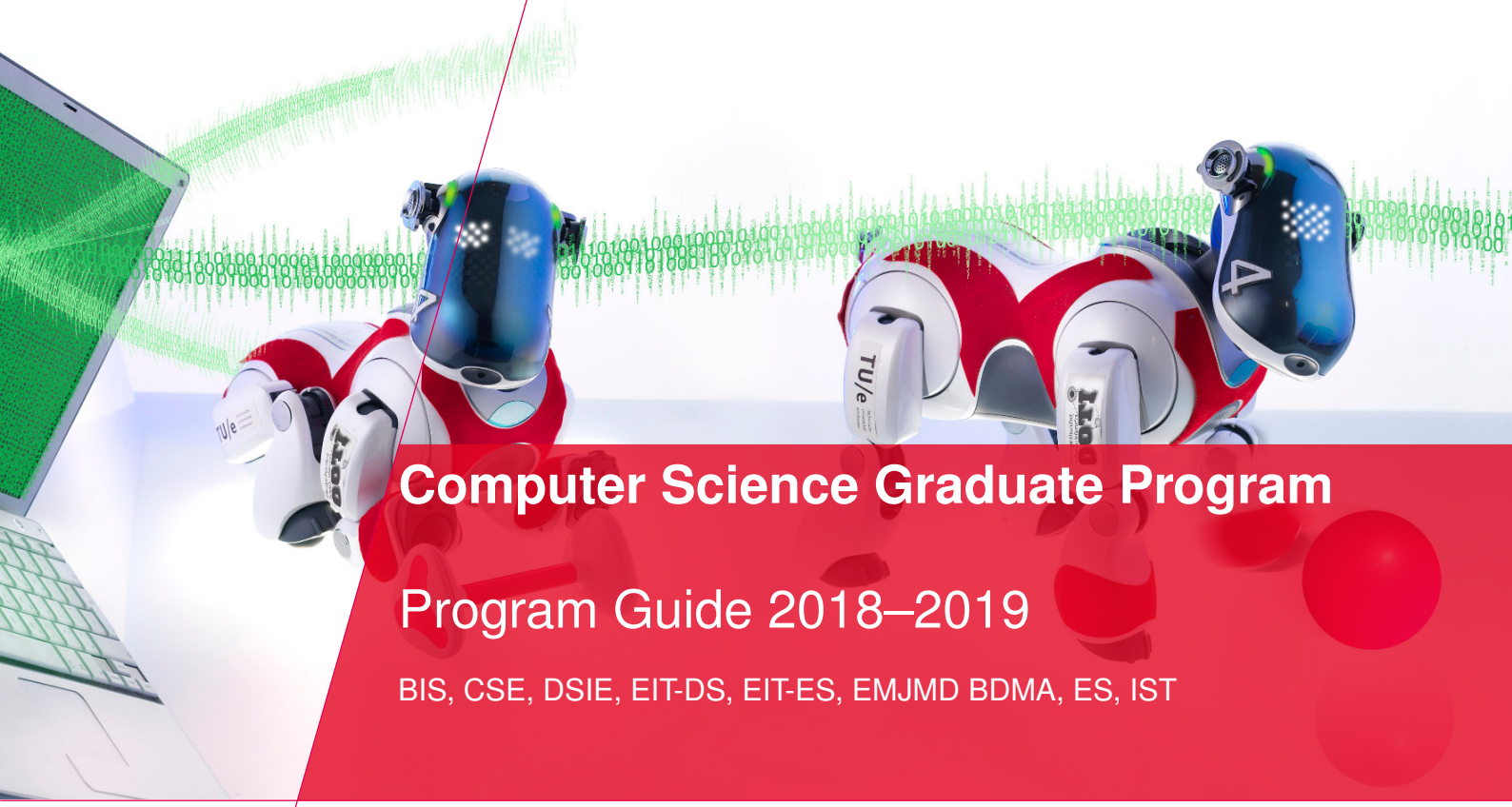
Department of Mathematics and Computer Science

Technische Universiteit
Eindhoven
University of Technology



Computer Science Graduate Program

Program Guide 2018–2019

BIS, CSE, DSIE, EIT-DS, EIT-ES, EMJMD BDMA, ES, IST

Where innovation starts

Computer Science Graduate Program

Program Guide 2018–2019

Business Information Systems
Computer Science and Engineering
Embedded Systems
Data Science in Engineering
Information Security Technology
EIT Service Design and Engineering
EIT Embedded Systems
EIT Data Science
Erasmus Mundus Joint Master Degree:
Big Data Management and Analytics

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Part I

General Information

1 Studying in the Computer Science Graduate Program

The Department of Mathematics and Computer Science (W&I) at the Eindhoven University of Technology (TU/e) offers undergraduate (Bachelor of Science), graduate (Master of Science) and postgraduate (PhD, PDEng) courses in Computer Science and Applied Mathematics.

The Computer Science Division (CS) focuses on Algorithms and Visualization, Information Systems, Model-Driven Software Engineering, Security and Embedded Networked Systems. The CS Division offers its graduate and postgraduate courses in the Computer Science Graduate Program. There are three master programs:

- Computer Science and Engineering (CSE). This master program has a track on Information Security Technology (IST), an interdisciplinary variant in cooperation with the Mathematics Division of the TU/e and the Radboud University Nijmegen, and a track on Data Science in Engineering (DSE), an interdisciplinary variant in cooperation with the Mathematics Division of the TU/e. Furthermore, this program has an EIT Digital Data Science track and hosts a Big Data Management and Analytics Erasmus Joint Master Degree.
- Business Information Systems (BIS), an interdisciplinary master program in cooperation with the Department of Industrial Engineering and Innovation Sciences (IE&IS). This program is being phased out and no new students are admitted as of the academic year 2018/2019.
- Embedded Systems (ES), an interdisciplinary master program in cooperation with the Department of Electrical Engineering (EE). This program has an EIT Digital Embedded Systems track.

The two postgraduate programs are:

- Software Technology, a Master of Technological Design (PDEng) program,
- The PhD program.

The CS Division also contributes to the Computer Science specialization of the master program Science Education and Communication (SEC), offered by the Eindhoven School of Education (ESoE), see http://www.tue.nl/esoe. Graduates in the CS specialization from the program are entitled to teach computer science at Dutch high schools. Graduates from one of the above mentioned master programs will also be admitted to the SEC-program and are offered a one-year program. Since 2009, double-degree programs are offered for CSE & SEC (see Section 3.5), as well as for BIS & SEC (see Section 6.5), which comprise 150 credits.

1.1 Structure of the master programs

All programs comprise two years of study or 120 credit points (EC); a credit point is equivalent to 28 hours of study and homework for an average student. Most courses are standardized to 5 credit points per course.

The two years of course work and practical training are divided into four parts, consisting of:

1. Mandatory core courses to create a sufficient layer of theory and general or program-related knowledge.

2. Elective courses to prepare for the specialization. Depending on the specialization there may be a longer or shorter list of preferred electives. In addition there is room for free electives. Most of the master programs are organized in *streams*. You choose a stream (with corresponding core courses and/or elective package) when you start the master. You are allowed to switch between streams after the start, provided that you can still fulfill the requirements of the stream you wish to switch to.

3. International experience. Students who do not have any international experience (a degree from another country or at least 15 EC of credits from a university outside the Netherlands) are strongly urged to take courses abroad or to do an internship abroad.

4. Master project and thesis to be spent on a specialist topic of theoretical or practical nature. This part presents the opportunity to show your independent engineering and academic skills in research and design. (International experience can also be gained by doing the master project abroad.)

1.2 Rules and regulations

Master programs of the department are subject to the following rules and regulations.

- Program and Examination Regulations. This is a legal document describing the master program. Topics covered include admission, structure of the program, testing and final examinations, study counseling and transitional arrangements.
- Regulations of the Examination Committee. Topics covered include exams, fraud, graduation and internship.
- Directive Double Diplomas.

The aforementioned documents can be found on the websites of the master programs: BIS, CSE (including DSIE, IST, EIT-DS and BDMA), ES (including EIT-ES).

Furthermore, everyone involved in education and research at TU/e bears personal responsibility for observing and maintaining scientific integrity. At TU/e we require strict compliance with the overall principles of professional scientific conduct in all cases. TU/e has its own Code of Scientific Conduct effective on September 1, 2014. Please read the code of conduct very carefully: you will be required to sign a declaration stating that you have read it and carrying out research, design and educational activities, I shall observe the five central values of scientific integrity, namely: trustworthiness, intellectual honesty, openness, independence and societal responsibility, as well as the norms and principles which follow from them.

A particular kind of integrity violation is **academic fraud**. Fraud includes any behavior or negligence on part of the student that makes it impossible for an examiner to form a correct judgement of his or her knowledge, insight and skills, or that is aimed at intentionally manipulating the examination process. Examples of fraud include identity fraud (e.g., when a student offers their work to others with the aim, knowledge or expectation that this work be submitted it as their own work), exam fraud (e.g., using not-allowed materials during an exam), plagiarism (e.g., taking credit for material that is not your own) and scientific fraud (e.g., fabricating data). In cases of fraud sanctions may be imposed not only on the perpetrator but also on others who are complicit in the fraud. Examples of possible sanctions in case of fraud are denying the student the right to take one or more examinations during a period up to one year or termination of the student's enrollment.

1.3 Lecture and interim examination periods

Each study year is divided into two semesters (September to January and February to July). Each semester consists of two quarters (quartiles), each consisting of eight weeks of lectures followed by an examination period of two weeks.

Quarter	Period
1	September 3, 2018—November 10, 2018
2	November 12, 2018—February 2, 2019
3	February 4, 2019—April 20, 2019
4	April 22, 2019—July 6, 2019
interim	August 12, 2019—August 17, 2019

You are expected to be available and present during all weeks with classes as well as weeks with exams. Some courses may have activities planned during the exam weeks, not yet scheduled before the course starts. Going on vacation during weeks with classes or with exams is not a valid reason for missing an activity!

1.4 Course and exam registration

Participation in a course is possible only if you have registered for the course via OSIRIS. In the first quarter, the registration deadline is set at the end of the first lecture week. In the remaining quarters, this deadline is in the week before the lectures start. Furthermore, the Graduate School would like to encourage you to enroll in time for your courses, this is mainly due to plannings issues in the past. This 'preferred' registration deadline is 15 days before the start of classes.

During the registration period, and in the first two lecture weeks, it is possible to withdraw from the course via OSIRIS yourself. Outside this period, you should contact the lecturer and the academic advisor if you wish to withdraw. (The lecturer has no authorization to register or deregister students in OSIRIS.)

Please note that the *course* you register for, determines the regulations you have to follow. If you take a Bachelor College course, Bachelor College regulations apply (even if you are a Graduate School Student). This rule is of particular importance for pre-master students as well as students with prescribed/recommended homologation courses. You should consult OSIRIS and check whether the course you intend to take is a Bachelor College course or a Graduate School course.

Important note, especially for Bachelor College graduates: Registration for a course does not constitute an automatic registration for the exam. You have to register for each exam separately via OSIRIS before the set deadlines. Note that if you are not registered for an exam, you cannot take part in it. (The lecturer has no authorization to register students for the exam.) For courses that are evaluated through assignments you do not need to register for the exam as there is no exam.

1.5 Examination and titles

In an examination at the end of the program the examination committee verifies and judges the final course results and the final master project grade. Completion of the program will lead to the title: *Master of Science* (MSc) with addition of the name of the program. Graduates are also entitled to use the Dutch title of *ingenieur* (ir).

1.6 Admissions

General and specific master program requirements are applicable to admissions. The specific requirements may be higher in terms of knowledge prerequisites, but may also provide more possibilities for entry for students from other related areas of specialization. The specific requirements for admission to each of the master programs are described in the corresponding chapters.

1.6.1 General admissions requirements

To be eligible for admission to any of the master programs, a Bachelor of Science degree is required. This degree must be of an equivalent academic level and approximate scientific content as the corresponding Dutch BSc degrees. In addition, sufficient proficiency in the English language is required.

1.6.2 Admissions with deficiencies

For admitted students from other universities, it may be necessary to repair deficiencies due to differences in programs. The admission committee will point out those so-called homologation courses to the students directly or via the academic advisor.

1.6.3 Foreign students

The applications of students with a foreign university BSc degree will be evaluated by the admissions committee, taking into account both the academic level of the degree and the subjects studied by the applicant. Here too a homologation program may be required. In some special cases, relevant work experience may also be considered. The level of the degree is determined by the national organization EP-NUFFIC (`http://www.epnuffic.nl`).

1.6.4 Polytechnic graduates (HBO)

Students who have completed a polytechnic program may be eligible to participate in the pre-master programs of 30 EC. Completion of the pre-master program gives access to the corresponding master program. In Chapter 2 further details about admission for HBO students and the premaster program can be found.

It is not possible to follow additional homologation courses in a master program after a finished pre-master. For a deficiency that exceeds 30 EC, students are advised to enroll in the preparatory Bachelors program.

1.6.5 Admissions procedure

The procedure to be followed depends on your particular situation. Detailed information on the application procedure can be found on the site of the Education and Student Service Center of the TU/e, `http://www.tue.nl/en/education/`. Foreign students must be aware that the admissions procedure, including visa application and other formalities, may take a considerable amount of time. In order to avoid delay in the start of your master study it is important to register and start the application procedure long in advance.

1.7 Eindhoven and more

You might also consider including in your study program courses offered by other universities or taking an internship in a company or research institution. In general, any course offered at the master level by any Dutch university might be included **as long as it approved by the Examination Committee** (see Section 1.9).

1.7.1 International Experience

All students are strongly urged to gain some international experience. Students who do not have a degree or certificate(s) for at least 15 EC obtained from a university in another country should gain that experience during their master study. Several options are available:

- Take subjects at a university abroad (at least 15 EC)

- Do an internship abroad (at least 15 EC, which is roughly 3 months)
- Do (a part of) the graduation project abroad

Procedures related to obtaining an international experience are further detailed in the "International experience guide", available at https://educationguide.tue.nl/programs/graduate-school/masters-programs/ (choose your master program, "Internship and Exchange").

Organizing your stay abroad requires careful planning. It is therefore essential that you contact the faculty international office as early as possible: international.office.win@tue.nl (Mr. Elmar Veenendaal, MF 5.104A, 040-2472752). The international office can help you with such topics as learning agreement, international insurance and scholarship. A good starting point for additional scholarship options is http://www.beursopener.nl/.

Since obtaining international experience is not a valid reason for not following mandatory or prescribed homologation courses, you are strongly encouraged to take those courses during the first year such that part of the second year can be spent abroad.

1.7.2 Internship

An internship is mostly performed to fulfill the international experience part of the master program. An internship takes 15 EC as part of the (free) electives.

Doing an internship requires approval from the internship coordinator. This approval must be obtained *in advance*. The procedure consists of:

- the internship plan, a form to be handed in with the internship coordinator;
- a request stating what is to be accomplished in the internship and why it is important for the coherence of your study program; (You may ask your mentor, graduation supervisor or the academic advisor for advice on internships and on the coherence of your program as a whole. These topics are also addressed in the Program and Examinations Regulations.)
- students requesting to perform an internship should also either have their study program been approved, or submit the study program form[1] together with the internship plan.

The internship coordinator is dr. Natasha Stash (see Section 1.12.2 for her office, email address and contact hours).

1.8 Admission to seminars, capita selecta, master project

Capita selecta courses (5 EC) are occasional educational elements, often with a research flavor. They may be experimental courses, a lecture series given by a visitor, or a special individual assignment as a preparation on future research. As opposed to regular courses, Capita Selecta courses are by invitation only, i.e., while you can indicate your interest in following this course it is up to the lecturer to decide whether you are admitted or not. Students, hence, do not have a "right" to do these courses, but they may be granted the possibility.

[1] Select the form corresponding to your program from the list available on the website.

The seminars, capita selecta, and master project are only open to students that are fully admitted. This means that they are not available for students that do not yet have their BSc diploma or students that did not yet complete the pre-master. Students are only allowed to take a seminar when they are at least in the fourth quarter of their study. Students that still have deficiencies (e.g. uncompleted homologation courses) are not allowed to start the master project. Each master program has additional specific rules regarding permission to start the master program and the allowed choices of graduation advisor.

1.9 Approval of study program

The Examinations Committee must approve your program consisting of the mandatory courses and your choice of the electives (possibly including an internship). In order to obtain this approval you construct a program, possibly with the help of your mentor and academic advisor, fill out the program form, sign it, get it approved by the master thesis supervisor of your choice (or another representative of the same research group) and hand it in at the student administration office (MF 5.103). To make sure you do not miss courses you should choose it is recommended to submit your study program around the start of Quarter 3 of your first year. If needed you can still make changes later and reapply for approval.

1.10 Honors programs

Two different honors programs are available for excellent students: Research CS Honors and Honors Academy. Students of all Master programs offered by the Computer Science division can apply. Both honors programs are extracurricular, i.e., done **on top** of the regular Master program, that is, the EC obtained do not count towards the 120 credits you need to accumulate for your Master program.

More information about the honors programs can be obtained from the honors programs' coordinators dr. Kevin Buchin, e-mail k.a.buchin@TUE.nl and dr. Wouter Meulemans w.meulemans@TUE.nl .

1.10.1 CS Research Honors

The goal of the program is to give the excellent students the opportunity to participate in and contribute to the research being done at the department. Concretely, the Honors program consists of:

- Two projects for 6 EC each, one in semester 1B of the Master program and one in semester 2A. These projects can be research-oriented or design-oriented and are done in different research groups in the department. The exact contents of the projects is determined by the supervisor of the research group where the project is done, in consultation with the student. The expected outcome of the project is a paper (published as a technical report of the department, and possibly also elsewhere).
- Beside the projects, the student participates in other activities of the research group (for example in research seminars) and is encouraged to participate in activities organized by one of the national Dutch research schools (ASCI, IPA, or SIKS). The latter activities are typically short courses or conferences.

Students who successfully complete the Honors program will receive a certificate upon graduation.

Participating in the Honors program is especially useful if you are interested in taking a PhD later on, since it allows you to experience what it is like to do research in two different areas. But above all, the Honors program is challenging and fun.

The program is aimed at highly motivated excellent students (among the top 10% of the Master students in the department) who had outstanding grades in their Bachelor programs and scored high grades during the first semester of the Master program (average at least 8). For admission to the honors program, an application procedure applies. Detailed instructions for application and the deadline will be announced by e-mail to all students in February of each year.

1.10.2 Honors Academy

Honors Academy is the university-broad program. It consists of two interrelated components: personal leadership development (5 EC) and professional development (15 EC). Activities related to the personal leadership component target students of all master programs and are organized by the Graduate School. Professional development activities might be related to 'excellence for science', 'excellence for industry' and 'excellence for society'. Examples of such activities can be international or industrial internships, taking courses at other universities or designing a business plan.

You can apply by submitting an application letter to the the honors programs' coordinators dr. Kevin Buchin, e-mail k.a.buchin@TUE.nl and dr. Wouter Meulemans w.meulemans@TUE.nl . In this letter you should motivate why you want to join the honors academy and what makes you an excellent candidate for the professional development as well as personal leadership part. You need to enclose two appendices: (1) evidence of your past performance and (2) a tentative plan for your professional development: what do you want to achieve and how?

1.11 Internal quality assurance

After each semester the individual courses as well as the program are evaluated by the educational management and the study program committee. Based on this evaluation follow-up actions for improvement are defined if necessary. Input for the evaluation sessions are statistical data on the examination results, and the aggregated results from the semester questionnaires for students. It is of vital importance that students cooperate in this respect since only questionnaires with a sufficient number of respondents are taken into consideration. Apart from that, the examination committee periodically carries out an investigation, in particular on the quality of the graduation projects and the quality of (partial) interim examinations.

The opinion of students on the quality of their graduation project and process is gathered by means of a graduation questionnaire, which is filled in after the assessment of the graduation project. These are collected and aggregated once a year. The results are discussed both in the study program committee and examination committee.

1.12 Individual support

Within the first few weeks of your study a *mentor* will be assigned to you. To allow us to assign you the mentor please register for one of the courses as indicated in the list below. The mentor will advise you with regards to the development of your professional skills (which includes assessment and training by the TU/e Skills Lab, see http://skillslabtue.nl/) and will help you in making the first choices for electives and in deciding which specialization best suits your interests.

At some point during your study your specialization will become clearer. You choice should be clear by the end of the first year of study. Your mentor will then help you in choosing a new mentor from the group that best matches that specialization. The new mentor will then help you in selecting elective courses to prepare you for doing a master project in your area of interest and in selecting a trajectory for getting international experience (if needed).

For more procedural aspects of your study such as obtaining approval of your study program and getting official permission to start your master project you should consult the academic advisor (see section 1.12.2). You can also discuss personal or study-related programs with the academic advisor; they can also refer you to student psychologists, should this be desired.

