest of participants, other religions and their relationships to states of relevance can be added.

Intended Learning Outcomes

By the end of this course, students should be able

- To understand the basic problems that have led to different models to regulate the relationship between the state and religion;
- To reflect critically the situation of state and religion in selected countries;
- To assess the values behind the concept of democracy and human rights;
- To use the acquired knowledge to strengthen the capacity towards respect for others and tolerance.

Usability and Relationship to other Modules

- The module is a mandatory elective module of the Big Questions area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- For students interested in State, Religion and secularism, this module complements modules from other programmes, such as IRPH and ISS

Examination Type: Module Examination

Assessment Type: Term paper

Length:1.500 – 3.000 words
Weight: 100%

Scope: All intended learning outcomes of the module.

7.29.2 Community Impact Project

<table>
<tr><td colspan="3">Module Name
Community Impact Project</td><td>Module Code
JTCI-CI-950</td><td>Level (type)
Year 3 (Jacobs Track)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>JTCI-950</td><td colspan="3">Community Impact Project</td><td>Project</td><td>5</td></tr>
<tr><td>Module Coordinator

CIP Faculty Coordinator</td><td colspan="3">Program Affiliation

• All undergraduate study programs except IEM</td><td colspan="2">Mandatory Status

Mandatory for all undergraduate study programs except IEM</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ at least 15 CP from CORE modules in the major
Co-requisites: ☒ None
Knowledge, Abilities, or Skills:
• Basic knowledge of the main concepts and methodological instruments of the respective disciplines</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching

• Introductory, accompanying, and final events: 10 hours
• Self-organized teamwork and/or practical work in the community: 115 hours</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Develop or join a community impact project before the 5th semester based on the introductory events during the 4th semester by using the database of projects, communicating with fellow students and faculty, and finding potential companies, organizations, or communities to target.</td></tr>
<tr><td colspan="6">Content and Educational Aims

CIPs are self-organized, major-related, and problem-centered applications of students’ acquired knowledge and skills. These activities will ideally be connected to their majors so that they will challenge the students’ sense of practical relevance and social responsibility within the field of their studies. Projects will tackle real issues in their direct and/or broader social environment. These projects ideally connect the campus community to other communities, companies, or organizations in a mutually beneficial way.
Students are encouraged to create their own projects and find partners (e.g., companies, schools, NGOs), but will get help from the CIP faculty coordinator team and faculty mentors to do so. They can join and collaborate in interdisciplinary groups that attack a given issue from different disciplinary perspectives.
Student activities are self-organized but can draw on the support and guidance of both faculty and the CIP faculty coordinator team.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes

The Community Impact Project is designed to convey the required personal and social competencies for enabling students to finish their studies at Jacobs as socially conscious and responsible graduates (part of the Jacobs mission) and to convey social and personal abilities to the students, including a practical awareness of the societal context and relevance of their academic discipline.</td></tr>
</table>

By the end of this project, students should be able to

- understand the real-life issues of communities, organizations, and industries and relate them to concepts in their own discipline;
- enhance problem-solving skills and develop critical faculty, create solutions to problems, and communicate these solutions appropriately to their audience;
- apply media and communication skills in diverse and non-peer social contexts;
- develop an awareness of the societal relevance of their own scientific actions and a sense of social responsibility for their social surroundings;
- reflect on their own behavior critically in relation to social expectations and consequences;
- work in a team and deal with diversity, develop cooperation and conflict skills, and strengthen their empathy and tolerance for ambiguity.

Indicative Literature

Not specified

Usability and Relationship to other Modules

- Students who have accomplished their CIP (6th semester) are encouraged to support their fellow students during the development phase of the next year's projects (4th semester).

Examination Type: Module Examination

Project, not numerically graded (pass/fail)
Scope: All intended learning outcomes of the module

7.29.3 Language Modules

The descriptions of the language modules are provided in a separate document, the "Language Module Handbook" that can be accessed from here: https://www.jacobs-university.de/study/learning-languages

8 Appendix

8.1 Intended Learning Outcomes Assessment-Matrix

Intelligent Mobile Systems BSc					Introduction to Robotics and Intelligent Systems	Algorithms and Data Structures	Programming in C and C++	Robotics	Machine Learning	RIS Lab	Automation	Embedded Systems	Control Systems	Computer Vision	Artificial Intelligence	RIS project	Marine Robotics	Human-Computer Interaction	Optimization	Calculus and Linear Algebra 1	Calculus and Linear Algebra 2	Probability and Random Processes	Discrete Mathematics / Numerical Methods	Internship	Big Questions	Langauge	Community Impact	Bachelor Thesis
Semester					2	2	1	3	4	3/4	4	3	3	3	4	4	5/6	5/6	5/6	1	2	3	4	5	5/6	5/6	5	6
mandatory/mandatory elective					m	m	m	m	m	me	me	me	me	me	m	m	me	me	me	m	m	m	me	m	me	me	m	m
Credits					7,5	7,5	7,5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	15	5	5	5	15
	Competencies*																											
Program Learning Outcomes	**A**	**E**	**P**	**S**																								
demonstrate knowledge of kinematics and dynamics of multi-body systems	x	x			x			x																				
design and develop linear and nonlinear control systems	x	x											x			x												
design basic electronics circuits	x	x			x							x																
show competence about operational principles of motors and drives	x	x									x					x												
design and develop Machine Learning algorithms and techniques for pattern-recognition, classification, and decision-making under uncertainty	x	x							x							x												
design and develop Computer Vision algorithms for inferring 3D information from camera images, and for object recognition and localization	x	x												x		x												
model common mechanical and electrical systems which are part of intelligent mobile systems	x	x			x			x				x	x															
design robotics systems and program them using popular robotics software frameworks	x	x						x		x						x												
use academic or scientific methods as appropriate in the field of Robotics and Intelligent Systems such as defining research questions, justifying methods, collecting, assessing and interpreting relevant information, and drawing scientifically-founded conclusions that consider social, scientific and ethical insights	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x									
develop and advance solutions to problems and arguments in their subject area and defend these in discussions with specialists and non-specialists	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x					x				x
engage ethically with academic, professional and wider communities and to actively contribute to a sustainable future, reflecting and respecting different views	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
take responsibility for their own learning, personal and professional development and role in society, evaluating critical feedback and self-analysis	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
apply their knowledge and understanding to a professional context;	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x									
work effectively in a diverse team and to take responsibility in a team;	x		x							x						x	x							x	x	x	x	
adhere to and defend ethical, scientific and professional standards	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Assessment Type																												
oral examination																	x											
written examination					x	x	x	x	x		x		x	x	x			x	x	x	x	x	x					
project												x				x											x	x
Term paper																								x				
(lab) report										x																		
poster presentation																												
presentation																x												x
variable																									x	x		
module achievements/bonus achievements					x	x	x							x														

*Competencies: A-scientific/academic proficiency; E-competence for qualified employment; P-development of personality; S-competence for engagement in society

Figure 4: Intended Learning Outcomes Assessment-Matrix