1.12.1 Mentoring

For the academic year 2018–2019 the following mentors have been assigned:

- 2IMC92 Business Information Systems: dr. Dirk Fahland
- 2IMC96 Computer Science and Engineering, Software Science stream: dr. Anton Wijs and dr. Michael Burch
- 2IMC94 Computer Science and Engineering, Systems Science stream: prof. dr. Jan-Friso Groote
- 2IMC95 Computer Science and Engineering, Web Science stream: dr. Decebal Mocanu
- 2IMC90 Data Science in Engineering: dr. Kevin Buchin, dr. Michael Burch, dr. Bart Jansen, dr. Dirk Fahland and dr. George Fletcher
- 2IMC93 EIT Digital Data Science (entry): dr. Renata Medeiros de Carvalho
- 2IMC98 EIT Digital Data Science (exit): dr. Renata Medeiros de Carvalho
- 2IMC85 EIT Digital Embedded Systems (entry): dr. Bas Luttik
- 2IMC86 EIT Digital Embedded Systems (exit): dr. Bas Luttik
- 2IMC84 Embedded Systems, Cyber-Physical Systems stream: dr. Dip Goswami
- 2IMC83 Embedded Systems, Embedded Networking stream: dr. Tanir Ozcelebi
- 2IMC82 Embedded Systems, Embedded Software stream: prof. dr. Jan-Friso Groote
- 2IMC81 Embedded Systems, Systems on Chip stream: prof. dr. Kees Goossens
- Erasmus Mundus Big Data Management and Analytics: dr. Renata Medeiros de Carvalho
- 2IMC91 Information Security Technology: dr. Nicola Zannone

1.12.2 Academic advisor

The academic advisor for all master programs is dr. Natasha Stash.

Office: MF 5.097
E-mail: AcademicadvisorMCS@tue.nl
Phone: 040-247 2322
Contact hours:
- brief questions (<5 minutes): Tuesday 12:45-14:00 and Friday 12:15-13:30.
- longer questions: by appointment only.

1.13 After graduation

As an MSc graduate from the Computer Science Graduate Program, you are optimally prepared for a broad range of ICT-related jobs. However, you might consider to qualify yourself further for special jobs like system or software architect or for an academic career. In the latter case, the department of Mathematics and Computer Science offers the following opportunities.

1.13.1 Software Technology PDEng degree program

The Professional Doctorate in Engineering (PDEng) degree program in Software Technology is provided in the context of the 3TU School for Technological Design, the Stan Ackermans Institute.

It is an accredited and challenging two-year post-graduate-level engineering degree program during which its trainees focus on strengthening their technical and non-technical competences related to the effective and efficient design and development of software-intensive systems, such as real-time embedded systems, in an industrial setting. The emphasis is on large-scale project-based design and development of this kind of software.

The various parts of the PDEng degree program aid to develop the capability of individuals to work within a professional context. It advocates a scientific research based approach to solving problems, a systematic way of collecting evidence and a critical, reflective, and independent mind for the analysis and interpretation of evidence.

It adds an additional dimension to a full MSc. program by extending it and integrating it with new elements. The emphasis is on developing and strengthening (exercising) the competencies necessary for finding complex technical solutions. For finding such solutions, an effective collaboration with representatives of different domains is inevitable, and this is practiced during the program. During the program, the PDEng trainees focus on multi-disciplinary systems architecting and designing software for software-intensive systems in multiple application domains for the High Tech Industry.

After successfully completing all requirements, trainees are awarded a Professional Doctorate in Engineering degree. More information can be found on: `http://www.tue.nl/softwaretechnology`

1.13.2 PhD programs

While obtaining a PhD is the first step in the academic career, numerous PhDs develop successful careers in industry, government and non-academic education.

A PhD program is an individual four year program, dedicated to sharpening your research and professional skills. You are typically hired on a specific research project and become part of the scientific staff of the research group in which the project takes place. Your main task is to perform research under the guidance of and in collaboration with the supervisor(s) appointed by the Department. At the end of the four-year period, a PhD thesis is written on the research results. You do not only perform research, but also receive scientific training and training related to professional skills and personal development. Moreover, some PhD students are involved in teaching and supervision of Master students.

More information about PhD programs can be found on: http://www.tue.nl/en/education/tue-graduate-school/phd-programs/

2 Pre-master programs

2.1 General rules

- To be admitted to one of our pre-master programs the candidates should meet the entrance requirements for Mathematics and English. These entrance requirement must have been met by passing an entrance test by September 1, 2018 in order to be enrolled as of September 1, 2018. By requiring these two entrance tests, we want to make sure your level of mathematics and English is corresponding with the level you need to be able succeed in a TU/e pre-Master program. Based on these tests, you could reconsider your choice or increase your chances by working at your Math and / or English level.
  - For **Mathematics** the entrance requirement is a certificate for the preliminary examination in Mathematics T or B. To obtain this certificate you can either take a preliminary examination at the Open University, or at Boswell-Beta in Utrecht. Students with the pre-university (VWO) certificate Mathematics B are exempted from this requirement.
  - For **English** the entrance requirement is a recent certificate (no older than two years) from one of the following examination organizations:
    - TOEFL certificate; overall band score of at least 90 AND a minimum score of 21 for each section.
    - IELTS certificate; overall band score of at least 6.5 and a minimum of 6.0 for each section.
    - Certificate of Proficiency in English of the Certificate in Advanced English (University of Cambridge).

    Students with the pre-university (VWO) certificate are exempted from this requirement.
- Students that have successfully completed a large part of their pre-master program during the first half-year of their studies and would be at a demonstrable disadvantage should they be required to wait for the completion of the pre-master prior to

joining the master program, can apply for a special permission of the Examinations Committee to follow master study's components:

- Students should have to pass all courses during the first half year to be eligible for this exception.
- Students following a 30 EC pre-master program that can be followed within half a year are not eligible.
- Maximum of 15 EC of master study's components can be approved.
- The eligible courses have to be determined in advance.
- The application should be discussed with and submitted to the study advisor, Dr. Natasha Stash (see below).

- Please note that the *course* you register for, determines the regulations you have to follow (see Section 1.4). You should consult OSIRIS and check whether the course you intend to take is a Bachelor College course or a Graduate School course.
- Successful completion of the pre-master program grants admission to the *corresponding* master program. Pre-master graduates cannot be admitted to international programs (EIT Embedded Systems, EIT Data Science, Erasmus Joint Master Degree: Big Data Management and Analytics).

It is not possible to follow additional homologation courses in a master program after a finished pre-master. For a deficiency that exceeds 30 EC, students are advised to enroll in the preparatory Bachelors program.

2.2 Computer Science and Engineering

The pre-master program for a student with a completed polytechnic program in computer science totals to 30 EC and consists of the following units:

Quarter	Code	Unit	ECTS
1	2WBB0	Calculus	5
1 or 3	2IT60	Logic and set theory[1]	5
2	2IT90	Automata, language theory and complexity	5
2	2ID50	Data modeling and databases[1]	5
2 or 4	2DE29/ 2DBI00	Linear algebra	5
3	2IL50	Data structures	5

[1] *The course Data modeling and databases should be preceded by Logic and set theory.*

2.3 Data Science in Engineering

The pre-master program for a student with a completed polytechnic program in computer science totals to 30 EC and consists of the following units:

Quarter	Code	Unit	ECTS
1	2DL10	Premaster calculus and probability	5
1 or 3	2IT60	Logic and set theory[1]	5
2 or 4	2DE29/ 2DBI00	Linear algebra	5
2	2ID50	Data modeling and databases[1]	5
2 or 4	2DL20	Statistics[2]	5
3	2IL50	Data structures	5
4	2DI90	Probability & statistics[2]	5

[1] *The course Data modeling and databases should be preceded by Logic and set theory.*

[2] *Exactly one of the two courses should be taken.*

2.4 Information Security Technology

The pre-master program for a student with a completed polytechnic program in computer science totals to 30 EC and consists of the following units:

Quarter	Code	Unit	ECTS
1	2WBB0	Calculus	5
1 or 3	2IT60	Logic and set theory[1]	5
2	2IT90	Automata, language theory and complexity	5
2	2ID50	Data modeling and databases[1]	5
3	2IL50	Data structures	5
4	2IC60	Computer networks and security	5

[1] *The course Data modeling and databases should be preceded by Logic and set theory.*

2.5 Business Information Systems

The program is being phased out. As of 2018/2019 no new students are admitted.

2.6 Embedded Systems

The pre-master program for a student with a completed polytechnic program in computer science or similar totals to 30 EC and consists of the following units:

Quarter	Code	Unit	ECTS
1	2DL10	Premaster calculus and probability	5
1	5ECA0	Circuits	5
1 or 3	2IT60	Logic and set theory	5
2	5LIU0	Premaster Linear Systems, Signals and Control	5
3	2DE20	Mathematics I	5
4	5XIE0	Computational modeling	5

The pre-master program for a student with a completed polytechnic program in electrical engineering or similar totals to 30 EC and consists of the following units:

Quarter	Code	Unit	ECTS
1	2DL10	Premaster calculus and probability	5
1	2INC0	Operating systems	5
1	2IT60	Logic and set theory	5
2	5LIU0	Premaster Linear Systems, Signals and Control	5
3	2DE20	Mathematics I	5
4	5XIE0	Computational modeling	5

Upon request, an alternative pre-master program Embedded Systems consisting of Q1 and Q2 courses only can be composed for students who prefer to complete the pre-master program in the first semester. Students interested in pursuing this option should contact the study advisor, Dr. Natasha Stash (see below).

2.7 Information sources

Study advisor and Coordinator:

dr. N. (Natasha) Stash,
MF 5.097
e-mail: AcademicAdvisorMCS@tue.nl

Part II

Master Programs

3 Computer Science and Engineering

The Master program in Computer Science and Engineering (CSE) gives a broad view of computer science from both a scientific and an engineering perspective, and provides ample opportunities for specialization. The program offers three different streams: Software Science, Systems Science, and Web Science and the possibility to follow a program partly outside these streams, for instance to prepare for getting a teaching degree. Each stream has a core program of five courses. There is a large list of stream electives from which you should choose some courses to prepare for your master project. There is also ample room in the program to choose electives from outside your stream. Apart from the three streams there are also two special tracks: Data Science in Engineering and Information Security Technology. These are described in separate chapters in this document.

3.1 Admission

A Bachelor degree in Computer Science obtained at a Dutch university provides direct admission to the CSE program. Students with a different degree and from foreign universities have to apply for admission via the admission committee. Dutch HBO graduates have to take a pre-master program before they can be admitted, see Section 2.2.

The admission procedure is described in Section 1.6, and the requirements are listed in the Teaching and Examination Regulations (see Appendix A.1).

3.2 Learning outcomes

A graduate from the master program

- is qualified to degree level within the domain of 'science engineering & technology';
- is competent in Computer Science and Engineering at the scientific Masters degree level;
- is able to conduct research and design independently;

- has the ability and attitude to include other disciplines in their research, where necessary;
- has a scientific approach to complex problems and ideas;
- possesses intellectual skills that enable them to reflect critically, reason and form opinions;
- has the ability to communicate the results of their learning, thinking and decision-making processes at an international level;
- is aware of the temporal and social context of science and technology (comprehension and analysis) and can integrate this context in their scientific work;
- in addition to a recognizable domain-specific profile, possesses a sufficiently broad basis to be able to work in an interdisciplinary and multidisciplinary context. In this context, multidisciplinary means being focused on other relevant disciplines needed to solve the design or research problem in question;
- has the ability and attitude to seek new potential applications, taking the social context into consideration.

In addition to these general learning outcomes, CSE graduates should also be experts in the subarea of computer science that they specialize in.

3.3 Curriculum

The Master program Computer Science and Engineering is a two-year program of 120 ECTS in total. The academic year is subdivided into two semesters, the fall semester starting in September, and the spring semester starting in February. It is possible to enter the program at the start of either semester; however, starting in September is preferred. The program is only offered as a full time study program.

The CSE curriculum is structured in *streams*, which provide an organized set of courses in particular subject areas within computer science. The streams provide guidance for the directions in which you can specialize, and ensure that you choose a comprehensive and coherent set of courses. When you enroll to the CSE master you should choose a stream right away because this determines the list of mandatory courses and the assignment of a mentor. The streams are:

- Software science (Section 3.3.1)
- Web science (Section 3.3.2)
- Systems science (Section 3.3.3)

Each stream has the same structure, as summarized in the following table.

Units	ECTS
CSE mandatory course	5
Stream mandatory courses	20
Stream elective courses	20
Free electives	40
Seminar	5
Master project	30

Each stream has a number of mandatory courses, and a selected set of elective courses from which at least 20 EC should be chosen. There is great flexibility in defining the remaining part of your individual study program from all courses that are offered by the computer science department (40 credit points). Within this remaining part you should include 15 credit points in international experience if you do not have it yet and are not doing your master project abroad. To prepare for the master project, you take a seminar course from one of the computer science research groups. In the following sections, more details for each of the streams are given.

3.3.1 Software Science stream

Innovative software systems are the driving force behind many exciting developments in society, industry, and science. However, designing software systems that function correctly, efficiently and securely, is far from easy. The CSE stream Software Science focuses on the formal techniques and technology you need for this. You learn model-driven engineering techniques to increase the quality of computer programs. As a graduate of the stream Software Science, you

- have in-depth knowledge of techniques needed to model and design efficient and reliable software
- understand the strengths and weaknesses of these techniques and can apply them in the appropriate situation, taking limitations of cost, time, and other resources into account
- can analyze existing software systems and understand the fundamental issues involved in software maintenance

Mentor of the Software Science stream are dr. Anton Wijs and dr. Michael Burch, prior to the beginning of the academic year you should register for 2IMC96. For further information about mentoring please consult Section 1.12.1.

The following table lists the mandatory courses and stream electives.

Quarter	Code	Unit	EC	Exam[1]
CSE mandatory course				***5***
1	2IMA10	Advanced algorithms	5	w+a
Stream mandatory courses				***20***
2	2IMP10	Program verification techniques	5	w+a
3	2IMP25	Software evolution	5	w+a
3	2IMD10	Database technology	5	w+a
4	2IMP20	Generic language technology	5	w+a
Stream electives [2]				***20***
1	2IMI15	Metamodeling and interoperability[3]	5	w+a
1	2IMG15	Algorithms for geographic data	5	a
2	2IMA15	Geometric algorithms	5	a
3	2IMF15	Proving with computer assistance	5	w+a
4	2IMF10	Process algebra	5	w+a
4	2IMV15	Simulation in computer graphics	5	a
Free electives (possibly including internship)				***40***
Seminar and master project)				***35***

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Quarter	Code	Unit	EC	Exam[1]
4 or 6		**Seminar** [4]	5	a
7 and 8	2IMC00	**Master project** [5]	30	a

[1] *w—written exam, a—assignments, o—oral exam.*

[2] *You have to choose at least 20 credit points from this list.*

[3] *The course is offered for the last time in 2018/2019.*

[4] *Seminars must be taken from the fourth quarter of your study program onwards. This means that if you enroll in September, you cannot take the seminars in quarter 2 in your first year, but that you have to wait until you have entered the second year. If you enroll in February, the seminars are effectively in the fourth quarter of your study.*

[5] *You can only start the master project if your individual study program has been approved by the Examinations Committee, and if all homologation units (if any) have been completed successfully, see also Section 3.4.*

3.3.2 Web Science stream

Over the past decade the use of web-based systems has exploded. Buying clothes, books, and DVDs, booking hotels, checking the weather forecast, contacting your friends: all of this is done on the internet nowadays, and novel web-based applications are developed every day. The CSE stream Web Science focuses on the technology behind these developments. In the stream you learn techniques needed to design intelligent and reliable web-based systems, their role in on-line business and you learn to analyze the use of such systems. As a graduate of the Web Science stream you

- have knowledge of the principles and technologies that drive the Web
- have the skills to design effective web-based systems, and to analyze existing web-based systems and the data generated through their use
- can design intelligent information services using semantic-web technology or machine-learning techniques
- have insight into business, privacy and security issues related to web-based systems

If you want to specialize more in the data-analysis aspect of Web Science you should consider the special track on Data Science in Engineering.

Mentor of the Web Science stream is dr. Decebal Mocanu, prior to the beginning of the academic year you should register for 2IMC95. For further information about mentoring please consult Section 1.12.1.

The following table lists the mandatory courses.

Quarter	Code	Unit	EC	Exam [1]
CSE mandatory course				***5***
1	2IMA10	Advanced algorithms	5	w+a
Stream mandatory courses				***20***
1	2IMM20	Foundations of data mining	5	a
2	2IMV20	Visualization	5	a
4	2IMM10	Recommender systems	5	w+a
4	2IMD15	Data engineering	5	a
Stream electives [2]				***20***

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Quarter	Code	Unit	EC	Exam [1]
1	2IMV25	Interactive virtual environments	5	a
1	2IMS25	Principles of data protection	5	w+a
2	2IMS20	Cyberattacks Crime and Defenses	5	w+a
3	2IMM15	Web information retrieval and data mining	5	a
3	2MMD30	Graphs and algorithms	5	w+a
3	2IMV10	Visual computing project	5	a
4	0EM190	Infonomics	5	a
Free electives (possibly including internship)				***40***
Seminar and master project)				***35***
4 or 6		**Seminar** [3]	5	a
7 and 8	2IMC00	**Master project** [4]	30	a

[1] *w—written exam, a—assignments, o—oral exam.*

[2] *You have to choose at least 20 credit points from this list.*

[3] *Seminars must be taken from the fourth quarter of your study program onwards. This means that if you enroll in September, you cannot take the seminars in quarter 2 in your first year, but that you have to wait until you have entered the second year. If you enroll in February, the seminars are effectively in the fourth quarter of your study.*

[4] *You can only start the master project if your individual study program has been approved by the Examinations Committee, and if all homologation units (if any) have been completed successfully, see also Section 3.4.*

3.3.3 Systems Science stream

High-tech systems are defined by a tight interaction between physical systems and computing systems. They are often called "Cyber-Physical Systems". They are characterized by complex architectures and complex interactions between physical sensors and actuators control, computation, and communication. In the CSE stream Systems Science you study these new technologies and the process to develop them. Protocols, interfaces and algorithms need to be designed to improve (energy) efficiency and automation. Larger systems are never built from scratch anymore, but composed from existing building blocks. An understanding of the essential structures and behaviors of a system - the architecture, laid down in models - is therefore essential. Models are further used to validate—often using mathematically based methods—and monitor required qualities (reliability, robustness, safety, security and privacy), and to drive the implementation. Experimentation and online methods (like self-monitoring) are essential ingredients. As a student graduating in the stream Systems Science you

- are familiar with the architectures and architectural principles of large-scale software systems
- are capable to apply complex model-based methods required for the rigorous functional and quantitative analysis of system behaviors
- understand the role of software—foundations as well as processes and tools—in its interaction with hardware and sensors in large-scale software-intensive systems.

Mentor of the Systems Science stream is prof. dr. Jan-Friso Groote, prior to the beginning of the academic year you should register for 2IMC94. For further information about mentoring please consult Section 1.12.1.

The following table lists the mandatory courses.

Quarter	Code	Unit	EC	Exam [1]
CSE mandatory course				***5***
1	2IMA10	Advanced algorithms	5	w+a
Stream mandatory courses				***20***
1	2IMF30	System validation	5	w+a
2	2IMN15	Internet of Things	5	w+a
2	2IMF25	Automated reasoning	5	w+a
3	2IMN20	Real-time systems	5	w+a
Stream electives [2]				***20***
1	2IMN10	Architecture of distributed systems	5	w+a
1	2IMF20	Hardware verification	5	w+a
2	2IMN25	Quantitative evaluation of embedded systems	5	w+a
3	2IMF35	Algorithms for model checking	5	w+a
3	2IMS15	Verification of security protocols	5	w
4	2IMN35	VLSI Programming	5	a
Free electives (possibly including internship)				***40***
Seminar and master project)				***35***
4 or 6		**Seminar** [3]	5	a
7 and 8	2IMC00	**Master project** [4]	30	a

[1] *w—written exam, a—assignments, o—oral exam.*

[2] *You have to choose at least 20 credit points from this list.*

[3] *Seminars must be taken from the fourth quarter of your study program onwards. This means that if you enroll in September, you cannot take the seminars in quarter 2 in your first year, but that you have to wait until you have entered the second year. If you enroll in February, the seminars are effectively in the fourth quarter of your study.*

[4] *You can only start the master project if your individual study program has been approved by the Examinations Committee, and if all homologation units (if any) have been completed successfully, see also Section 3.4.*

3.3.4 Free stream

The streams have been set up such that they provide a structured set of courses related to important topics in computer science. The "free stream" enables you to follow a different program. In any case you have to take the CSE mandatory course together with the four mandatory courses from one of the predefined streams (Software Science, Web Science or Systems Science) but then take a set of electives that does not contain 20 EC from the stream electives of that stream. You have to ask permission to the Examinations Committee, and motivate why you cannot set up a desired individual study program that falls within one of the streams.

A commonly accepted reason for choosing the free stream is to follow a teacher-training program with courses and other credits from the Eindhoven School of Education (ESoE) aimed at obtaining a teaching degree (with or without going for a double degree). Instead of 20 EC in stream electives plus 40 EC in free electives you then take only 15 EC in electives from your chosen stream plus 45 EC as teacher training program.

3.3.5 Free electives

This section provides a list of courses that are generally recommended for the free electives space in the curriculum. The list applies to all streams. In principle all master courses offered at the TU/e can be chosen as free electives so you are not restricted to this list.

Your complete study program including the free electives always requires approval by the examinations committee. Your mentor will help you to compose a balanced program that is very likely to be approved.

If you do not (yet) have a degree from another country or at least 15 credit points in international experience you should reserve 15 credits from the room for free electives to take courses abroad or to do an internship of 15 credits abroad, see Section 1.7.2. (This does not apply to students taking the teacher training.)

3.3.6 Homologation courses

Some courses may be prescribed or recommended as homologation courses (up to 15 EC) to make up for deficiencies in former education. This prescription/recommendation is part of the admission decision.

Upon discussion with your mentor and/or academic advisor and approval by the exam committee, you might include not more than 15 EC of bachelor-level units as part of the free electives. It is not possible to follow additional homologation courses in a master program after a finished pre-master.

Quarter	Code	Unit	EC	Exam
1	2IMM20	Foundations of data-mining	5	a
1	2IMN10	Architecture of distributed systems	5	w+a
1	2IMI15	Metamodeling and interoperability[5]	5	w+a
1	2IMA10	Advanced algorithms	5	w+a
1	2IMV25	Interactive virtual environments	5	a
1	2IMF30	System validation	5	w+a
1	2IMS25	Principles of data protection	5	w+a
1	2IMF20	Hardware verification	5	w+a
1	2IMG15	Algorithms for geographic data	5	a
2	2IMS20	Cyberattacks Crime and Defenses	5	w+a
2	2IMP10	Program verification techniques	5	w+a
2	2IMA15	Geometric algorithms	5	a
2	2IMN15	Internet of things	5	w+a
2	2IMI20	Advanced process mining	5	w+a
2	2IMN25	Quantitative evaluation of embedded systems	5	w+a
2	2IMV20	Visualization	5	a
2	2IMF25	Automated reasoning	5	w+a
2	2DMT00	Applied statistics	5	w+a
3	2IMA25	Exact Algorithms for NP-hard Problems	5	w+a
3	2IMM15	Web information retrieval and data mining	5	a
3	2IMF15	Proving with computer assistance	5	w+a
3	2IMN20	Real-time systems	5	w+a
3	2IMP25	Software evolution	5	w+a
3	2IMV10	Visual computing project	5	a

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Quarter	Code	Unit	EC	Exam
3	2IMF35	Algorithms for model checking	5	w+a
3	2IMS15	Verification of security protocols	5	w
3	2IMD10	Database technology	5	w+a
3	2MMD30	Graphs and algorithms	5	w+a
3	2DI70	Statistical learning theory	5	w+a
4	2IMM10	Recommender systems	5	w+a
4	2IMD15	Data engineering	5	a
4	2IMP20	Generic language technology	5	w+a
4	2IMF10	Process algebra	5	w+a
4	2IMG10	Topological data analysis	5	w+a
4	2IMN35	VLSI programming	5	a
4	2IMP15	Software project management	5	a
4	2IMP30	System design engineering	5	w+a
4	2IMV15	Simulation in computer graphics	5	a
4	2IMNT2	Real-time software development	5	a
4	2DD23	Time-series analysis & forecasting	5	a+o
5	2IMS10	Physical aspects of digital security	5	w
		Courses at Utrecht University[1]		
2	2IUU1	Intelligent agents	7.5	w
3	2IUU2	Multi-agent systems	7.5	w+a
3	2IUU3	Computer vision	7.5	w+a
4	2IUU4	Computer animation	7.5	a
4	2IUU5	Games and agents	7.5	a
		Seminars[2]		
4	2IMS00	Seminar information security technology	5	a
4	2IMA00	Seminar algorithms	5	a
6	2IMG00	Seminar applied geometric algorithms	5	a
6	2IMM00	Seminar data mining	5	a
6	2IMI00	Seminar analytics for information systems	5	a
6	2IMD00	Seminar databases	5	a
6	2IMN00	Seminar systems architecture and networking	5	a
6	2IMP00	Seminar software engineering and technology	5	a
6	2IMV00	Seminar visualization	5	a
6	2IMF00	Seminar formal system analysis	5	a
		Capita selecta courses/internship[3]		
	2IMF05	Capita selecta formal system analysis	5	a
	2IMP05	Capita selecta software engineering and technology	5	a
	2IMS05	Capita selecta security	5	a
	2IMA05	Capita selecta algorithms	5	a
	2IMG05	Capita selecta applied geometric algorithms	5	a
	2IMM05	Capita selecta data mining	5	a
	2IMN05	Capita selecta systems architecture and networking	5	a
	2IMV05	Capita selecta visualization	5	a
	2IMD05	Capita selecta databases	5	a
	2IMI05	Capita selecta analytics for information systems	5	a
	2IMC10	Internship[4]	15	a

[1] *Secondary enrollment ("neveninschrijving") at Utrecht University is required to follow these courses. Note that all teaching activities take place in Utrecht. Definitive availability and scheduling depends on Utrecht University and are not guaranteed when this document is published.*

[2] *Seminars can be taken from the fourth quarter of your study program onwards. This means that if you enroll in September, you cannot take the seminars in quarter 2 in your first year, but that you have to wait until you have entered the second year. Similarly, if you enroll in February, the seminars in quarter 4 can only be followed in your second year.*

[3] *Capita selecta can only be taken with permission of the responsible lecturer. They can be taken at any time but typically during the second year of your master study.*

[4] *The internship can be followed only after having obtained permission of the internship coordinator (see Section 1.7.2).*

[5] *The course is offered for the last time.*

3.4 Final project

The final project of 30 credit points can be completed in any of the research groups in the CS-division. The practical execution may be performed in industry or a research institute, in the Netherlands or abroad, as long as a CS staff member is supervising it.

The start of your master project is marked by submitting a completed graduation plan containing the necessary information on the project (name, place, period, supervisor, and so on), and stating the fact that you have completed your curricular part of the program (see Section 1.9). The form must be accompanied by a project description and signed by you, your supervisor, the head of the relevant specialization and the academic advisor.

3.4.1 Admission

During the master project, you should be able to work and concentrate on your project full-time. In practice, however, it turns out to be rather difficult to plan all your curricular activities and, especially, their success:

- If all courses have been completed, permission to start the master project will be granted.
- If more than two courses or 10 EC (whichever is lower) have not been completed, such permission will not be granted.
- In other cases (no more than two courses or 10 EC not yet completed) it depends on the status of the uncompleted courses whether permission to start the master project will be granted, and if so, whether it is feasible to work on the project full time.

Courses that are to be taken as homologation units must be completed and passed before you are allowed to start the master project. Also, be aware that you are not allowed to finish your project (with presentation and defense) before you have completed all your courses. For more information, please contact the academic advisor, AcademicAdvisorMCS@tue.nl.

3.4.2 Planning

Together with your supervisor, you decide on a description of your topic and a global planning. You also arrange the supervision method, including how often you and your supervisor will meet to discuss progress. The project is concluded with a thesis and a presentation followed by a defense.

In general, the master project should be completed within 6 months from the start. An extension to 9 months is possible. In exceptional cases, and only if it is clear that the project can be finished, the exam committee may allow for an additional 3 months period. It is important to note that the project must be finished within 1 year. A project not finished within 1 year is automatically cancelled and graded as "fail". You then have to start a new project with a different supervisor. The complete examination regulations can be found on the website.

3.4.3 Final presentation and defense

The final presentation is public and is held in buildings of Eindhoven University of Technology. It is customary that the final presentation takes ca. 30 minutes. The defense following the presentation, however, is not public; only the student and the assessment committee (see below) are present unless both parties have no objection to the presence of others.

3.4.4 Assessment

Your final project is graded by an assessment committee. The committee usually consists of your supervisor, a staff member from your specialization area, and a staff member from one of the other CS research groups. The supervisor is responsible for forming this committee at least one month before graduation.

The assessment committee takes the following criteria into account:

Results:	Significance of the results versus difficulty of the problem or project goals.
Report:	Structure, completeness, correctness, readability, argumentation.
Graduation presentation:	Structure, contents, clarity, contact with audience.
Defense:	Argumentation, demonstration of knowledge, competency in discerning main aspects from details of the project.
Execution of the project:	Level of independence, planning, organization, handling deadlines and setbacks, level of own contribution.

The actual assessment form used by the committee has a more fine-grained list of criteria for evaluating the work. Not all criteria are equally important. The assessment committee decides the relative importance of each criterion to arrive at a final grade. The motivation for the grade is documented in an assessment report, see the MSc assessment form.

3.4.5 Cum laude regulations

The Examination Committee may award the classification "cum laude" if

- the student achieves an average grade of 8.0 or higher for all the study components,
- the graduation project must have a grade of 9.0 or higher,
- none of the study components may have a grade lower than a 6.0.

The average grade is computed **without** taking into account the number of EC associated with the course.

3.4.6 Checklist

The graduation checklist (Appendix B) summarizes all the steps required starting with getting your study program approved and ending with the graduation ceremony.

3.5 Double degree program CSE and SEC

The qualification to teach computer science to senior secondary school pupils is coupled to the 3TU master program Science Education and Communication (SEC). This program encompasses 120 credits. In Eindhoven it is offered by the Eindhoven School of Education (ESoE). In the Education track of the SEC program, a student specializes in one of four disciplines: maths, physics, chemistry or computer science. Please note that the SEC program is completely lectured in Dutch!

BSc graduates in computer science are directly admitted to the SEC-program. So are MSc graduates from a computer science oriented program; their SEC-program is reduced to 60 credits because of exemptions. For this last category an even shorter route is available by taking the double degree program, which amounts up to 150 credits. Enrollment is required for both master programs (one main enrollment and a second enrollment). Certificates will be granted after completion of the whole program.

Details about the curriculum are available at the ESoE website: `http://www.tue.nl/esoe/`.

It is possible to take 45 credits worth of components of the SEC program within the CSE master. The TU/e strives to have this become sufficient to obtain a teaching qualification without doing a double degree CSE and SEC master.

4 Data Science in Engineering

A Master of Science in Data Science in Engineering (DSIE) is a multidisciplinary academic expert in many aspects of handling data and information. Growing amounts of data will significantly change the jobs of (future) engineers. A data scientist understands how to transform data into actionable information that can be used to influence operational processes, e.g. reducing waiting times in care processes, improving compliance in banks and making high-tech systems more robust. To this end the DSE master combines topics from computer science, mathematics and industrial engineering.

The DSIE master is embedded as a special track within the Computer Science and Engineering (CSE) master and the Industrial and Applied Mathematics (IAM) master. There are two streams, leading to a DSIE master associated with either the CSE or the IAM master diploma. This document only describes the Computer Science stream of the DSIE master.

After taking some courses, you will probably have a more clear picture of the academic direction you want to pursue in your studies. If not, you may want to talk to several staff members or the academic advisor. In the specialization for your subject, there are people that you may want to be involved with for your final master project (see Section 4.4). In order to compose a well-balanced program that provides adequate prerequisites for this project, it is advisable to first choose and consult a project supervisor in the specialization of your interest before choosing elective courses. As a rule of thumb, you should start your search for a supervisor and the construction of your individual program no later than at the end of your first year.

4.1 Admission

A Bachelor degree in Computer Science obtained at a Dutch university provides direct admission to the DSIE program. Students with a different degree and from foreign universities have to apply for admission via the admission committee. Dutch HBO graduates have to take a pre-master program before they can be admitted, see Section 2.3.

Admissions to the DSiE requires basic working knowledge and skills in the following subjects, as acquired in approved Bachelors level coursework: logic and set theory (2IT60),

linear algebra (2DE29 or 2DBI00), data modeling and databases (2ID50), calculus-based statistics and probability (2DI90), and data structures and algorithms (2IL50 and 2ILC0).

Note that these courses themselves have mandatory prerequisites. Lack of knowledge in up to three of the indicated subjects can be compensated for during the Masters program.

The admission procedure is described in Section 1.6, and the requirements are listed in the Teaching and Examination Regulations (see Appendix A.1).

4.2 Learning outcomes

A graduate from the master program

- is qualified to degree level in the domain of science, engineering and technology;
- is competent in the relevant domain-specific discipline, namely computer science and engineering;
- is capable of acquiring knowledge independently;
- approaches computer-science problems in a thorough and scientifically founded manner;
- is capable of critical thinking, can reason logically and form opinions;
- has design skills, presentation skills, and communication skills;
- has insight into the role of computer science in industry, society, and science;
- and, in addition to a recognizable domain-specific profile, possesses a sufficiently broad basis to be able to work in an interdisciplinary and multidisciplinary context.

In addition to these general learning outcomes, a graduate from DSIE

- has a broad view of data science;
- should be able to understand and develop technology for handling structured and semi-structured and possibly distributed big data;
- should be able to analyse data to draw meaningful conclusions from data, effectively turning data into value;
- should understand the role of data in organisations, enabling the shift towards data-driven decision making in industry;
- should understand legal and social aspects of collecting, owning and manipulating data.

4.3 Curriculum

The Master track Data Science in Engineering is a two-year program of 120 EC in total. The academic year is subdivided into two semesters, the fall semester starting in September, and the spring semester starting in February. It is possible to enter the program at the start of either semester; however, starting in September is preferred. The program is only offered as a full time study program.

The DSIE curriculum contains courses from computer science and mathematics. It is structured similarly to other streams of the Master program Computer Science and Engineering (Section 3.3).

Units	ECTS
CSE mandatory course	5
Stream mandatory courses	25
Stream elective courses	20
Free electives	35
Seminar	5
Master project	30

The following table lists the mandatory courses and stream electives.

Quarter	Code	Unit	EC	Exam[1]
CSE mandatory course				***5***
1	2IMA10	Advanced algorithms	5	w+a
Stream mandatory courses				***25***
2	2DMT00	Applied statistics	5	w+a
2	2IMV20	Visualization	5	a
2	2IMI20	Advanced process mining	5	w+a
3	2DI70	Statistical learning theory	5	w+a
4	2IMD15	Data Engineering	5	a
Stream electives [2]				***20***
1	2IMM20	Foundations of data mining	5	a
1	2IMS25	Principles of data protection	5	w+a
1	2IMG15	Algorithms for geographic data	5	a
3	2IMI35	Introduction to process mining	5	w+a
3	2IMM15	Web information retrieval and data mining	5	a
3	2IMD10	Database technology	5	w+a
4	2DD23	Time-series and forecasting	5	a+o
4	2MMS20	Statistic for big data	5	w+a
Free electives (possibly including internship)				***35***
Seminar and master project)				***35***
4 or 6		**Seminar** [3]	5	a
7 and 8	2IMC00	**Master project** [4]	30	a

[1] *w—written exam, a—assignments, o—oral exam.*

[2] *You have to choose at least 20 credit points from this list.*

[3] *Seminars must be taken from the fourth quarter of your study program onwards. This means that if you enroll in September, you cannot take the seminars in quarter 2 in your first year, but that you have to wait until you have entered the second year. If you enroll in February, the seminars are effectively in the fourth quarter of your study.*

[4] *You can only start the master project if your individual study program has been approved by the Examinations Committee, and if all homologation units (if any) have been completed successfully, see also Section 3.4.*

Mentor of the Data Science in Engineering program are dr. Kevin Buchin, dr. Michael Burch, dr. Bart Jansen, dr. Dirk Fahland and dr. George Fletcherprior to the beginning of the academic year you should register for 2IMC90. For further information about mentoring please consult Section 1.12.1.

4.3.1 Alternative for teacher training stream

Like in the standard CSE program you can reduce the electives from the above list to 10 credits to make room for a 45 credit teacher training program offered by the Eindhoven School of Education (ESoE).

4.3.2 Free electives

In principle all master courses offered at the TU/e can be chosen as free electives. We do recommend to take more than the required minimum number of courses from the above lists. In addition other courses from the CSE program, as well as courses from the OML and BIS masters are recommended.

Your complete study program including the free electives always requires approval by the examinations committee. Your mentor will help you to compose a balanced program that is very likely to be approved.

If you do not (yet) have a degree from another country or at least 15 credit points in international experience you should reserve 15 credits from the room for free electives to take courses abroad or to do an internship of 15 credits abroad, see Section 1.7.2. (This does not apply to students taking the teacher training.)

4.3.3 Homologation courses

Some courses may be prescribed or recommended as homologation courses (up to 15 EC) to make up for deficiencies in former education. This prescription/recommendation is part of the admission decision. Upon discussion with your mentor and/or academic advisor and approval by the exam committee, you might include not more than 15 EC of bachelor-level units as part of the free electives.

It is not possible to follow additional homologation courses in a master program after a finished pre-master.

4.4 Final project

Prior to starting the final project you should first choose and consult the intended final project supervisor. As final project supervisors can act assistant professors, associate professors and full professors from the Computer Science sub-department within the Mathematics and Computer Science department. Furthermore, as final project supervisors of DSiE students can assistant professors, associate professors and full professors from the Statistics group of the Mathematics sub-department within the Mathematics and Computer Science department. If you are in doubt how to choose the graduation supervisor please consider contacting your mentor.

The start of your master project is marked by submitting a completed graduation plan containing the necessary information on the project (name, place, period, supervisor, and so on), and stating the fact that you have completed your curricular part of the program (see Section 1.9). The form must be accompanied by a project description and signed by you, your supervisor, the head of the relevant specialization and the academic advisor.

4.4.1 Admission

During the master project, you should be able to work and concentrate on your project full-time. In practice, however, it turns out to be rather difficult to plan all your curricular activities and, especially, their success:

- If all courses have been completed, permission to start the master project will be granted.
- If more than two courses or 10 EC (whichever is lower) have not been completed, such permission will not be granted.
- In other cases (no more than two courses or 10 EC not yet completed) it depends on the status of the uncompleted courses whether permission to start the master project will be granted, and if so, whether it is feasible to work on the project full time.

Courses that are to be taken as homologation units must be completed and passed before you are allowed to start the master project. Also, be aware that you are not allowed to finish your project (with presentation and defense) before you have completed all your courses. For more information, please contact the academic advisor, AcademicAdvisorMCS@tue.nl.

4.4.2 Planning

Together with your supervisor, you decide on a description of your topic and a global planning. You also arrange the supervision method, including how often you and your supervisor will meet to discuss progress. The project is concluded with a thesis and a presentation followed by a defense.

In general, the master project should be completed within 6 months from the start. An extension to 9 months is possible. In exceptional cases, and only if it is clear that the project can be finished, the exam committee may allow for an additional 3 months period. It is important to note that the project must be finished within 1 year. A project not finished within 1 year is automatically cancelled and graded as "fail". You then have to start a new project with a different supervisor. The complete examination regulations can be found on the website.

4.4.3 Final presentation and defense

The final presentation is public and is held in buildings of Eindhoven University of Technology. It is customary that the final presentation takes ca. 30 minutes. The defense following the presentation, however, is not public; only the student and the assessment committee (see below) are present unless both parties have no objection to the presence of others.

4.4.4 Assessment

Your final project is graded by an assessment committee. The committee usually consists of your supervisor, a staff member from your specialization area, and a staff member from one of the other CS research groups. The supervisor is responsible for forming this committee at least one month before graduation.

The assessment committee takes the following criteria into account:

Results:	Significance of the results versus difficulty of the problem or project goals.
Report:	Structure, completeness, correctness, readability, argumentation.
Graduation presentation:	Structure, contents, clarity, contact with audience.
Defense:	Argumentation, demonstration of knowledge, competency in discerning main aspects from details of the project.
Execution of the project:	Level of independence, planning, organization, handling deadlines and setbacks, level of own contribution.

The actual assessment form used by the committee has a more fine-grained list of criteria for evaluating the work. Not all criteria are equally important. The assessment committee decides the relative importance of each criterion to arrive at a final grade. The motivation for the grade is documented in an assessment report, see the MSc assessment form.

4.4.5 Cum laude regulations

The Examination Committee may award the classification "cum laude" if

- the student achieves an average grade of 8.0 or higher for all the study components,
- the graduation project must have a grade of 9.0 or higher,
- none of the study components may have a grade lower than a 6.0.

The average grade is computed **without** taking into account the number of EC associated with the course.

4.4.6 Checklist

The graduation checklist (Appendix B) summarizes all the steps required starting with getting your study program approved and ending with the graduation ceremony.

4.5 Double degree program DSIE and SEC

The qualification to teach computer science to senior secondary school pupils is coupled to the 3TU master program Science Education and Communication (SEC). This program encompasses 120 credits. In Eindhoven it is offered by the Eindhoven School of Education (ESoE). In the Education track of the SEC program, a student specializes in one of four disciplines: maths, physics, chemistry or computer science. Please note that the SEC program is completely lectured in Dutch!

BSc graduates in computer science are directly admitted to the SEC-program. So are MSc graduates from a computer science oriented program; their SEC-program is reduced to 60 credits because of exemptions. For this last category an even shorter route is available by taking the double degree program, which amounts up to 150 credits. Enrollment is required for both master programs (one main enrollment and a second enrollment). Certificates will be granted after completion of the whole program.

Details about the curriculum are available at the ESoE website: `http://www.tue.nl/esoe/`.

It is possible to take 45 credits worth of components of the SEC program within the DSIE master. The TU/e strives to have this become sufficient to obtain a teaching qualification without doing a double degree DSIE and SEC master.

5 Information Security Technology

A Master of Science in Information Security Technology (IST) is an academic expert in the area of digital communication in general, and in information security technology in particular. Information security technology protects data that are stored, transmitted, accessed, or modified against all kinds of threats. This can vary from unauthorized access to malicious manipulations. Information security technology is essential for secure communication and data protection in many situations.

The IST track offered in collaboration with Radboud University (RU). These universities have joined their forces with respect to security education. This master track is called the "TRU/e Master in Cyber Security" (see https://true-security.nl).

Each of the mandatory and special elective courses is taught at only one of these universities. This implies that students have to travel to other sites for part of their education. The program is set up in such a way that averaged over the two years of their master's studies students will have to travel one day per week to another university.

After taking some courses, you will probably have a more clear picture of the academic direction you want to pursue in your studies. If not, you may want to talk to several staff members or the academic advisor. In the specialization for your subject, there are people that you may want to be involved with for your final master project (see Section 5.4). In order to compose a well-balanced program that provides adequate prerequisites for this project, it is advisable to first choose and consult a project supervisor in the specialization of your interest before choosing elective courses. As a rule of thumb, you should start your search for a supervisor and the construction of your individual program not later than at the end of your first year.

A Master of Science in Information Security Technology can become involved in cryptographic primitives, security protocols, data storage, communication, or information security management. Additionally, the graduate can act as internal or external consultant, regarding the security of information systems and networks, or regarding the security policy of an organization. A Master of Science in Information Security Technology can enter a job in the following institutions: research laboratories and academic institutes (both for theoretical and applied work); applied R&D in industry; the financial world; governmental agencies; consultancy agencies (all with respect to security in the area of information systems and

relevant policymaking).

5.1 Admission

A Bachelor degree in Computer Science obtained at a Dutch university provides direct admission to the CSE program. Students with a different degree and from foreign universities have to apply for admission via the admission committee. Dutch HBO graduates have to take a pre-master program before they can be admitted, see Section 2.4.

The admission procedure is described in Section 1.6, and the requirements are listed in the Teaching and Examination Regulations (see Appendix A.1).

5.2 Learning outcomes

The goal of the program is to transform Bachelors in Computer Science and Mathematics into academic experts in the area of digital communication in general and in information security in particular. Alumni will be able to function as researcher or as system developer in university or society. They will be well aware of the state-of-the-art in information security technology at the master level. They will be able to analyze complex security situations and to reduce them to solvable problems.

A graduate from the master program

- is qualified to degree level in the domain of science, engineering and technology;
- is competent in the relevant domain-specific discipline, namely computer science and engineering;
- is capable of acquiring knowledge independently;
- approaches computer-science problems in a thorough and scientifically founded manner;
- is capable of critical thinking, can reason logically and form opinions;
- has design skills, presentation skills, and communication skills;
- has insight into the role of computer science in industry, society, and science;
- and, in addition to a recognizable domain-specific profile, possesses a sufficiently broad basis to be able to work in an interdisciplinary and multidisciplinary context.

In addition to these general learning outcomes, a graduate from IST

- has a broad view of information security;
- should be able to evaluate existing and newly designed security systems;
- should be able to list relevant security requirements in an application and to select the right techniques to address these issues;
- is an expert in at least one subarea of information security;
- can contribute to discussions about the role of information security in our society;
- has experience in the process of specifying, designing, and realization of an application in which security plays an important role.

5.3 Curriculum

The Master track Information Security Technology is a two-year program of 120 ECTS in total. The academic year is subdivided into two semesters, the fall semester starting in September, and the spring semester starting in February. The program is only offered as a full time study program. The curriculum contains both computer science courses and mathematics courses, and consists of a mandatory core program and elective courses.

The IST master has the following structure:

Units	ECTS
Mandatory courses	30
IST electives	15
Free electives	40
Seminar	5
Master project	30

Mentor of the Information Security Technology program is dr. Nicola Zannone. Prior to the beginning of the academic year you should register for 2IMC91. For further information about mentoring please consult Section 1.12.1.

5.3.1 Core program

The mandatory part of the program contains the following courses:

Quarter	Code	Unit	EC	Exam	Location
1	2MMC10	Cryptology	5	w+a	Eindhoven
1	2IMS25	Principles of Data Protection	5	w+a	Eindhoven
1-2	2IRU15	Software security	5	w	Nijmegen
1-2	2IRU20	Security in organizations	5	w+a	Nijmegen
3	2IMS15	Verification of security protocols	5	w	Eindhoven
3-4	2IRU25	Advanced network security	5	w+a	Nijmegen
3-4	2IRU30	Privacy seminar[1]	6	a	Nijmegen
4	2IMS00	Seminar Information Security Technology[1]	5	a	Eindhoven
7-8	2IMC00	Master project[2]	30		

[1] *Either 2IRU30 or 2IMS00 should be followed but not both.* [2] *In case the master project is done within the Mathematics Division the code is 2MMR30.*

5.3.2 IST Electives

The list below contains the preferred electives for the IST program. At least 15 EC must be taken from this list. Note that courses in quartiles 1 and 2 can be taken in the second year in quartiles 5 or 6.

Quarter	Code	Unit	EC	Exam	Location
1-2	2IRU35	Law in cyberspace	6	w+a	Nijmegen
2	2IMS20	Cyberattacks Crime and Defenses	5	w+a	Eindhoven
2	2DMI10	Applied cryptography	5	w+a	Eindhoven

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Quarter	Code	Unit	EC	Exam	Location
3	2DMI00	Cryptographic protocols	5	w+a	Eindhoven
3-4	2IRU10	Hardware security	6	a	Nijmegen
3-4	2IRU40	Cryptographic Engineering	6	w+a	Nijmegen
5	2IMS10	Physical aspects of digital security	5	w	Eindhoven

5.3.3 Free electives

In principle all master courses offered at the TU/e can be chosen as free electives. We do recommend to take more than the required minimum number of courses from the above lists. Other mathematics and computer science related courses from the TU/e and RU are also recommended, as well as security-related courses from other universities (provided their topics do not overlap with the TU/e and RU courses you already take).

Your complete study program including the free electives always requires approval by the examinations committee. Your mentor will help you to compose a balanced program that is very likely to be approved.

If you do not (yet) have a degree from another country or at least 15 EC in international experience you should reserve 15 EC from the room for free electives to take courses abroad or to do an internship of 15 EC abroad, see Section 1.7.2. (This does not apply to students taking the teacher training.)

5.3.4 Homologation courses

Some courses may be prescribed or recommended as homologation courses (up to 15 EC) to make up for deficiencies in former education. This prescription/recommendation is part of the admission decision. Upon discussion with your mentor and/or academic advisor and approval by the exam committee, you might include not more than 15 EC of bachelor-level units as part of the free electives.

It is not possible to follow additional homologation courses in a master program after a finished pre-master.

5.4 Final project

Prior to starting the final project you should first choose and consult the intended final project supervisor. As final project supervisors can act assistant professors, associate professors and full professors from the Computer Science sub-department within the Mathematics and Computer Science department, or from the Coding Theory and Cryptology section within the Mathematics and Computer Science department. If you are in doubt how to choose the graduation supervisor please consider contacting your mentor.

The start of your master project is marked by submitting a completed graduation plan containing the necessary information on the project (name, place, period, supervisor, and so on), and stating the fact that you have completed your curricular part of the program (see Section 1.9). The form must be accompanied by a project description and signed by you, your supervisor, the head of the relevant specialization and the academic advisor.

5.4.1 Admission

During the master project, you should be able to work and concentrate on your project full-time. In practice, however, it turns out to be rather difficult to plan all your curricular activities and, especially, their success:

- If all courses have been completed, permission to start the master project will be granted.
- If more than two courses or 10 EC (whichever is lower) have not been completed, such permission will not be granted.
- In other cases (no more than two courses or 10 EC not yet completed) it depends on the status of the uncompleted courses whether permission to start the master project will be granted, and if so, whether it is feasible to work on the project full time.

Courses that are to be taken as homologation units must be completed and passed before you are allowed to start the master project. Also, be aware that you are not allowed to finish your project (with presentation and defense) before you have completed all your courses. For more information, please contact the academic advisor, AcademicAdvisorMCS@tue.nl.

5.4.2 Planning

Together with your supervisor, you decide on a description of your topic and a global planning. You also arrange the supervision method, including how often you and your supervisor will meet to discuss progress. The project is concluded with a thesis and a presentation followed by a defense.

In general, the master project should be completed within 6 months from the start. An extension to 9 months is possible. In exceptional cases, and only if it is clear that the project can be finished, the exam committee may allow for an additional 3 months period. It is important to note that the project must be finished within 1 year. A project not finished within 1 year is automatically cancelled and graded as "fail". You then have to start a new project with a different supervisor. The complete examination regulations can be found on the website.

5.4.3 Final presentation and defense

The final presentation is public and is held in buildings of Eindhoven University of Technology. It is customary that the final presentation takes ca. 30 minutes. The defense following the presentation, however, is not public; only the student and the assessment committee (see below) are present unless both parties have no objection to the presence of others.

5.4.4 Assessment

Your final project is graded by an assessment committee. The committee usually consists of your supervisor, a staff member from your specialization area, and a staff member from one of the other CS research groups. The supervisor is responsible for forming this committee at least one month before graduation.

The assessment committee takes the following criteria into account:

Results:	Significance of the results versus difficulty of the problem or project goals.
Report:	Structure, completeness, correctness, readability, argumentation.
Graduation presentation:	Structure, contents, clarity, contact with audience.
Defense:	Argumentation, demonstration of knowledge, competency in discerning main aspects from details of the project.
Execution of the project:	Level of independence, planning, organization, handling deadlines and setbacks, level of own contribution.

The actual assessment form used by the committee has a more fine-grained list of criteria for evaluating the work. Not all criteria are equally important. The assessment committee decides the relative importance of each criterion to arrive at a final grade. The motivation for the grade is documented in an assessment report, see the MSc assessment form.

5.4.5 Cum laude regulations

The Examination Committee may award the classification "cum laude" if

- the student achieves an average grade of 8.0 or higher for all the study components,
- the graduation project must have a grade of 9.0 or higher,
- none of the study components may have a grade lower than a 6.0.

The average grade is computed **without** taking into account the number of EC associated with the course.

5.4.6 Checklist

The graduation checklist (Appendix B) summarizes all the steps required starting with getting your study program approved and ending with the graduation ceremony.

6 Business Information Systems

The program is being phased out. As of 2018/2019 no new students are admitted. The information below is intended for students that started their education prior to 2018/2019.

The Department of Mathematics and Computer Science and the Department of Industrial Engineering and Innovation Sciences play an active role in the development of new, innovative and application-oriented technology. The cooperation between the Information Systems section within Computer Science and the Information Systems section within Industrial Engineering and Innovation Sciences is long established and fruitful. The master program in Business Information Systems (BIS) at TU/e is illustrative of these cooperative efforts.

The program rests on a sound theoretical foundation with emphasis on the design of business information systems in their application context, technology for information systems, and data- and process mining techniques for analyzing information systems. As a graduate of this program, the student will have developed a scientific attitude and a model-driven, engineering approach to the field. The student is trained in the use of formal models allowing for specification analysis. The area of expertise will be the development of business information systems from a business perspective. The student will be able to play a leading role in the analysis, development and application of business information systems in various sections of society (profit and non-profit).

After taking some courses, you will probably have a more clear picture of the academic direction you want to pursue in your studies. If not, you may want to talk to several staff members or the academic advisor. In the specialization for your subject, there are people that you may want to be involved with for your final master project (see Section 6.4). In order to compose a well-balanced program that provides adequate prerequisites for this project, it is advisable to first choose and consult a project supervisor in the specialization of your interest before choosing elective courses. As a rule of thumb, you should start your search for a supervisor and the construction of your individual program not later than at the end of your first year.

6.1 Admission

The program is being phased out. As of 2018/2019 no new students are admitted.

6.2 Learning outcomes

A graduate from the master program

- is qualified to degree level in the domain of science, engineering and technology;
- is competent in the relevant domain-specific discipline, namely business information systems;
- is capable of acquiring knowledge independently;
- approaches computer-science problems in a thorough and scientifically founded manner;
- is capable of critical thinking, can reason logically and form opinions;
- has design skills, presentation skills, and communication skills;
- has insight into the role of computer science in industry, society, and science;
- and, in addition to a recognizable domain-specific profile, possesses a sufficiently broad basis to be able to work in an interdisciplinary and multidisciplinary context.

A BIS graduate should also

- possess knowledge of the mathematical formalisms, methods, tools and their mutual dependencies needed to understand and model business processes and data;
- have the engineering skills needed to apply this knowledge to design high-quality business information systems;
- understand the role of IT in the context of organizations, business processes and their management.

6.3 Curriculum

The Master program Business Information Systems is a two-year program of 120 EC in total. The academic year is subdivided into two semesters, the fall semester starting in September, and the spring semester starting in February. It is possible to enter the program in either semester; however, starting in September is preferred. The program is full time.

BIS students should select one of the two business process intelligence variants as well as one of the three specialization *streams*. The streams are:

- Information management
- Advanced Modeling and Analysis
- International

Structure of the program is therefore as follows

Units	ECTS
Mandatory courses	30
Business process intelligence	10
Stream mandatory	10–15
Free electives	35–40
Master project	30

The above table shows that there is great flexibility in defining your individual study program as there are at least 35 credits in free electives. Within this part you are strongly encouraged to include 15 credit points in international experience if you do not yet have that and are not doing your master project abroad. Furthermore, students that opt for the International stream can spend an entire semester abroad. In the following sections, more details for each of the streams are given.

Mentor of the Business Information Systems program is dr. Dirk Fahland, prior to the beginning of the academic year you should register for 2IMC92. For further information about mentoring please consult Section 1.12.1.

6.3.1 Core and stream program

The mandatory courses for the BIS master are as follows.

Quarter	Code	Unit	ECTS	Exam
1	1BM10	Electronic business	5	a+o
2	1BM05	Business process management	5	w+a
2	1BM41	Business information systems architecture	5	w+a
3	2IMI30	Business process simulation[1]	5	a
3	2IMI10	Business process management systems[1]	5	o
4	2IMD15	Data engineering	5	a

[1] *Courses 2IMI10 and 2IMI30 are no longer offered in 2018/2019. Students should contact the academic advisor: AcademicAdvisorMCS@tue.nl.*

The business process intelligence variants aim at data analysis side of business information systems. The focus of this stream is on the analysis of data and other sources of information such as event logs. Two variants of the streams exist, with different background requirements.

Quarter	Code	Unit	EC	Exam
		Data mining		
3	2IMM15	Web information retrieval and data mining[2]	5	w+a
5	2IMM20	Foundations of data mining[2]	5	a
		Process mining		
4	1BM120	Computational intelligence	5	w+a
5	2IMI35	Introduction to process mining[3]	5	w+a

[2] *Courses 2IMM15 and 2IMM20 changed their position in the schedule. Students who started in 2017/2018 and are taking the "Data mining" variant and only took 2IMM20 in 2017/2018 are allowed to replace 2IMM15 by 2IMM00 Seminar Data Mining.*

[3] *Students who took the course 2IIE0 or 2IIF0 in their bachelor are not allowed to take 2IMI35 because of overlap. These students can skip this course, and are not required to take 2IMM15 instead.*

Streams distinguish various profiles within the BIS program. In principle, one of the following stream packages has to be chosen as part of the program.

Information Management stream. The focus of the information management stream is on the managerial side of information technology. Emphasis is placed on how people interact with software, how software should be managed and how innovative organizations should be organized. Furthermore, the students are trained in writing a business plan and maintaining a business network.

Advanced Modeling and Analysis stream. Analyzing models is an essential part of the BIS Master program. Many modeling techniques are discussed in various courses and various analysis techniques are taught. In this stream, students take analysis of models to the next level.

International stream. The international stream entails a full semester abroad. This semester should be coherent and contain courses relevant for the BIS domain. Typically, this semester is the third semester in the program.

The stream courses can be found in the table below.

Quarter	Code	Unit	EC	Exam
		Information Management		
4	1BM20	Software requirements management	5	w+a
5	2IMI15	Metamodelling and interoperability[4]	5	w+a
6	1BM70	Healthcare business networks	5	a+o
		Advanced Modeling and Analysis		
3	2DI66	Advanced simulation	5	a
6	2IMI20	Advanced process mining	5	w+a
6	2IMV20	Visualization	5	a
		International		
3	2DI66	Advanced simulation	5	a
4	1BM20	Software requirements management	5	w+a

[4] *The course is offered for the last time in 2018/2019.*

6.3.2 Electives

In your study program, you complement the core and stream courses with your personal choice of free elective courses based on the following recommendations:

- You can choose any of the stream courses from the other streams, listed in the previous section.

- In principle all master courses offered at the TU/e can be chosen as free electives so you are not restricted to the courses specifically listed for the BIS master. We suggest you at least have a look at all master courses offered by the Departments of Mathematics and Computer Science and of Industrial Engineering and Innovation Science.
- We advise to take a seminar or a literature study in the specialization area in which you want to do your Master project (see the list below).
- Students with an interest in research can be invited to a do Capita Selecta course (see the list below).

Quarter	Code	Unit	ECTS	Exam
Any		Any master-level course offered at the university, provided you meet the course prerequisites; in particular, courses from the faculties of Mathematics & Computer Science, and of Industrial Engineering & Innovation Sciences.		
		Seminars[3]		
4	2IMS00	Seminar information security technology	5	a
4	2IMA00	Seminar algorithms	5	a
6	2IMG00	Seminar applied geometric algorithms	5	a
6	2IMM00	Seminar data mining	5	a
6	2IMI00	Seminar analytics for information systems	5	a
6	2IMD00	Seminar databases	5	a
6	2IMN00	Seminar systems architecture and networking	5	a
6	2IMP00	Seminar software engineering and technology	5	a
6	2IMV00	Seminar visualization	5	a
6	2IMF00	Seminar formal system analysis	5	a
6	1BM95	Literature study for BIS-students[1]	5	a
		Capita selecta courses[2]		
	2IMF05	Capita selecta formal system analysis	5	a
	2IMP05	Capita selecta software engineering and technology	5	a
	2IMS05	Capita selecta security	5	a
	2IMA05	Capita selecta algorithms	5	a
	2IMG05	Capita selecta applied geometric algorithms	5	a
	2IMM05	Capita selecta data mining	5	a
	2IMN05	Capita selecta systems architecture and networking	5	a
	2IMV05	Capita selecta visualization	5	a
	2IMD05	Capita selecta databases	5	a
	2IMI05	Capita selecta analytics for information systems	5	a

[1] *This literature study can only be followed by students that will perform their master project in the Information Systems group of IE&IS.*

[2] *Capita selecta can only be taken after prior approval by the responsible lecturer.*

[3] *It is a good idea (but not mandatory) to take a seminar (or literature study) in the group where you are going to do your master thesis project. Seminars or the literature study for BIS can be taken from the fourth quarter of your study program onwards. This means that if you enroll in September, you cannot take the seminars in quarter 2 in your first year, but that you have to wait until you have entered the second year. Similarly, if you enroll in February, the seminars in quarter 4 can only be followed in your second year.*

Your complete study program including the free electives always requires approval by the examinations committee. Your mentor will help you to compose a balanced program that is very likely to be approved.

Some elective courses may be prescribed as homologation courses (up to 15 credits) to make up for deficiencies in former education. This prescription is part of the admission decision.

If you do not (yet) have a degree from another country or at least 15 credit points in international experience you should reserve 15 credits from the room for free electives to take courses abroad or to do an internship of 15 credits abroad, see Section 1.7.2. (This does not apply to students taking the teacher training.) Taking International Stream (see Section 6.3.1) may help you combine studies abroad with the core BIS program.

When not taking a full homologation package (see below), the following courses can be taken earlier than indicated above:

- 2IMI35 Introduction to Process Mining in Q1 instead of Q5
- 2IMV20 Visualization in Q2 instead of Q6
- 1BM70 Healthcare Business Networks in Q2 instead of Q6

6.3.3 Homologation units

Homologation units are bachelor courses that should be taken to make up for deficiencies in former education.

Students who have a Dutch university bachelor degree in Computer Science have to include the following unit as an elective:

Quarter	Code	Unit	EC	Exam
2	2DD50	Mathematics 2	5	w

Students who have a Dutch university bachelor degree in Industrial Engineering have to include one of the following units as an elective:

Quarter	Code	Unit	EC	Exam
1	2IBP90	Programming	5	w+a
1	1BK50	Algorithmic Programming for Operations Management	5	a

Upon discussion with your mentor and/or academic advisor and approval by the exam committee, you might include not more than 15 EC of bachelor-level units as part of the free electives. It is not possible to follow additional homologation courses in a master program after a finished pre-master.

Students who have a foreign bachelor degree may be prescribed different courses. This is done on an individual basis by the Admissions Committee.

6.4 Final project

The knowledge and experience, which were acquired in the first part of the program, are applied in an individual setting in order to develop to the necessary level to function as an academic professional in the field of Business Information Systems. The project can be completed in any of the specializations listed in Section 10.1 and Section 10.2, provided that a staff member of the associated group has the supervision.

Prior to starting the final project you should first choose and consult the intended final project supervisor. If you are in doubt how to choose the graduation supervisor please consider contacting your mentor.

The start of your master project is marked by submitting a completed graduation plan containing the necessary information on the project (name, place, period, supervisor, and so on), and stating the fact that you have completed your curricular part of the program (see Section 1.9). The form must be accompanied by a project description and signed by you, your supervisor, the head of the relevant specialization and the academic advisor. Note that when the master project is carried out under supervision of a staff member from the Department Math&CS the code is 2IMC00 and when it is done in the Department IE&IS the code is 1BM91.

6.4.1 Admission

During the master project, you should be able to work and concentrate on your project full-time. In practice, however, it turns out to be rather difficult to plan all your curricular activities and, especially, their success:

- If all courses have been completed, permission to start the master project will be granted.
- If more than two courses or 10 EC (whichever is lower) have not been completed, such permission will not be granted.
- In other cases (no more than two courses or 10 EC not yet completed) it depends on the status of the uncompleted courses whether permission to start the master project will be granted, and if so, whether it is feasible to work on the project full time.

Courses that are to be taken as homologation units must be completed and passed before you are allowed to start the master project. Also, be aware that you are not allowed to finish your project (with presentation and defense) before you have completed all your courses. For more information, please contact the academic advisor, AcademicAdvisorMCS@tue.nl.

6.4.2 Planning

Together with your supervisor, you decide on a description of your topic and a global planning. You also arrange the supervision method, including how often you and your supervisor will meet to discuss progress. The project is concluded with a thesis and a presentation followed by a defense.

In general, the master project should be completed within 6 months from the start. An extension to 9 months is possible. In exceptional cases, and only if it is clear that the project can be finished, the exam committee may allow for an additional 3 months period. It is

important to note that the project must be finished within 1 year. A project not finished within 1 year is automatically cancelled and graded as "fail". You then have to start a new project with a different supervisor. The complete examination regulations can be found on the website.

6.4.3 Final presentation and defense

The final presentation is public and is held in buildings of Eindhoven University of Technology. It is customary that the final presentation takes ca. 30 minutes. The defense following the presentation, however, is not public; only the student and the assessment committee (see below) are present unless both parties have no objection to the presence of others.

6.4.4 Assessment

Your final project is graded by an assessment committee. The Assessment Committee consists of three voting members including the graduation supervisor and the graduation tutor. An assessment committee should contain a voting member from both the Industrial Engineering & Innovation Sciences department and the Computer Science sub-department within the Mathematics and Computer Science department. Furthermore, at least one voting member should be from the Information Systems group of the Mathematics and Computer Science department or from the Information Systems group of the Industrial Engineering & Innovation Sciences department. The supervisor is responsible for forming this committee at least one month before graduation.

The assessment committee takes the following criteria into account:

Results:	Significance of the results versus difficulty of the problem or project goals.
Report:	Structure, completeness, correctness, readability, argumentation.
Graduation presentation:	Structure, contents, clarity, contact with audience.
Defense:	Argumentation, demonstration of knowledge, competency in discerning main aspects from details of the project.
Execution of the project:	Level of independence, planning, organization, handling deadlines and setbacks, level of own contribution.

The actual assessment form used by the committee has a more fine-grained list of criteria for evaluating the work. Not all criteria are equally important. The assessment committee decides the relative importance of each criterion to arrive at a final grade. The motivation for the grade is documented in an assessment report, see the MSc assessment form.

6.4.5 Cum laude regulations

The Examination Committee may award the classification "cum laude" if

- the student achieves an average grade of 8.0 or higher for all the study components,
- the graduation project must have a grade of 9.0 or higher,
- none of the study components may have a grade lower than a 6.0.

The average grade is computed **without** taking into account the number of EC associated with the course.

6.4.6 Checklist

The graduation checklist (Appendix B) summarizes all the steps required from having your study program approved to the graduation ceremony.

6.5 Double degree program BIS and SEC

The qualification to teach computer science to senior secondary pupils is coupled to the 3TU program Science Education and Communication (SEC). This program encompasses 120 credits. In Eindhoven it is offered by the Eindhoven School of Education (ESoE). In the Education track of the SEC program a student specializes in one of four disciplines: maths, physics, chemistry or computer science. Please note that the SEC program is completely lectured in Dutch!

BSc graduates in computer science are directly admitted to the SEC-program. So are MSc graduates from a computer science oriented program like BIS; their SEC-program is reduced to 60 credits because of exemptions. For this last category an even shorter route is available by taking the double degree program, which amounts up to 150 ects. In the BIS-part of the program the stream is replaced by SEC subjects. Enrollment is required for both master programs (one main enrollment and a second enrollment). Certificates will be granted after completion of the whole program.

Details about the curriculum are available at the ESoE website: `http://www.tue.nl/esoe/`.

It is possible to take 45 credits worth of components of the SEC program within the BIS master. The TU/e strives to have this become sufficient to obtain a teaching qualification without doing a double degree BIS and SEC master.

7 Embedded Systems

The design of innovative software and hardware is the core of technological and industrial progress. Both the departments of Mathematics and Computer Science and Electrical Engineering play an active role in the development of new, innovative technology. The Master of Science program in Embedded Systems at the TU/e is illustrative of this active role, as it is a co-production of these two departments, awaiting students with a background in computer science, as well as graduates from the field of electrical engineering.

The program rests on a sound theoretical foundation, with an emphasis on the design of quality embedded systems. As a graduate of this program, you will have developed a scientific attitude and an engineering approach to the field. Your position will be the design of embedded systems from a high-level architecture viewpoint, via requirements and behavioral specifications and using platforms, hardware and silicon. You will be able to play a leading role in the development of embedded systems, either in scientific research, in industry or governmental organizations.

The Embedded Systems program focuses on the design of efficient and reliable systems. To be able to compose dependable protocols for the behavior of such systems, you need knowledge of algorithms, performance, hardware, methods of design and documentation, and an insight into the variability and maintainability of these protocols. All these aspects are addressed in the compulsory part of the program. The Embedded Systems program at the TU/e is offered in close collaboration with Delft University of Technology (TUD) and the University of Twente (UT) in the context of the 4TU federation: the programs at the three locations share a mandatory common core of 25 EC and jointly offer specialisation courses and homologation modules through tele-lecture and online facilities.

7.1 Admission

A Bachelor degree in Computer Science or in Electrical Engineering obtained at a Dutch university provides direct admission to the ES program. Students with a different degree and from foreign universities have to apply for admission via the admission committee. Dutch HBO graduates have to take a pre-master program before they can be admitted, see Section 2.6.

The admission procedure is described in Section 1.6, and the requirements are listed in the Teaching and Examination Regulations (see Appendix A.3).

7.2 Learning outcomes

Intended learning outcomes of the program:

1. The graduate has an all-embracing view on embedded systems, their design and their application in systems of various sizes (e.g. from small robots to cyber physical and networked systems) including their evolution over time, demonstrated by an integration approach in system design.
2. The graduate is capable of analysing the functional behaviour of complex embedded systems in a structural way using appropriate abstractions.
3. The graduate is able to describe and study the non-functional aspects of embedded systems, e.g. resource boundedness and dependability.
4. The graduate has a thorough knowledge of state-of-the-art methods and techniques for embedded systems design such as requirements engineering, hardware-software integration, performance modelling and analysis, validation and testing.
5. The graduate is able to design embedded systems that satisfy the functional and non-functional requirements, taking into account the performance of the system during its lifetime. The graduate is also aware of costs and environmental issues making optimal use of the available resources.
6. The graduate has the ability and attitude to include other disciplines or involve practitioners of these disciplines in their work, where necessary. As an engineer the graduate is therefore able to work in a multidisciplinary setting.
7. The graduate is able to conduct research and design independently and has a scientific approach to complex problems and ideas.
8. The graduate possesses intellectual skills that enable critical reflection, reasoning and forming opinions.
9. The graduate has the ability to communicate the results of their learning, thinking and decision-making processes at an international level.
10. The graduate is aware of the temporal and social context of science and technology (comprehension and analysis) and can integrate this context in the scientific work.

7.3 Curriculum

The master program on Embedded Systems is a two-year program of 120 ECTS in total. The curriculum consists of courses offered by the Computer Science division of the department Mathematics and Computer Science and the department of Electrical Engineering. A schematic overview of the program is shown in Figure 7.1 (NB: the overview shows the

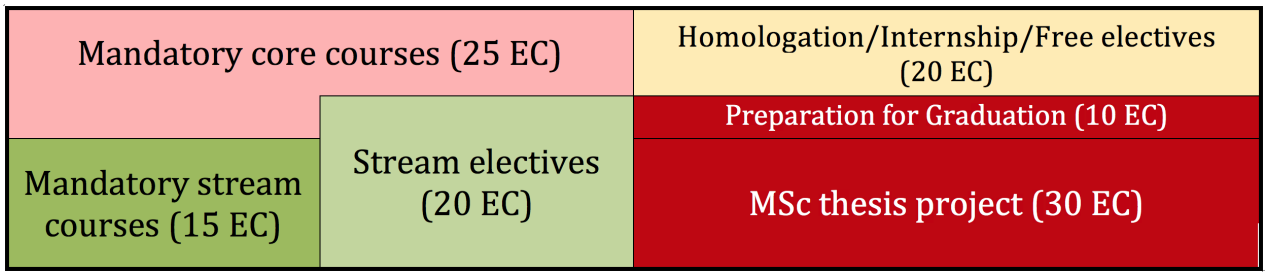

Figure 7.1: *A schematic overview of the Embedded Systems program. The overview shows the building blocks of the program, but does not take into account the scheduling of the components in those blocks*

building blocks of the program, but does not take into account the scheduling of the components in those blocks).

The curriculum has a core of 25 EC consisting of five courses that are mandatory for all Embedded Systems students (see Section 7.3.1). The curriculum is further structured into four steams:

- Systems on Chip (Section 7.3.2)
- Embedded Software (Section 7.3.3)
- Embedded Networking (Section 7.3.4)
- Cyber-Physical Systems (Section 7.3.5)

The purpose of the streams is, on the one hand, to provide guidance to students in composing coherent individual study programs, and on the other hand, to preserve the multidisciplinary nature of each individual Embedded Systems study program. Associated with every stream is a mandatory part of 15 EC and an elective part of 20 EC; the elective part should be composed of courses selected from a list of stream electives associated with the stream (see some recommendations in Section 7.3.6). The graduation project of the Embedded Systems program consists of a 10 EC preparation phase and a 30 EC master project. The remaining 20 EC of the program may be composed of free electives, homologation units (at most 15 EC), and (optionally) an internship (15 EC).

We strongly encourage you to include 15 credit points in international experience within your study program. This experience is particularly valuable to students that do not yet have international experience yet and are not intending on doing your master project abroad. To prepare for the master project, you start with a master thesis preparation in quarters 5 and 6, followed by the master project in quarters 7 and 8. Preparation for Graduation Project ES has to be completed before the start of the master project If homologation units are chosen then they must be completed before start of preparation project. In the following sections, more details for each of the streams are given.

7.3.1 Mandatory program elements

The mandatory program elements for all students are listed below:

Quarter	Code	Unit	EC	Exam[1]
1	2IMF30	System Validation	5	w+a
2	5SIA0	Embedded Computer Architecture	5	w/o+a
2	2IMN25	Quantitative Evaluation of Embedded Systems	5	w+a
3	2IMN20	Real-time Systems	5	w+a
4	5LIB0	Embedded Systems Laboratory	5	w+a
5-6	2IMC05/5T514	**Preparation graduation project ES**[2]	10	a
7-8		**Master thesis project**	30	

[1] *w - written exam, a - assignments, o - oral exam; w/o+a - assignments + either a written or an oral exam depending on the number of students.*
[2] *Preparation for graduation project ES consists of a literature survey and feasibility study for the graduation project.The course Preparation graduation project ES (2IMC05/5T514) has to be completed and assessed before the start of the Master graduation project (2IMC00/5T746).*

7.3.2 Systems on Chip stream

Modern chips are rapidly evolving into complete Systems on Chip (SoCs). The emergence of SoCs leads to new challenges in VLSI design, design automation, programming and code generation, task and communication mapping and scheduling, memory management, and model-driven design-space exploration. This stream addresses the design of SoCs with special attention for the various design trade-offs and formal verification techniques to support correct design.

Mentor of the Systems on Chip stream is prof. dr. Kees Goossens, prior to the beginning of the academic year you should register for 2IMC81. For further information about mentoring please consult Section 1.12.1.

Quarter	Code	Unit	ECTS	Exam[1]
Stream mandatory courses				***15***
1	2IMF20	Hardware verification	5	w+a
3	5LIE0	Multiprocessors	5	a+o
4	5LID0	Systems on silicon	5	w+a
Stream electives [2]				***20***
1	5LIN0	Video processing	5	w
1	5LIL0	Intelligent architectures	5	a
2	5LIH0	Digital integrated circuit design[3]	5	w+a
2	5LIF0	Advanced digital circuit design	5	w/o
2	2IMF25	Automated reasoning	5	w+a
2	5LIG0	Applied combinatorial algorithms	5	a+o
3	5LIM0	Parallelism, compilers and platforms	5	w+a
3	5SIB0	Electronic design automation	5	w+a
3	5LIJ0	Embedded control systems	5	w
4	2IMN35	VLSI programming	5	a
6	2IMF00	Seminar formal system analysis[4]	5	a

[1] *w - written exam, a - assignments, o - oral exam; w/o - either a written or an oral exam depending on the number of students.*

[2] *You have to choose at least 20 credit points from this list.*

[3] *Students cannot include both 5LIH0 and 5LIP0 in their program.*

[4] *A seminar may be followed starting from the fourth quarter of the program. For students starting in the first semester, this implies that the seminar may be followed in the second quarter of the second year*

7.3.3 Embedded Software stream

The behaviour and functionality of embedded systems is largely determined by the software that it runs. This stream focusses on the development of embedded software addressing aspects such as model-driven design, domain specific languages, code generation techniques, and formal techniques to solve scheduling problems.

Mentor of the Embedded Software stream is prof. dr. Jan-Friso Groote, prior to the beginning of the academic year you should register for 2IMC82. For further information about mentoring please consult Section 1.12.1.

Quarter	Code	Unit	EC	Exam[1]
Stream mandatory courses				***15***
2	2IMF25	Automated reasoning	5	w+a
3	5LIM0	Parallelization, compilers and platforms	5	w+a
4	2IMP30	System design engineering	5	w+a
Stream electives [2]				***20***
1	5LIN0	Video processing	5	w
1	2IMN10	Architecture of distributed systems	5	w+a
1	2IMA10	Advanced algorithms	5	w+a
1	5LIL0	Intelligent architectures	5	a
1-2	2IRU15	Software security[3]	5	
2	2IMP10	Program verification techniques	5	w+a
2	5LIG0	Applied combinatorial algorithms	5	a+o
3	2IMP25	Software evolution	5	w+a
3	2IMF35	Algorithms for model checking	5	w+a
3	5LIE0	Multiprocessors	5	a+o
3	5LIJ0	Embedded control systems	5	w
4	2IMN35	VLSI programming	5	a
4	5LIK0	Embedded signal processing systems	5	w+a
4	2IMP20	Generic language technology	5	w+a
6	2IMF00	Seminar formal system analysis[4]	5	a
6	2IMN00	Seminar systems architecture and networking[4]	5	a
6	2IMP00	Seminar software engineering and technology[4]	5	a

[1] *w - written exam, a - assignments, o - oral exam.*

[2] *You have to choose at least 20 credit points from this list.*

[3] *The course is offered by and at the Radboud Universiteit in Nijmegen. Secondary enrollment at the Radboud University is required. Students should have basic knowledge of network security comparable to the bachelor course 2IC60 Computer Networks and Security.*

[4] *A seminar may be followed starting from the fourth quarter of the program. For students starting in the first semester, this implies that the seminar may be followed in the second quarter of the second year.*

7.3.4 Embedded Networking stream

Embedded Networking (EN) refers to the powerful trend of the last twenty years of connecting embedded systems into networks. For electronic systems in automotive, for example, the network is often the point of integration. More recently we have seen the concept of the Internet of Things, the vision that everyday objects get enriched with embedded electronics, that these objects are uniquely identified and communicate using a unified protocol and naming scheme (indeed, the Internet protocols). EN includes the fields of sensor networks, but also networked systems that represent a platform and are not identical to the application. From the sensor network domain, concerns of effective resource management (like size, energy, memory, communication bandwidth) are derived. Quality metrics for EN include performance (latency, throughput), dependability (quality of service) and scalability. Besides these, EN challenges lie in the architecture of system and software, in management and sharing of distributed resources, in interoperability and semantics, in security and privacy, and in application development. While it is fairly easy to sketch advanced applications, it is not straightforward to realize these in a cost-effective manner. Relevant topics for this stream are: distributed systems (architecture and protocols), networked systems, data semantics, network security, system correctness, and resource management.

Mentor of the Embedded Networking stream is dr. Tanir Ozcelebi, prior to the beginning of the academic year you should register for 2IMC83. For further information about mentoring please consult Section 1.12.1.

Quarter	Code	Unit	ECTS	Exam[1]
Stream mandatory courses				***15***
1	2IMN10	Architecture of distributed systems	5	w+a
1	5LIC0	Networked embedded systems	5	a+o
2	2IMN15	Internet of things	5	w+a
Stream electives [2]				***20***
1	2IMA10	Advanced algorithms	5	w+a
1	2IMF20	Hardware verification	5	w+a
2	5LIH0	Digital integrated circuit design[5]	5	w+a
2	5LIF0	Advanced digital circuit design	5	w/o
2	2IMF25	Automated reasoning	5	w+a
2	2IMS20	Cyberattacks Crime and Defenses	5	w+a
3	5SIB0	Electronic design automation	5	w+a
3	2IMS15	Verification of security protocols	5	w
3-4	2IRU25	Advanced network security[3]	5	w+a
4	5LIA0	Embedded visual control	5	a
4	5LID0	Systems on silicon	5	w+a
4	5LIK0	Embedded signal processing systems	5	w+a
4	2IMP30	System design engineering	5	w+a
6	2IMF00	Seminar formal system analysis[3]	5	a
6	2IMN00	Seminar systems architecture and networking[4]	5	a

[1] *w - written exam, a - assignments, o - oral exam; w/o - either a written or an oral exam depending on the number of students.*

[2] *You have to choose at least 20 credit points from this list*

[3] *The course is offered by and at the Radboud Universiteit in Nijmegen. Secondary enrollment at the Radboud University is required. Students should have basic knowledge of network security comparable to the bachelor course 2IC60 Computer Networks and Security.*

[4] *A seminar may be followed starting from the fourth quarter of the program. For students starting in the first semester, this implies that the seminar may be followed in the second quarter of the second year.*

[5] *Students cannot include both 5LIH0 and 5LIP0 in their program.*

7.3.5 Cyber-Physical Systems stream

Cyber-Physical Systems are characterised by a tight coupling between embedded computer (cyber) systems and physical processes, monitored and controlled by those computer systems. Cyber-physical systems require integral, multidisciplinary design, involving computer engineering, control, mechatronics, networking, signal processing, and mathematical modelling. The stream focusses on the control and signal processing aspects of cyber-physical systems.

Mentor of the Cyber-Physical Systems stream is dr. Dip Goswami, prior to the beginning of the academic year you should register for 2IMC84. For further information about mentoring please consult Section 1.12.1.

Quarter	Code	Unit	ECTS	Exam[1]
Stream mandatory courses				***15***
2	2IMN15	Internet of things	5	w+a
3	5LIJ0	Embedded control systems	5	w
4	5LIK0	Embedded signal processing systems	5	w+a
Stream electives [2]				***20***
1	2IMN10	Architecture of distributed systems	5	w+a
1	2IMA10	Advanced algorithms	5	w+a
1	5LIC0	Networked embedded systems	5	a+o
1	5LIL0	Intelligent architectures	5	a
1	2IMF20	Hardware verification	5	w+a
2	5LIF0	Advanced digital circuit design	5	w/o
2	5LIV0	Video Health Monitoring	5	w/o
2	5LIG0	Applied combinatorial algorithms	5	a+o
3	2IMP25	Software evolution	5	w+a
3	5LIE0	Multiprocessors	5	a+o
3	5LIM0	Parallelism, compilers and platforms	5	w+a
3	5SIB0	Electronic design automation	5	w+a
4	2IMP20	Generic language technology	5	w+a
4	5LIA0	Embedded visual control	5	a
4	2IMN35	VLSI programming	5	a
4	2IMP30	System Design Engineering	5	w+a

[1] *w - written exam, a - assignments, o - oral exam; w/o - either a written or an oral exam depending on the number of students.*

[2] *You have to choose at least 20 credit points from this list*

7.3.6 Free Electives

In principle all master courses offered at the TU/e can be chosen as free electives. Also courses from the Embedded Systems programs in TU Delft and the University of Twente may qualify as suitable free electives, provided that there is no content-wise overlap with other courses in your individual study program. You need to obtain permission from the study advisor before enrolling in courses from Delft or Twente to confirm there is no overlap issue.

Your complete study program including the free electives always requires approval by the examinations committee. Your mentor will help you to compose a balanced program that is very likely to be approved.

Some courses may be prescribed as homologation courses (up to 15 credits) to make up for deficiencies in former education (see Section 7.3.7). This prescription is part of the admission decision.

If you do not (yet) have a degree from another country or at least 15 credit points in international experience you should reserve 15 credits from the room for free electives to take courses abroad or to do an internship of 15 credits abroad, see Section 1.7.2.

7.3.7 Homologation units

Students entering the Embedded Systems master program have very diverse backgrounds and consequently most students do not satisfy all BSc-level knowledge and skills required for the master program. Students should evaluate themselves to what extent they satisfy the prerequisites of courses of the Embedded Systems program. At least, they should make sure that they satisfy the prerequisite knowledge and skills of the mandatory courses of the program and the mandatory stream courses. To allow students to repair deficiencies, upon discussion with their mentor and/or academic advisor and approval of the examination committee, students may include bachelor courses in their study programs. In addition to the regular bachelor courses the Embedded Systems master program offers the homologation modules below, specially designed to repair deficiencies.

Homologation modules must be completed before start of preparation project (see Section 7.4).

If you feel that you lack knowledge and skills not addressed by one of the homologation modules above, then contact the academic advisor. Master students are also allowed to include bachelor courses in their program subject to approval of the academic advisor. Bachelor courses, including homologation modules, are considered to be free elective and should constitute not more than 15EC. It is not possible to follow additional bachelor courses in a master program after a finished pre-master.

Quarter	Code	Unit	ECTS	Exam[1]
1	5LFK0	Circuit analysis	2.5	
1	5LIS0	Computer architecture and C programming	2.5	
1	2IHT10	Logic and set theory	2.5	
2	5LIP0	Digital integrated circuits: fundamentals[2]	2.5	
2	5LIQ0	Linear Systems, signals and control	2.5	
2	5LIR0	Linear Systems, signals and control (DBL)	2.5	

[1] *w - written exam, a - assignments, o - oral exam; w/o - either a written or an oral exam depending on the number of students.*

[2] *Students cannot include both 5LIH0 and 5LIP0 in their program.*

In some cases, these homologation modules are offered as self-study courses, based on online course material, with some guidance by a responsible lecturer. In other cases, the homologation modules are associated with existing bachelor courses, with regular lectures, tutorials and lab sessions.

7.3.8 Seminars, Internship and multi-disciplinary design project

Especially when the master project will be performed in an industrial environment, it is usually advised to spend the rest of the study program on regular courses. In some cases, however, an internship (code 2IMC10 or 5L990) may be a valuable addition to the program, provided that it enhances practical experience, provides deepening of knowledge, contributes to the specialization, and perhaps provides international experience. See Section 1.7.2 for details on internships. Instead of an internship, a multi-disciplinary design project (2IMC25) can be performed, in which students work in groups of 2 to 3 on an embedded design under the supervision of a member of staff. We refer to the course page for more information. Note that it is not possible to do both an internship and the multi-disciplinary design project.

The Computer Science division of the department Mathematics and Computer Science offers seminars and "capita selecta" that may help you prepare for your master project by studying topics not covered by regular courses. The table below lists the possibilities and codes for seminars, capita selecta, internship and multi-disciplinary design project.

Quarter	Code	Unit	EC	Exam
		Seminars		
4	2IMS00	Seminar information security technology[1]	5	a
4	2IMA00	Seminar algorithms[1]	5	a
6	2IMM00	Seminar data mining[1]	5	a
6	2IMG00	Seminar applied geometric algorithms[1]	5	a
6	2IMD00	Seminar databases[1]	5	a
6	2IMI00	Seminar analytics for information systems[1]	5	a
6	2IMN00	Seminar systems architecture and networking[1]	5	a
6	2IMP00	Seminar software engineering and technology[1]	5	a
6	2IMV00	Seminar visualization[1]	5	a
6	2IMF00	Seminar formal system analysis[1]	5	a
6	2IMA00	Seminar algorithms[1]	5	a
		Capita Selecta		
	2IMS05	Capita selecta security[2]	5	a
	2IMD05	Capita selecta databases[2]	5	a
	2IMF05	Capita selecta formal system analysis[2]	5	a
	2IMI05	Capita selecta analytics for information systems[2]	5	a
	2IMA05	Capita selecta algorithms[2]	5	a
	2IMM05	Capita selecta data mining[2]	5	a
	2IMG05	Capita selecta applied geometric algorithms[2]	5	a
	2IMN05	Capita selecta systems architecture and networking[2]	5	a

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Quarter	Code	Unit	EC	Exam
	2IMP05	Capita selecta software engineering and technology[2]	5	a
	2IMV05	Capita selecta visualization[2]	5	a
		Internship / Multi-disciplinary design project[3] (second year)		
	2IMC10/5L990	Internship	15	a
	2IMC25	Multi-disciplinary design project	10	a

[1] *A seminar may be followed starting from the fourth quarter of the program.*
[2] *Capita Selecta courses are by lecturer's invitation only.*
[3] *Note that only one of these may be chosen, and that the Internship requires permission of the coordinator. See Section 1.7.2 for the details.*

7.4 Final project

Prior to starting the final project you should first choose and consult the intended final project supervisor. The project can be completed in any of the specializations listed in Section 10.1 and Section 10.3, provided that a staff member of the associated group has the supervision. In case the project is carried out under supervision of a staff member of the Mathematics and Computer Science department, the course code is 2IMC00. In case the supervisor is from the Electrical Engineering department, the code is 5T746. If you are in doubt how to choose the graduation supervisor please consider contacting your mentor.

To prepare for the master project, you start with a master thesis preparation followed by the master project itself. Preparation for Graduation Project ES (2IMC05/5T514) has to be completed before the start of the master project

The start of your master project is marked by submitting a completed graduation plan containing the necessary information on the project (name, place, period, supervisor, and so on), and stating the fact that you obtained approval of your study program (see Section 1.9) and that you fulfill all requirements listed in Section 7.4.1. The form must be accompanied by a project description and signed by you, your supervisor, the head of the relevant specialization, and the academic advisor.

7.4.1 Admission

During the master project, you should be able to work and concentrate on your project full-time. In practice, however, it turns out to be rather difficult to plan all your curricular activities and, especially, their success:

- If all courses have been completed, permission to start the master project will be granted.
- If more than two courses or 10 EC (whichever is lower) have not been completed, such permission will not be granted.
- In other cases (no more than two courses or 10 EC not yet completed) it depends on the status of the uncompleted courses whether permission to start the master project will be granted, and if so, whether it is feasible to work on the project full time.

Courses that are to be taken as homologation units must be completed and passed before you are allowed to start the master project. Note that the *preparation for graduation ES project* (2IMC05 or 5T514) must be finished and graded before you can start the master

project. Also, be aware that you are not allowed to finish your project (with presentation and defense) before you have completed all your courses.

For more information, please contact the academic advisor, AcademicAdvisorMCS@tue.nl.

7.4.2 Planning

Together with your supervisor, you decide on a description of your topic and a global planning. You also arrange the supervision method, including how often you and your supervisor will meet to discuss progress. The project is concluded with a thesis and a presentation followed by a defense.

In general, the master project should be completed within 6 months from the start. An extension to 9 months is possible. In exceptional cases, and only if it is clear that the project can be finished, the exam committee may allow for an additional 3 months period. It is important to note that the project must be finished within 1 year. A project not finished within 1 year is automatically cancelled and graded as "fail". You then have to start a new project with a different supervisor. The complete examination regulations can be found on the website.

7.4.3 Final presentation and defense

The final presentation is public and is held in buildings of Eindhoven University of Technology. It is customary that the final presentation takes ca. 30 minutes. The defense following the presentation, however, is not public; only the student and the assessment committee (see below) are present unless both parties have no objection to the presence of others.

7.4.4 Assessment

Your final project is graded by an assessment committee. The committee usually consists of your supervisor, a staff member from your specialization area, and a staff member from one of the other research groups of the division of Computer Science of the department of Mathematics and Computer Science or of the department of Electrical Engineering. The supervisor is responsible for forming this committee at least one month before graduation.

The assessment committee takes the following criteria into account:

Results:	Significance of the results versus difficulty of the problem or project goals.
Report:	Structure, completeness, correctness, readability, argumentation.
Graduation presentation:	Structure, contents, clarity, contact with audience.
Defense:	Argumentation, demonstration of knowledge, competency in discerning main aspects from details of the project.
Execution of the project:	Level of independence, planning, organization, handling deadlines and setbacks, level of own contribution.

The actual assessment form used by the committee has a more fine-grained list of criteria for evaluating the work. Not all criteria are equally important. The assessment committee decides the relative importance of each criterion to arrive at a final grade. The motivation for the grade is documented in an assessment report, see the MSc assessment form.

7.4.5 Cum laude regulations

The Examination Committee may award the classification “cum laude” if

- the student achieves an average grade of 8.0 or higher for all the study components,
- the graduation project must have a grade of 9.0 or higher,
- none of the study components may have a grade lower than a 6.0.

The average grade is computed **without** taking into account the number of EC associated with the course.

7.4.6 Checklist

The graduation checklist (Appendix B) summarizes all the steps required from having your study program approved to the graduation ceremony.

8 EIT Tracks

EIT Digital Master School offers an international Master program on *ICT Innovation*, combining and integrating technical majors with a fully standardized minor on Innovation and Entrepreneurship. As a student in the EIT digital Master School you not only get fundamental knowledge and skills on a technical topic, but also learn how to drive your innovative ideas to the market.

Mobility

A distinctive feature of the ICT Innovation program is geographic mobility: you will study at two top-notch universities in two different European countries. When you apply for admission to the two-year program, you select an entry point (the university at which you do the first year of the program), and an exit point (the university at which you do the second year of the program). You will also travel to a kick-off event, summer and winter schools to meet other students, business partners and professionals. Learning about cultural and language differences enables our students to become experts in their technical field and also succeed as managers in global markets.

Double Degrees and the EIT digital certificate

When you successfully complete the program you will receive a double degree from your entry point university and your exit point university. In addition, you will get the EIT digital certificate, documenting the EIT digital specific learning outcomes on Innovation and Entrepreneurship.

Tracks

Eindhoven University of Technology offers the following tracks in the context of the ICT Innovation program:

Data Science: This program will provide the mathematical and computer science competences for analyzing big data and the entrepreneurial skills to successfully apply these in a corporate environment.

	At the TU/e this track leads to a degree in Computer Science and Engineering.
Embedded Systems:	This program equips engineers of tomorrow to specify, design, and implement computer systems that are widely used in a variety of personal and industrial devices in e.g. transportation and health-care. At the TU/e this track leads to a degree in Embedded Systems.

8.1 Embedded Systems

The term embedded system refers to electronic components (which almost invariably include one or more software programmable parts) of a wide variety of personal and industrial devices, e.g., transportation systems, health-care equipments as well as equipments in the construction industry. In all these areas, embedded systems confer added value to the products by either extending the range of the delivered functionalities or by enhancing the quality of a "traditional" functionality that is rendered to the user.

The graduates of this program will have a holistic view on the specification, design, and implementation of complex embedded systems, taking issues such as resource-constraints, budget and development time into account. In addition to the technical skills, the EIT program offers insights on the elements of business and developing innovations into successful business ideas.

A distinctive feature of the program is that you study at two universities in two different institutions and in two different countries: you spend one year at the entry node taking the common base courses and part of your innovation and entrepreneurship module and then you move to the exit node for your specialization courses and your graduation project as well as the rest of the innovation and entrepreneurship module.

Mentor of the EIT Embedded Systems program is dr. Bas Luttik, prior to the beginning of the academic year you should register for 2IMC85 (entry) or 2IMC86 (exit). For further information about mentoring please consult Section 1.12.1.

Graduation options

The EIT Digital Embedded Systems program requires mobility among six renowned European universities, listed below:

- Aalto University (Aalto), Finland
- Royal Institute of Technology (KTH), Sweden
- Technische Universität Berlin (TU Berlin), Germany
- 3TU.Federation (3TU), represented by TU/e, The Netherlands
- Turku Centre for Computer Science (TUCS), Finland
- University of Trento (UNITN), Italy.

After being admitted to one of the entry nodes (KTH, TU Berlin or TU/e), during your second year, you will have the option of specializing in one of the following areas offered at the exit nodes:

- UNITN: Real-Time Embedded Systems
- TU/e: Embedded Networking
- KTH: Embedded Platforms
- TUCS: Energy Efficient Computing
- Aalto: Mobile Cyber-Physical Systems
- TU Berlin: Embedded Multicore Processing

8.1.1 Goals

The general learning outcomes of the programme are:

- The graduate has an all-embracing view on embedded systems, their design and their application in systems of various sizes (e.g. from small robots to cyber physical and networked systems) including their evolution over time, demonstrated by an integration approach in system design.
- The graduate is capable of analysing the functional behaviour of complex embedded systems in a structural way using appropriate abstractions.
- The graduate is able to describe and study the non-functional aspects of embedded systems, e.g. resource boundedness and dependability.
- The graduate has a thorough knowledge of state-of-the-art methods and techniques for embedded systems design such as requirements engineering, hardware-software integration, performance modelling and analysis, validation and testing.
- The graduate is able to design embedded systems that satisfy the functional and non-functional requirements, taking into account the performance of the system during its lifetime. The graduate is also aware of costs and environmental issues making optimal use of the available resources.
- The graduate has the ability and attitude to include other disciplines or involve practitioners of these disciplines in their work, where necessary. As an engineer the graduate is therefore able to work in a multidisciplinary setting.
- The graduate is able to conduct research and design independently and has a scientific approach to complex problems and ideas.
- The graduate possesses intellectual skills that enable critical reflection, reasoning and forming opinions.
- The graduate has the ability to communicate the results of their learning, thinking and decision-making processes at an international level.
- The graduate is aware of the temporal and social context of science and technology (comprehension and analysis) and can integrate this context in the scientific work.
- The graduate has an understanding how technological innovations can be developed into successful business ideas. The graduate is aware of the basic concepts of business organisation, product development, entrepreneurial finance, and market dynamics. The graduate is also able to start up and manage a technology-based company and understands how to develop and lead human resources of such a company.

8.1.2 Entry point program

KTH, TU Berlin, and TU/e offer an entry-point programme for the ES technical major. It consists of a *Technical Common Base*, an *(entry point) I&E module*, and *Electives*. The following table summarises the TU/e entry-point programme:

Quarter	Code	Unit	ECTS	Exam[1]
Technical common base				
1	2IMF30	System validation	5	w+a
2	5SIA0	Embedded computer architecture	5	w/o+a
2	2IMN25	Quantitative evaluation of embedded systems	5	w+a
3	2IMN20	Real-time systems	5	w+a
4	5LIB0	Embedded systems laboratory	5	w+a
Innovation & entrepreneurship module				
2	1ZM20	Technology entrepreneurship	5	a
3-4	1ZM150	Innovation Space project	10	a
3-4	2IEIT0	Winter school	1	a
	2IEIT5	Summer school	4	a
Electives Embedded Systems			10	
Electives Innovation & entrepreneurship			5	

[1] *w - written exam, a - assignments, o - oral exam; w/o+a - assignments + either a written or an oral exam depending on the number of students.*

Electives Innovation & entrepreneurship should be selected from the following list:

Quarter	Code	Unit	ECTS	Exam[1]
2	1ZM120	Entrepreneurial Marketing	5	w+a
2	0HM220	Network Society	5	w+a
2	1ZM140	Strategy and Technology Management	5	a
2	0EM160	Innovation and Intellectual Property Rights	5	w+a
3	1CM22	Integrated Finance & Operations Management	5	w
3	1ZM65	System Dynamics	5	w+a
4	1ZM90	Open Innovation	5	w+a
4	0LM150	Entrepreneurship and corporate social responsibility	5	w+a
4	1CM15	Project & process management	5	a
4	1ZM70	Entrepreneurial Finance	5	w+a

[1] *w - written exam, a - assignments, o - oral exam.*

8.1.3 Exit point program

The TU/e offers an exit-point program with a specialisation in Embedded Networking. The following table summarises the programme:

Quarter	Code	Unit	ECTS	Exam[1]
1	2IMN10	Architecture of distributed systems	5	w+a
1	5LIC0	Networked embedded systems	5	a+o

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Quarter	Code	Unit	ECTS	Exam[1]
2	2IMN15	Internet of things	5	w+a
		Electives	10	
1–2	1ZS30	**Innovation and entrepreneurship study**	6	a
3–4	2IMC00/5T746	**Master project**[2]	30	a

[1] *w - written exam, a - assignments, o - oral exam.*
[2] *The student is allowed to start with the graduation project only after the Masters study program has been approved by the examinations committee. See Section 7.4 for further details on planning and assessment of the Master project.*

Electives

The courses listed in Section 7.3.6 and in the different streams of the regular Embedded Systems program are suitable as electives.

8.2 Data Science

The EIT Digital technical programs involve a 2-year master program (120 ECTS) that includes a common technical competence base, which constitutes the curriculum for the first study year, and a specialisation that will be the starting point for the thesis work during the second year. In all, this compiles 90 ECTS. In addition, a Minor in Innovation & Entrepreneurship will provide you with valuable knowledge on how to drive your innovations to the market. Note that it is compulsory for students that the first year program at the entry point university is followed by a second year program at a different university (exit point university). The students will obtain a degree of both the entry and exit university and an EIT digital certificate.

Mentor of the EIT Data Science program is dr. Renata Medeiros de Carvalho, prior to the beginning of the academic year you should register for 2IMC93 (entry) or 2IMC98 (exit). For further information about mentoring please consult Section 1.12.1.

Graduation options

The EIT Data Science program requires mobility among five renowned European universities, listed below:

- Royal Institute of Technology (KTH), Sweden
- Technische Universität Berlin (TU Berlin), Germany
- Eindhoven University of Technology (TU/e), The Netherlands
- UPM Madrid, Spain
- UNS Nice Sophia-Antipolis, France
- POLIMI, Milan, Italy

After being admitted to one of the entry nodes (TU/e, UPM Madrid, UNS Nice Sophia Antipolis or POLIMI), during your second year, you will have the option of specializing in one of the following areas offered at the exit nodes:

- KTH Stockholm: Distributed Systems and Data Mining for Really Big Data

- TUB Berlin: Design, Implementation and Usage of Data Science Instruments
- TU/e Eindhoven: Business Process Intelligence
- UPM Madrid: Infrastructures for Large Scale Data Management and Analysis
- UNS Nice Sophia-Antipolis: Multimedia and Web Science for big data
- Aalto: Machine Learning, Big Data Management, and Business Analytics

8.2.1 Goals

The general learning outcomes of the programme are:

- The graduate has a broad view of data science as a specialization of computer science, engineering and technology;
- The graduate should be able to understand and develop technology for handling structured and semi-structured and possibly distributed big data;
- The graduate should be able to analyse data to draw meaningful conclusions from data, effectively turning data into value;
- The graduate should understand the role of data in organisations, enabling the shift towards data-driven decision making in industry;
- The graduate should understand legal and social aspects of collecting, owning and manipulating data.

8.2.2 Entry point program

TU/e, UPM and UNS offer an entry-point programme for the Data Science master. It consists of a set of *Common Core Competences*, a bases in Entrepreneurship and Electives. The following table summarises the TU/e entry-point programme:

Quarter	Code	Unit	ECTS	Exam[1]
Technical common base				
1	2IMI35	Introduction to process mining[2]	5	w+a
1	2IMM20	Foundations of data mining	5	a
1	2IMA10	Advanced Algorithms	5	w+a
2	2IMV20	Visualization	5	a
2	2DMT00	Applied statistics	5	w+a
Core Electives (2 out of 5)				
1	2IMG15	Algorithms for geographic data[3]	5	a
2	2IMA15	Geometric algorithms[3]	5	a
3	2IMV10	Visual computing project	5	a
3	2DI70	Statistical learning theory	5	w+a
4	2IMD15	Data Engineering	5	a
Suggested Electives (on top of program)				
1	2MMS10	Probability and stochastics 1	5	w
1	2IMV25	Interactive virtual environments	5	a
1	2IMS25	Principles of Data Protection	5	w+a
2	2MMS30	Probability and stochastics 2	5	w
3	2IMM15	Web information retrieval and data mining	5	a

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Quarter	Code	Unit	ECTS	Exam[1]
3	2IMD10	Database technology	5	w+a
4	2IMV15	Simulation in Computer Graphics	5	a
4	2DD23	Time-series analysis & forecasting	5	a+o
Innovation & entrepreneurship module				
2	1ZM20	Technology entrepreneurship	5	a
3-4	1ZM150	Innovation Space project	10	a
3-4	2IEIT0	Winter school	1	a
	2IEIT5	Summer school	4	a
4	0LM150	Entrepreneurship and corporate social responsibility	5	w+a

[1] *w - written exam, a - assignments, o - oral exam.*
[2] *Students who took the course 2IIE0 or 2IIF0 in their bachelor are not allowed to take 2IMI35 because of overlap.*
[3] *Students should be advised that due to three other mandatory courses in this quartile, selecting this course implies that you need to* follow *four courses in the same quartile.*

8.2.3 Exit point program

The TU/e offers an exit-point program with a specialisation in Process Mining. The following table summarises the programme:

Quarter	Code	Unit	ECTS	Exam[1]
1	2IMI35	Introduction to process mining[2]	5	w+a
1	2IMS25	Principles of Data Protection	5	w+a
2	2IMV20	Visualization	5	a
2	2IMI20	Advanced process mining	5	w+a
2	2IMI00	Seminar analytics for information systems [3]	5	a
2	2IMD00	Seminar databases [3]	5	a
2	2IMM00	Seminar data mining [3]	5	a
1–2	1ZS30	**Innovation and entrepreneurship study**	6	a
3–4	2IMC00	**Master project** [4]	30	

[1] *w - written exam, a - assignments, o - oral exam.*
[2] *Students who took the course 2IIE0 or 2IIF0 in their bachelor are not allowed to take 2IMI35 because of overlap and should replace this course with 2IMA10 Advanced algorithms.*
[3] *One of these three seminars has to be chosen.*
[4] *The student is allowed to start with the graduation project only after the Masters study program has been approved by the examinations committee. See Section 3.4 for further details on admission, planning and assessment of the Master project.*

9

Erasmus Mundus Joint Master Degree: Big Data Management and Analytics

Today, public and private organizations in all sectors face an avalanche of data. Business Intelligence (BI) enables an organization to collect and analyze internal and external data to generate knowledge that support the decision-making processes. Encouraged by the success of Business Intelligence, Big Data expands the analytical capabilities of organizations to the extent that any piece of relevant data must be gathered, processed, and analyzed. Big Data implies the complete digitalization of the organizations' internal processes and the incorporation of external data from any available relevant source. The Erasmus Mundus Joint Master Degree in "Big Data Management and Analytics" (BDMA) is designed to provide understanding, knowledge, and skills in the broad scope of fields underlying business intelligence and big data. Its main objective is to train computer scientists who have an in-depth understanding of the stakes, challenges, and open issues of gathering and analyzing large amounts of heterogeneous data for decision-making purposes. The program will prepare the graduates to answer the professional challenges of our data-driven society through a strong connection with industry, but also to pursue their studies into doctorate programs through a strong connection with research and innovation.

The curriculum is jointly delivered by Université libre de Bruxelles (ULB), Belgium, Universitat Politècnica de Catalunya (UPC), Spain, Technische Universit´at Berlin (TUB), Germany, Eindhoven University of Technology (TU/e), the Netherlands, and François Rabelais University, Tours (UFRT). Academic partners around the world and partners from leading industries in business intelligence and big data, private research&development companies, excellence centers, service companies, start-up incubators, public research institutes, and public authorities will contribute to the program by giving lectures, training students, providing software, course material, and internships or job placements.

Big Data Management and Analytics is a 2-year (120 ECTS) program. The first two semesters are devoted to fundamentals on business intelligence (ULB) and big data (UPC). Then, all students participate to the European Business Intelligence and Big Data Summer School (eBISS). In the third semester, students chose one of the three specializations Large-Scale Data Analytics (TUB), Business Process Analytics (TU/e), and Content and Usage

Analytics (UFRT). The fourth semester is dedicated to the master's thesis and can be carried out as an internship in industry or in a research laboratory in any full or associated partner. Eventually, all students attend the Final Event devoted to master's theses defenses and the graduation ceremony. The tuition language is English.

The program targets students with a Bachelor of Science (or a level equivalent to 180 ETCS) with major in Computer Science, as well as an English proficiency corresponding to level B2 of CEFR. The program will deliver a joint degree to graduates following the mobility ULB, UPC, and UFRT, and three degrees from ULB, UPC, and the university of the specialization (UFRT, TUB or TU/e) to graduates following the other mobilities.

The Big Data Management and Analytics program is offered starting from 2017-2018; Business Process Analytics specialization at TU/e—from 2018-2019. As of 2019-2020 UFRT will be replaced by CentraleSupélec, France that will offer Decision Support and Analytics as specialization.

Mentor of the Big Data Management and Analytics program is dr. Renata Medeiros de Carvalho. For further information about mentoring please consult Section 1.12.1.

9.1 Specialization

The following table summarizes the specialization program:

Quarter	Code	Unit	EC
1	2IMI35	Introduction to process mining	5
1	2IIH0	Process modeling and simulation	5
1	0FC05	Ethics and Technology	5
2	2DMT00	Applied statistics	5
2	2IMV20	Visualization	5
2	2IMI00	Seminar Analytics for Information System	5
	2IMC00	**Master project** [1]	30

[1] *The student is allowed to start with the graduation project only after the Masters study program has been approved by the examinations committee. See Section 3.4 for further details on admission, planning and assessment of the Master project.*

Part III

Organization and regulations

10 Research groups

In this chapter, you can read about the different research groups associated with the master programs. Each group provides a short description of their research area, and mentions some courses that are relevant for students who wish to participate their research. The courses are not meant to be obligatory for candidate graduates, but they give an impression of the predispositions of the staff. The contact person mentioned may give you additional information on the possibilities of a graduation project in the corresponding group.

Starting from 2015-2016 all master courses offered by the Computer Science department start with 2IM followed by a letter representing a research group, as follows:

A: Algorithms (Section 10.1.1),
C: Courses not specific for a research group such as internship or master project,
D: Databases (Section 10.1.4),
F: Formal System Analysis (Section 10.1.6),
G: Applied Geometric Algorithms (Section 10.1.2),
I: Analytics for Information Systems (Section 10.1.3),
M: Data Mining (Section 10.1.5),
N: System Architecture and Networking (Section 10.1.7),
P: Software Engineering and Technology (Section 10.1.9),
S: Security (Section 10.1.8),
V: Visualization (Section 10.1.10).

Check which groups offer the courses you have enjoyed most and use this information when choosing your master project.

10.1 Research groups in the CS department

This section describes the research groups that provide graduation projects for all master programs, i.e., BIS, CSE, DSIE, ES, and IST.

10.1.1 Algorithms (A)

Contact person: prof. Mark de Berg

The design and analysis of algorithms and data structures forms one of the core areas within computer science. The Algorithms Group performs fundamental research in this area, focusing on algorithmic problems for spatial data and on algorithms for network problems.

- Spatial data (that is, data describing objects 2-, 3- or higher dimensional space) arise in many application areas, including geographic information science and automated cartography, robotics, computer graphics, CAD/CAM, and many other application areas. Computational geometry is the field within algorithms research dealing with the design and analysis of algorithms and data structures for spatial data. It combines clever algorithmic techniques with beautiful geometric concepts to obtain efficient solutions to algorithmic problems involving spatial data. We perform research on fundamental computational-geometry problems, but also on problems inspired by the application areas mentioned above.
- Networks of various kinds transportation networks, communication networks, energy, social networks, and so on form the backbone of our society. Hence, it is of crucial importance to be able to analyze, control and optimize networks. A second theme of the Algorithms Group is therefore the study of algorithmic network problems, where techniques from graph algorithms and computational geometry (in case of spatial networks) play an important role. Many important algorithmic network problems are NP-hard. To get a grip on such problems we study so-called fixed-parameter tractable algorithms, which can be proven to work efficiently on "easy" instances (where a certain parameter of the instance is small), while they are slow on "difficult" instances (where the parameter is large).

Master thesis projects in the Algorithms Groups range from theoretical to experimental, and can be done internally or at a company. See https://www.win.tue.nl/algo/masterthesis/ for some example projects that we have supervised in the past.

Relevant courses are:

- Advanced algorithms (2IMA10)
- Geometric algorithms (2IMA15)
- Exact Algorithms for NP-hard Problems (2IMA25)
- Seminar algorithms (2IMA00)
- Capita selecta algorithms (2IMA05)

Other relevant courses:

- Algorithms for geographic data (2IMG15)
- Visualization (2IMV20)
- Seminar applied geometric algorithms (2IMG00)
- Foundations of Data Mining (2IMM20)

10.1.2 Applied Geometric Algorithms (G)

Contact person: prof. Bettina Speckmann

The research area of geometric algorithms, also called computational geometry, has an exciting variety of application areas which include robotics, databases, computer graphics, geographic information science (GIScience), information visualization, and molecular biology, to name a few. The Applied Geometric Algorithms group focusses in particular on (applications of) geometric algorithms to spatial data in the areas of GIScience, including automated cartography and moving object analysis, (geo-)visualization, visual analytics, and e-humanities.

- (Automated) cartography is focused mostly on the visualization aspects of GIScience and has established itself as its own research area. In recent years the computational aspects of thematic mapping have received considerable interest. Maps are effective tools for communicating information and hence spatial data (and also some non-spatial data) can be displayed well using maps. Thematic maps often depict a single theme or attribute, such as population, income, crime rate, or migration. There are many possibilities for creative projects with both an experimental and a theoretical competent in the area of automated cartography.
- Over the past years the availability of devices that can be used to track moving objects — GPS satellite systems, mobile phones, radio telemetry, surveillance cameras, RFID tags, and more - has increased dramatically, leading to an explosive growth in movement data. Objects being tracked range from animals (for behavioral studies) and cars (for traffic prediction), to hurricanes, sports players (for video analysis of games), and suspected terrorists. Naturally the goal is not only to track objects but also to extract information from the resulting data. The study of algorithms for the analysis and visualization of movement data is hence a rapidly expanding research area at the intersection of computational geometry, geographic information science, automated cartography, and information visualization. There is a broad spectrum of possible projects in this area, ranging from very fundamental and theoretical to purely experimental, with (nearly) any combination possible.
- The increased digitization of cultural heritage artifacts such as books, manuscripts, or musical scores, creates an ever growing set of highly complex data which humanities researchers aim to analyze and understand. The fields of information visualization and visual analytics develop computer-supported, interactive, visual representations which allow users to extract meaning from large and heterogeneous data sets. While such visual techniques have become common practice in the sciences, they are little employed by researchers in the humanities, despite similar increases in available data. The area of e-humanities, which deals with the development and use of digital technologies in the humanities and social sciences, is hence an beautiful application area for algorithmic visualization with a potentially high impact on society. Here there are again many possibilities for projects which combine an experimental and a theoretical component. In addition, collaboration with humanities researchers is often a (desired) possibility.

Relevant courses are:

- Algorithms for geographic data (2IMG15)

- Advanced algorithms (2IMA10)
- Geometric algorithms (2IMA15)
- Seminar applied geometric algorithms (2IMG00)
- Capita selecta applied geometric algorithms (2IMG05)
- Topological Data Analysis (2IMG10)

Other relevant courses:

- Visual computing project (2IMV10)
- Visualization (2IMV20)
- Interactive virtual environments (2IMV25)

10.1.3 Analytics for Information Systems (I)

Contact person: dr. Dirk Fahland

The Architecture of Information Systems (AIS) research group investigates methods, techniques and tools for the design and analysis of Process-Aware Information Systems (PAIS), i.e., systems that support business processes (workflows) inside and between organizations. AIS is not only interested in these information systems and their architecture, but also model and analyze the business processes and organizations they support. The group aims at results that are highly original and applicable in real-life situations. The main three research lines of AIS are:

- Process Modeling and Analysis. Models are commonly used to answer questions related to correctness and performance. One of the main goals here is to further improve verification techniques to check various properties such as soundness, data/resource soundness, accordance, controllability, and selected temporal properties. Pattern-based approaches are used for correctness-by-design. Another goal is to develop innovative simulation approaches that better reflect reality and that can be used in an operational setting while using process mining results.
- Process Mining. Process mining techniques are used to extract process-related information from event logs, e.g., to automatically discover models, check conformance, and augment existing models with additional insights extracted from some event log. The goals are to significantly improve the state-of-the-art in process discovery, to advance the state-of-the-art in conformance checking, and to predict problems, i.e., provide warnings based on historic information (e.g., a case will be late or an error is likely to occur).
- PAIS Technology. PAISs are used to manage and execute operational processes involving people, applications, and/or information sources. Examples are WFM (Workflow Management), BPM (Business Process Management), and ERP (Enterprise Resource Planning) systems. Increasingly, these systems are driven by models and produce high-quality event logs. We are interested in the artifacts used and produced by these systems (i.e., models and logs) as these are essential for testing the techniques developed in the two other research lines. For example, it is interesting to convert and verify process models expressed in some particular industry language. The same holds of course for event logs. Service-orientation plays an important role here and this new architectural style poses new research questions.

Relevant courses are:

- Business process management systems (2IMI10)
- Metamodeling and interoperability (2IMI15)
- Introduction to process mining (2IMI35)
- Advanced process mining (2IMI20)
- Business process simulation (2IMI30)
- Seminar analytics for information systems (2IMI00)
- Capita selecta analytics for information systems (2IMI05)

10.1.4 Databases (D)

Contact person: dr. George Fletcher

Data-intensive systems are crucial in modern computing, analytics, and data science. The Database (DB) group studies core engineering and foundational challenges in scalable and effective management of big data. Current research in the DB group focuses primarily on problems in streaming data, data approximation, and the management of massive graphs such as social networks, financial networks, and biological networks. Expertise within the group includes query language design and foundations, query optimization and evaluation, data analytics, data integration, and personalization. In addition to dissemination of research results in the leading scientific venues in the data management field, the DB group impacts the broader community through open-source software development, training and mentoring of early-career scientists, industrial R & D collaborations, and serving on international efforts such as the LDBC Graph Query Language Standardization Task Force.

DB group investigations into both the theory and engineering of data management systems are inspired by real-world application scenarios in close cooperation with public-sector and industrial research partners. Academic partners of the group range across leading research groups in Europe, Asia, and North America. Recent collaborators include Oracle Labs, Neo4j, University of Toronto, National University of Singapore, University of Lyon 1, and TU Dresden.

Relevant courses are:

- Seminar databases (2IMD00)
- Capita selecta databases (2IMD05)
- Database technology (2IMD10)
- Data Engineering (2IMD15)

10.1.5 Data Mining (M)

Contact person: prof. Mykola Pechenizkiy

Data mining and information retrieval automate the extraction of information and knowledge from large amounts of data; often so much data is collected that manual analysis is no longer possible. Data mining and information retrieval assist data analysts in locating relevant information and patterns in the data.

Relevant courses are:

- Web information retrieval and data mining (2IMM15)
- Foundations of Data Mining (2IMM20)
- Recommender systems (2IMM10)
- Seminar Data Mining (2IMM00)
- Capita selecta data mining (2IMM05)

10.1.6 Formal System Analysis (F)

Contact person: prof. Jan Friso Groote

The focus of the specialization FSA is on modeling and verifying behavior of systems and programs. Behavior must be understood as all possible actions that a system can consecutively perform during its lifetime.

Computer-based systems are so complex, that it is impossible to program them without understanding how the different software components communicate, and what the responsibilities of these parts are. By modeling the behavior, these responsibilities are made explicit. Due to the complexity of the matter at hand, it is also non-trivial to get these behavioral models correct. For this purpose we use analysis techniques. Primarily, these are used to find flaws in the model, and ultimately these are employed to show that the modeled behavior satisfies all the requirements. For instance, a data communication protocol must not lose messages, and a firewall should under no circumstance let an intruder pass. With current modeling techniques it is no problem to model the communication patterns of even the most complex systems. Using modal formulas most requirements can be formulated in a formal, precise way. Using one of the many existing process equivalences, it is very well possible to state the behavioral equivalence between implementations and specifications. So, in general, it is not really problematic (but sometimes hard) to formulate the properties that a system ought to have.

The current technological bottleneck is our capability to prove that a requirement holds for a given model (the model checking problem) or that two processes are actually equivalent (the equivalence checking problem). The major research activity of this group is to increase the strength of the analysis tools. The core problem of the analysis of behavior is the state space explosion problem. There are so many states in which a system can end up, that it is generally impossible to explore these all individually. For this purpose, we must use so-called symbolic techniques to enable the verification. These techniques come from the realm of automatic reasoning, term rewriting and computer assisted theorem checking. Also, state space reduction techniques (abstract interpretation, confluence checking) are relevant to reduce the problem size. Visualization turns out to be a relevant tool, to detect unforeseen problems and to increase insight in the behavior. Knowledge of algorithms, including I/O-efficient algorithms is relevant, to construct analysis tools capable of dealing with huge state spaces.

In order to investigate how effective our analysis techniques are, we are constantly assessing their practical use. For instance, the FSA group is involved in the standardization of several protocol standards (e.g. firewire). Our role is to assist the standardization process by showing where the protocol does not conform to its intention. With several of the embedded system industries around Eindhoven, we have a similar relationship: we design, model and analyze (parts of) the behavior of the equipment they are building.

Relevant courses are:

- Automated reasoning (2IMF25)
- System validation (2IMF30)
- Algorithms for model checking (2IMF35)
- Seminar formal system analysis (2IMF00)
- Capita selecta formal system analysis (2IMF05)
- Program verification techniques (2IMP10)
- Process algebra (2IMF10)
- Proving with computer assistance (2IMF15)
- Architecture of distributed systems (2IMN10)
- Advanced algorithms (2IMA10)
- Generic language technology (2IMP20)
- Visualization (2IMV20)
- Hardware Verification (2IMF20)

10.1.7 System Architecture and Networking (N)

Contact person: dr. Reinder Bril

Imagine just any electronic system that is not somehow networked with other systems. Found one? Must be a pretty boring system then, since one of the fascinating developments of the last years is that devices of all form factors and functionality become connected. In our group we study parallel and distributed systems with an emphasis on pervasive systems or, as we call it, Resource Constrained Networked Embedded Systems.

Master thesis assignments are related to the research topics of SAN, which focus on distributed aspects of RCNES (middleware and networked services), on the platform (predictable and reliable resource management) and on efficient embedded computations (typical for signal processing). Research questions are, for example, how to build and manage applications composed from distributed services, and how to perform distributed resource management.

We pay a lot of attention to quality aspects, which include performance, predictability, dependability, programmability and security. A dominant issue in our work is therefore the architecture of these RCNES, in particular the software architecture, as this is where the quality aspects are addressed. We relate our work to application domains which we see as vehicles for our research. Example application domains include distributed media systems, wireless sensor networks, automotive electronics, smart lighting and cyber physical systems. Much of this work is done in cooperation with industry through national and international projects. Have a look at our research page to see the projects we are involved in.

Relevant courses are:

- Real-time systems (2IMN20)
- Architecture of distributed systems (2IMN10)
- Internet of things (2IMN15)
- Seminar system architecture and networking (2IMN00)
- Capita selecta system architecture and networking (2IMN05) (not always given)

Other relevant courses are:

- Quantitative Evaluation of Embedded Systems (2IMN25)
- VLSI programming (2IMN35)
- Seminar information security technology (2IMS00)
- Principles of data protection (2IMS25)
- Advanced algorithms (2IMA10)
- Generic language technology (2IMP20)
- System validation (2IMF30)

10.1.8 Security (S)

Contact person: prof. Sandro Etalle

Advanced and nation-state malware, evolving attack engineering techniques evading sophisticated monitoring mechanisms, to the new frontiers of IoT security, access control, and physical security, cybersecurity challenges are countless.

In reaction to this, SECs approach to system security is multi-faceted and covers offensive and defensive aspects of system security, trust management and compliance control systems, system monitoring and cyber-physical security, always targeting concrete security problems and addressing the underlying, fundamental issues at their core. SEC's strength lies precisely in its ability to empirically and theoretically understand the full security process: from attack generation and system management, to policy specification and user aspects.

Research in the Security (SEC) group spans three areas vital to the security of decentralized and embedded systems:

- Security policy specification & enforcement
- Security of embedded systems
- Threat intelligence and defense

SEC sits at the cutting edge intersection of these areas, addressing particularly challenging operative and theoretical problems: for example, by monitoring underground activities and studying the techno-economic principles driving attack production, SEC maintains a unique perspective on the offensive side of computer security. This understanding channels into novel approaches such as new monitoring techniques to detect attacks targeting IT and IoT systems alike and respond to these with adaptive security and authentication mechanisms. SEC has made significant contributions to secure key storage in embedded systems by devising algorithms for randomness extraction from Physical Unclonable Functions (PUFs). Furthermore, SEC pioneered Quantum Readout of PUFs, an object authentication technology that is immune to spoofing.

Relevant courses are:

- Seminar information security technology (2IMS00)
- Verification of security protocols (2IMS15)
- Principles of data protection (2IMS25)
- Cyberattacks Crime and Defenses (2IMS20)

- Cryptology (2MMC10)
- Cryptographic Protocols (2DMI00)
- Applied Cryptography (2DMI10)
- Physical aspects of digital security (2IMS10)
- Software evolution (2IMP25)

10.1.9 Software Engineering and Technology (P)

Contact person: prof. Mark van den Brand

Software has become one of the key enablers of modern society. In almost all activities that we do as human beings software plays a role, whether this is social media, buying goods, monitoring our sports activities, or in the production of goods.

The high-tech industry, in particular, is facing two trends. First of all, the amount of software is growing rapidly. Secondly, the quality of software is decreasing. These trends result in new research challenges. How to develop more high quality software in less time? How to guarantee the quality of the software? How to deal with the huge amount of existing software? The answers to these questions are not straightforward. A common theme in the answer to these questions is model driven software engineering. Models provide a higher level of abstraction and thus allow the specification of more functionality in less code. The models can also be used as starting point for simulation and verification. Finally, existing software can be analysed and the underlying models can be extracted. The research focus of the research group SET is on model based software development and on software evolution.

The field of model based software development is broad. We concentrate on the development of tooling to support the development of models in domain specific formalisms using meta-modeling techniques. Research on tooling for model based software development includes the modularity of meta-models, the description of semantics of domain specific languages, the verification of model transformation formalisms, and the co-evolution of models and meta-models. The ultimate goal is to provide a tool set which provides high fidelity software generation.

As the process software evolution encompasses the entire life cycle of a software system, from inception to phase out. As research domain software evolution aims at obtaining insights in how and why does software evolve as well as at translating those insights into techniques for assessing system evolvability and facilitating evolution. Given the fact that software evolution is an activity carried by humans, on top of technological challenges software evolution research also considers social and socio-technical ones. Lion's share of the software evolution research is empirical in nature, i.e., it requires combination of software development skills with data analysis skills.

Relevant courses are:

- Generic language technology (2IMP20)
- Software evolution (2IMP25)
- Program verification techniques (2IMP10)
- Software project management (2IMP15)
- System design engineering (2IMP30)
- Seminar Software Engineering and Technology (2IMP00)

- Capita Selecta Software Engineering and Technology (2IMP05)

Other relevant courses:

- Architecture of distributed systems (2IMN10)
- Foundations of Data Mining (2IMM20)

10.1.10 Visualization (V)

Contact person: dr. Huub van de Wetering

Data visualization aims to provide insight in large data sets by using interactive graphics, exploiting the unique capabilities of the human visual system to detect patterns and structures. By presenting data visually, people can see unexpected relations; by offering interaction they are enabled to explore huge data sets, driven by their interest.

The focus of this specialization is on the development of new methods and techniques for interactive visualization. The main fields of interest are information visualization and visual analytics, both aiming at insight in abstract data, such as tree structures, networks, and multivariate data, for applications in areas as software engineering, bioinformatics, health care, security, and traffic analysis. Our aims are to develop new visual representations and interaction methods, and to evaluate these on real world use cases to verify if they are effective. Some typical challenges are dealing with combinations of different data types, integration of methods from machine learning, handling dynamic data, and understanding the needs and wants of users. Another interest is in high performance scientific computing: exploiting the power of GPUs for visualization and computer graphics, with physically based animation and 3D shape analysis as typical applications.

Furthermore, in cooperation with the Centrum voor Wiskunde en Informatica (CWI) virtual reality systems are studied. Typical topics include the design and evaluation of 3D interactive techniques, and methods for improving image quality in virtual reality displays.

Relevant courses for the VIS specialization are:

- Visualization (2IMV20)
- Geometric algorithms (2IMA15)
- Visual computing project (2IMV10)
- Simulation in computer graphics (2IMV15)
- Interactive virtual environments (2IMV25)
- Seminar visualization (2IMV00)
- Capita selecta visualization (2IMV05)

Other relevant courses:

- Web information retrieval and data mining (2IMM15)

10.2 Research group in the IE&IS department relevant for BIS

Students in the BIS program can do a graduation project in any of the Computer Science research groups mentioned in Section 10.1. In addition, a project is possible in the Information Systems research group in the IE&IS department.

Contact person: dr. Rik Eshuis

The specializations of the Information Systems group are as follows:

- *Business Process Intelligence.* Research focuses on computational intelligence methods for decision models in which qualitative, linguistic information can be combined with quantitative, numerical information from data. The practical relevance of the resulting context-aware, adaptive decision support systems are studied in industry cases from e-commerce, logistics and healthcare.
- *Business Process Management.* The research of the Business Process Management (BPM) is conducted against the insight that operational performance is most effectively managed in many domains by a focus on cross-functional business processes and the application of information technology.
- *Healthcare.* The objective is to develop the scientific and practical know-how and technologies for boosting information usage in healthcare. We leverage expertise from Business Process Intelligence and Business Process Management and we focus on the following research areas: Advanced clinical decision support, Big data in health care, Healthcare process modeling and analysis, Process re-design and automation, Citizen-centric health data storage, Lifelong Personal Health Records
- *Smart Mobility.* Information systems for smart mobility support the intelligent routing of business objects in complex business processes. Business objects can be physical or non-physical (digital) artifacts. Business processes for smart mobility typically span multiple collaborating organizations, for instance transportation processes in the context of supply chains. Information systems for smart mobility build on well-established IT paradigms like Business Process Management (BPM) and Business Intelligence (BI).

For more information see `http://is.tm.tue.nl/`

10.3 Research group in the EE department relevant for ES

Students in the ES program can do a graduation project in any of the Computer Science research groups mentioned in Section 10.1. In addition, a project is possible in the Electronic systems research group of the EE department.

Contact person: ms. Marja de Mol

The mission of the section electronic systems is to provide a scientific basis for design trajectories of digital electronic circuits and systems "from (generalized) algorithm to realization". To identify the key problems, and verify the validity, robustness and completeness of our results, we develop, implement and maintain consistent and complete flows, and use them for realizing innovative multimedia hardware with emphasis on video processing and embedded architectures.

The research focuses on how to convert the "art" of designing electronic systems into methodology, an absolute necessity, because

- the complexity of modern integrated circuits continues to increase,
- new physical phenomena at submicron feature dimensions are having more and more impact, not only on performance, but even on the functionality,

- and the heavy demand pull from signal processing applications, in particular multimedia and telecommunications, requires rigorous and robust answers.

The approach taken is an algorithmic one, based on combinatorics and process algebra. The main application area is video processing. More information can be found on `http://www.es.ele.tue.nl`.

Relevant courses are:

- Applied combinatorial algorithms (5LIG0)
- Embedded computer architecture (5SIA0)
- Electronic design automation (5SIB0)
- Embedded signal processing systems (5LIK0)
- Video processing (5LIN0)

11 Academic administration

11.1 Academic administration of the department

The structure of the academic organization is based on the Academic Administration Structure Modernization Act (MUB), as implemented in the academic year 1997–1998. A student may contribute to the improvement of the academic organization as a member or advisor on the Department Board, the Study-program Committee or the Department Council. Participation in these organizations offers special privileges, such as facilities for oral instead of written exams or extra opportunities for taking examinations outside regular scheduling.

Important organizations:

- The Department Board (Faculteitsbestuur);
- The Study-program Director (Opleidingsdirecteur);
- The Study-program Committee (Opleidingscommissie);
- The Examinations Committee (Examencommissie);
- The Department Council (Faculteitsraad);
- The CS Division and Professors (Capaciteitsgroep en Hoogleraren);
- The CS Division Board (Capaciteitsgroepsbestuur);
- The Department Office (Faculteitsbureau);
- The Student Council (Studentenraad).

11.1.1 Department Board of Mathematics and Computer Science

The Department Board appoints a study-program director for the graduate program, vice study-program director and a program manager for each master program. The study-program director and program manager are mandated to develop, organize and implement the master program. Although some authority is delegated to the study-program director, the Department Board retains final responsibility for each master program. This means that the study-program director must report to the Department Board. The Department Board establishes the program and examination regulations (PER, in Dutch OER) and the program

budget, and oversees the implementation of the master program. The Department Board is comprised of four members: the dean and chairperson, two vice-deans and the managing director. A student advisor also participates in the board meetings, as advisor. Other attendees at the board meetings are the policy advisors and the department secretary.

The current members of the Department Board are:

Dean:	prof. dr. J.J. Lukkien
Vice-dean:	prof. dr. E.R. van den Heuvel
Managing director:	dr. R.C. van der Drift
Secretary:	dr. O. Houben - van Herwijnen

11.1.2 Study-program Director

Every year the study-program director outlines in the PER the academic program and policies, including the program structure and curriculum. He develops the program curriculum in close consultation with the teaching staff and the curriculum committee. The Study-program Committee advises the study-program director on his curriculum and quality plans. The study-program director is also in charge of the development and implementation of a quality management system. The study-program director advises the Division Board on the academic program. Whenever necessary, he also advises the Division Board on quality improvement and performance of the academic staff. The study-program director relies on the Department Office for administrative and managerial support. The Department Office also advises the study-program director on academic issues.

In the Computer Science graduate program, some of the responsibilities of the study-program director are delegated to program managers. Each master program has a program manager. The study-program director, the vice-director, and the program managers together form the Educational Board:

Study-program director:	prof.dr. M.G.J. van den Brand
Vice-director:	dr. A. Serebrenik
Program manager CSE:	dr. G.H.L. Fletcher
Program manager DSIE:	dr. G.H.L. Fletcher and dr. D. Fahland
Program manager BIS:	dr. D. Fahland
Program manager ES and EIT-ES:	dr. S.P. Luttik
Program manager IST:	dr. B. Škorić
Program manager EIT-DS and EMJMD BDMA:	dr. R. Medeiros de Carvalho

11.1.3 Study-program Committee

The study-program committee (OC) is appointed by the Department Board, and it has the following tasks:

- to advise the study-program director and the Department Board on issues relating to the PER
- to annually evaluate the implementation of the PER
- to advise on all issues relevant to the academic program

The department has three study-program committees: for the CSE program including the special tracks IST and DSE, for the BIS program, and for the ES program including the special track EIT-ES.

11.1.4 Examinations Committee

The Departmental Board appoints an Examinations Committee for each program. This committee is responsible for organizing and coordinating the examinations, and for appointing examiners in accordance with the provisions of Art. 7.12 of the Higher Education and Scientific Research Act 1997. Its members are all drawn from the Computer Science and Engineering teaching staff. The Examination Committee must approve the Examination Regulations to ensure the probity and integrity of all examinations, and will take all necessary measures in this regard. Its secretary is dr. P. Veltkamp.

11.1.5 Department Council

The Departmental Council has a statutory advisory function and certain decisions made by the Departmental Board require the formal approval of the Departmental Council. This will be the case if those decisions entail any amendment to department statutes, or the Education and Examination Regulations. The Departmental Council has ten members, of whom five are staff members who are elected by the staff, and five are students elected by students within the department.

You can find more information on the activities of the Department Council on their web site: `http://www.win.tue.nl/fr/`.

11.1.6 CS Division and professors

The general tasks of the CS Division are:

- to contribute to the preparation and implementation of the educational and exam programs
- to contribute to the research programs
- to contribute to the interdepartmental and inter-university education and research programs

In addition, the CS Division Board aims to come to agreement with the study-program director on issues of quantity and quality of academic staff.

The tasks of the professors are:

- to develop their assigned research areas
- to advise the study-program director and program manager on the contents of the educational program.

Full professors: a complete list is available on the web site

11.1.7 Academic advisors and Education secretariat:

Academic advisor pre-master: dr. ir. N.V. Stash (MF 5.097)

Academic advisor master: dr. ir. N.V. Stash (MF 5.097)

Student administration: (MF 5.104a)
csa.mcs@tue.nl

ms. J. Berger-van der Aalst	(040-)2478343
ms. M.J.C.P. van Geenen	(040-)2478938
ms. M.A.W. van Rooij	(040-)2476210
ms. M.M.G. Staghouwer - Heuvelmans	(040-)2472113
mr. E. Veenendaal	(040-)2472379
mr. P.W.J.A. Verkooijen	(040-)2476016

Education secretariat: (MF 5.105)
secretariaat.opleiding.win@tue.nl
(040-)2475630 or (040-)2474272
ms. C.C.H. Welten-Verhulst
ms. P.C.J. Gudden-van den Boomen

11.1.8 Student Council

The Student Council's (StudentenRaad, SR) main goal is to help solve problems in the educational process, such as problems with examinations, time tables or professors. The SR also mediates in cases where individual students encounter problems, and it serves as a first information point for students who do not know who to go to if they have a question. In many cases, the SR can refer students to the right place. Students with complaints or questions can reach the SR in the following ways:

- During one of the biweekly meetings.
- By e-mail: sr@win.tue.nl or complaints@gewis.nl
- By contacting the education commissary of GEWIS: oc@gewis.nl

Finally, the SR attempts to stimulate and facilitate contact among student members of the study program committees (OCI, ECM, OC-BIS, OC-CSE, OC-ES, OC-SEC), the Faculty Council (FR), University Council (UR) and the Student advisory Body (SAO) and to discuss the items on the agendas of each of these bodies. This is why members of these bodies are always encouraged to be present at SR meetings.

11.2 Facilities

11.2.1 Buildings

The department of Mathematics and Computer Science is located in the upper five floors of MetaForum. Regulations on access to university buildings are described in the departmental chapter of the student statutes and on the use of computer rooms are outlined on the website. For oral English explanation of these regulations, contact the Computer Services Office in room MF 3.083, telephone number (040)(247) 2802 or e-mail wshelp@win.tue.nl.

11.2.2 Lecture rooms, halls and other instruction facilities

The department uses lecture rooms within the whole university. Lecture rooms and halls are managed at institutional level. Reservations of the meeting and instruction rooms in MetaForum can be arranged through the department student administration, telephone number (040)(247) 2379/8343. Or on e-mail studadm.win@tue.nl. Alternatively, you can book a smaller room using the Book My Space app, see the intranet website of Book My Space.

11.2.3 Library services

The TU/e Library holds a large and up-to-date collection of scientific information. The TU/e Library website http://www.tue.nl/library provides round-the-clock access from any workplace to a wealth of digital information resources using advanced search tools. The TU/e Library collection is focused mainly on the technical sciences. Collection policy is linked directly to fields of research at TU/e departments.

The fully redeveloped and centralized TU/e Library is now located in MetaForum, the building in the centre of the campus. It provides the TU/e community with an inspiring and information-oriented environment for individual and collective study and work. There are over 950 study seats divided into quiet areas near the book collection and workspaces where groups of students can discuss their assignments. Each seat is equipped with wireless Internet access. Students may borrow publications from the Library free of charge using a fully automated loan system.

Regular opening hours of the TU/e Library are: Monday-Friday 8.00 a.m.–10.30 p.m. and Saturday-Sunday 10.00 a.m.–10 p.m. During the examination periods the library is open till 11 p.m.! For all further information about TU/e Library service go to our website: http://www.tue.nl/library.

11.2.4 Sale of study materials

Study material can be bought at the Lecture Notes Shop. Daily opening hours are from 8:00 to 16:30. The shop is closed during the introduction week. Inquiries can be made at: MF 1.552, telephone number (040) (247) 2446.

11.2.5 Computer Services Office

For problems with student related ICT problems, please contact the ICT Services Students Desk at MetaForum 1.557, telephone number (040)(247) 8888.

Students can print at the multifunctional printers all over the campus. Working locations for notebook use are available at the lower levels of MetaForum. Details on the regulations on the use of the computer facilities can be accessed at https://educationguide.tue.nl/organization/official-rules-and-regulations/code-of-conduct-for-computer

11.2.6 Conditions for computer use

The use of all computer and network facilities is subject to the rules listed in the document "Code of Conduct for Computer and Network Use" (Code of Conduct for Computer and Network Use), which can be downloaded from https://educationguide.tue.nl/

organization/official-rules-and-regulations/code-of-conduct-for-computer-ar
Use of any facilities implies your acceptance of these rules in full.

The department's policy is that students should be able to print program-related documents free of charge. There are Multifunctional printers available on all floors of MetaForum, as well as in other buildings on campus. Each student has an own printing account on which a balance of 15 euros is added at the beginning of each year. This balance can be checked and raised via OSIRIS.

Any problems or technical faults with hardware or software should be reported to the ICT Services Students Desk at MetaForum 1.557 , as should any infractions of the rules governing the use of the computer rooms, computers and networks.

11.3 Study association GEWIS

The study association GEWIS (union of math- and computer-science students) was founded over 25 years ago. GEWIS champions student rights, promotes student interests and offers students extracurricular activities. It organizes excursions to national companies and tries to organize an international study trip on a regular basis. It organizes the freshmen introduction week and the weekly drink on Thursdays from 16:30 until 19:00 in MF 3.155.

GEWIS publishes a magazine "Supremum", a yearbook, and organizes sporting events, (sailing-) weekends, parties and numerous other activities. On request, it is possible to organize an informal gathering at GEWIS. Every weekday from 12:30 to 13:30, GEWIS provides a book sale in MF 3.155, offering study books at reduced prices. In addition, the GEWIS-website offers old exams. The education commissary of GEWIS plays an important role as representative of students in the education processes.

GEWIS can be reached at: MF 3.155, phone number (040)(247) 2815, the website http://www.gewis.nl, and e-mail: bestuur@gewis.nl.

11.4 Information resources

Current information on program regulations, program changes, changes in the course schedules, practical courses, exams and other important matters is available as listed below.

Leading information on the program:

- The master program guide is digitally available.

Personal contact at the department:

- The master study advisor: dr. Natasha Stash
- Student Administration in room MF 5.104a (inquiries desk) or at telephone number (040)(247) 4040, for general information and inquiries about study arrangements, regulations, schedules and calendars and study results. The opening times of the inquiries desk are for students from 11:00 to 12:00, and from 13:00 to 15:00.
- International students coordinator: mr. E. Veenendaal in room MF 5.104a, telephone number (040)(247) 2379 or e-mail international.office.win@tue.nl
- The Study Association GEWIS is in room MF 3.155 or at telephone number (040)(247) 2815.

Personal contact at the university:

- The Education and Student Service Center is in room MF 1.214 or at telephone number (040)(247) 4747 for general information and inquiries about financial aid, student assistantships, admissions, university passes, exam regulations etc.

Several internet sources of information are available:

- The website at `http://www.tue.nl/` provides general TU/e information.
- Information about the department, academic counseling, social events and activities, etc. can be found at `http://w3.win.tue.nl/`.
- The electronic course catalog can be accessed at `http://education.tue.nl/` and contains current course information. Also examinations and course schedules are available at this webpage.
- Video recordings of lectures: `http://videocollege.tue.nl/`

A

Teaching and Examination Regulations

A.1 CSE (including DSIE, EIT-DS, EMJMD BDMA and IST)

Available at the website:

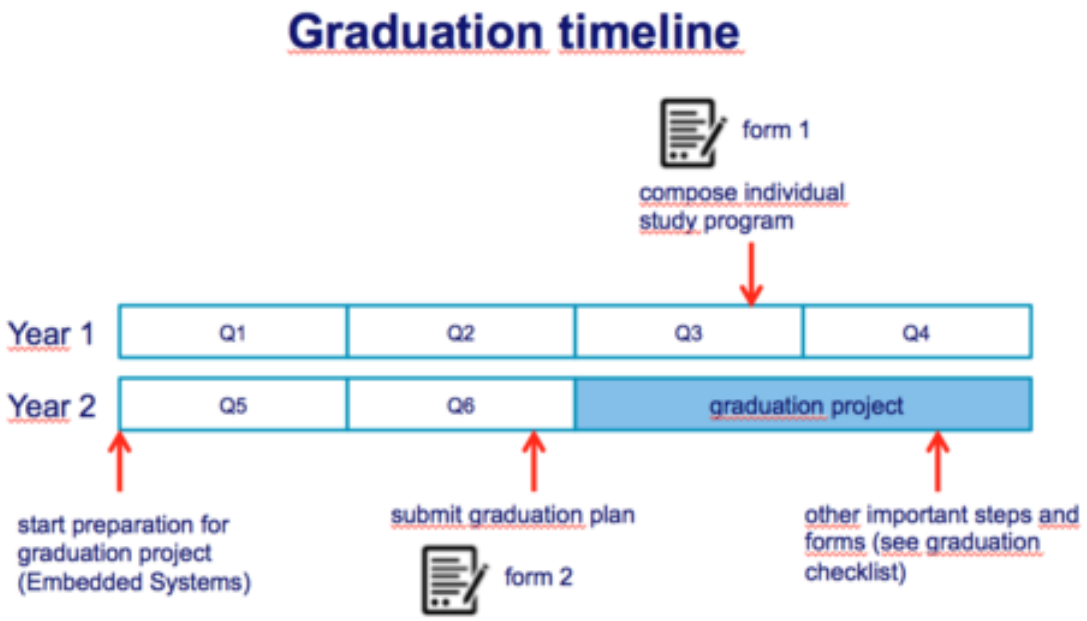
A.2 BIS

Available at the website:

A.3 ES (including EIT-ES)

Available at the website:

B
Graduation checklist



Months before you start the project

Submit **study program** if you have accumulated 40–50 credits.

Form 1: Forms are available in the web version of this document at `http://educationguide.tue.nl`. Look under your program, then 'Graduation' and then 'Graduation checklist'.

Make sure both you and your graduation supervisor sign the form. If you did not yet decide on your graduation supervisor, the form should be signed by your mentor. Submit a signed paper version at the student administration and a digital version (in Word-format, without signatures) to: studadm.win@tue.nl.

ES: Preparation for Graduation Project

If you are an Embedded Systems student (following the regular ES program and not the EIT-ES program), then you need to do a preparation for graduation project (2IMC05 or 5T514, 10EC). The preparation for graduation project is best done in the semester preceding your graduation project. The preparation for graduation project is supervised by your graduation tutor and/or graduation supervisor, it involves a literature and feasibility survey, and it should result in a concrete project description with a detailed project planning. At the end of the preparation for graduation project you should present the project proposal report to the assessment committee that will also evaluate your Master project. After the presentation, your supervisor submits an assessment form to the student administration.

Weeks before you start the project

Read the **graduation regulations**.

Submit your **graduation plan**.

Form 2: See the web version of this guide.

Gather all the required signatures on the form and make a separate problem description. Submit all documents to the student administration.

While executing your project

Consult the dates of the examination committee meetings and **register** for one of them at the latest four weeks in advance via OSIRIS. You can do this by clicking on Progress and then Qualification request. Please select the date of your preference from the list above and fill in the date in the OSIRIS form.

EIT students that have followed their entry year at Eindhoven University of Technology and are currently following their exit year at one of the partner institutions should select one of the dates of the examination committee meetings and register by contacting Ms. Jessica Berger.

In this meeting, the examinations committee determines whether or not you qualify for the diploma.

Ensure that the assessment committee is composed at the latest 1 month before your final presentation. The *graduation supervisor* must assemble the committee according to the regulations, sign the form, and submit it to the student administration for the approval by the Examinations Committee.

Form 3: See the web version of this document.

At the end of your project

Graduation presentation at the latest 2 weeks before the examination meeting.

You can book a room for your presentation at the student administration (provided all results of your study program are registered at the administration). After the presentation, only minor corrections in the graduation report can be introduced.

Your supervisor should submit at the student administration:

- your grade with the assessment report,

- your graduation report,
- and the declaration concerning the TU/e Code of Scientific Conduct signed by you.

Fill out the "Graduation Form" (form 4), which you receive by e-mail from the student administration. Submit it 2 weeks before the examination meeting to the student administration.

After you completed your project

Fill out the graduation survey. You will get an e-mail with the link from the student administration.

Attend the **graduation ceremony**. You will get an email with the invitation from the student administration.