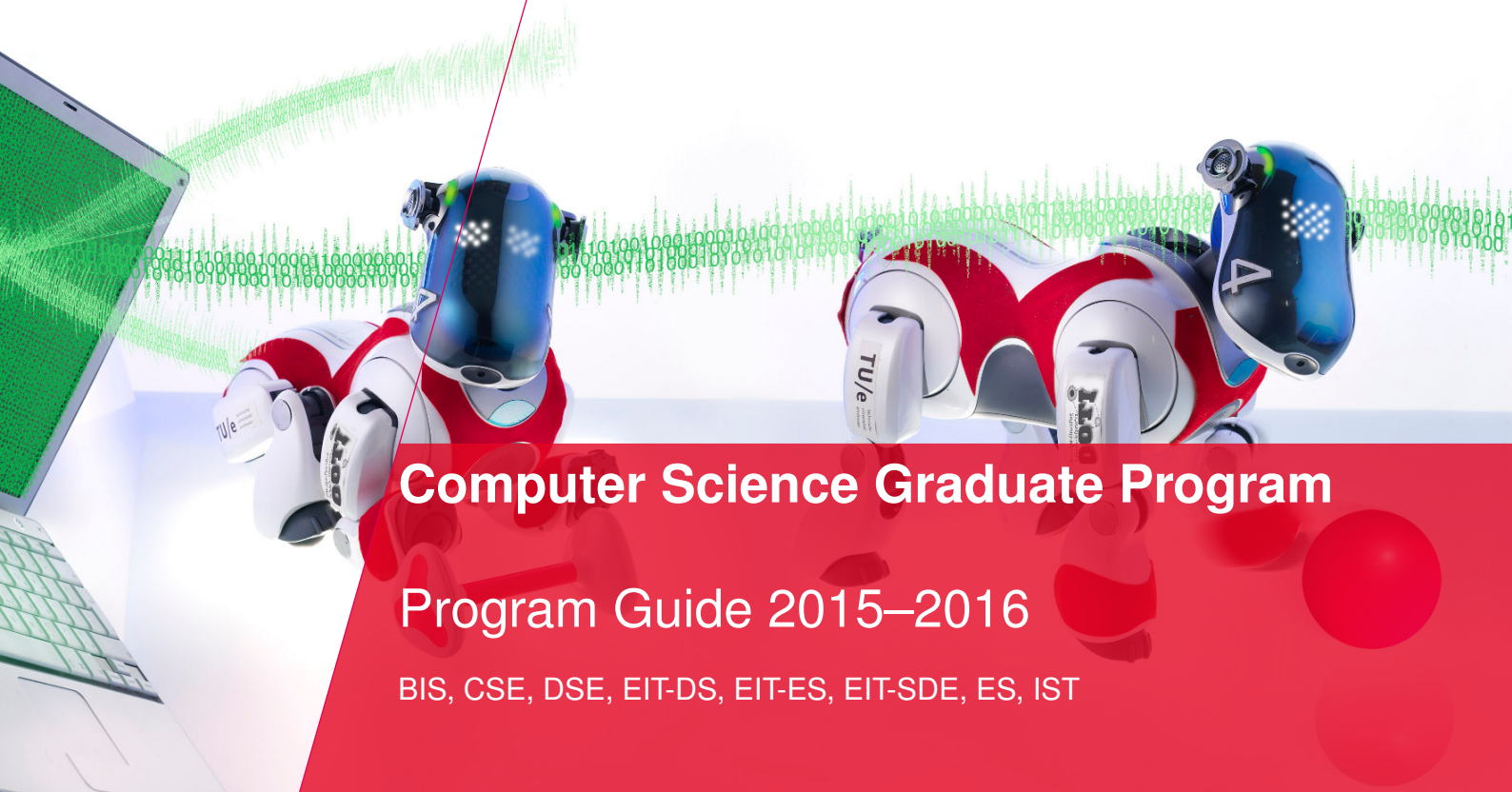**TU/e** Technische Universiteit
Eindhoven
University of Technology

Computer Science Graduate Program

Program Guide 2015–2016

BIS, CSE, DSE, EIT-DS, EIT-ES, EIT-SDE, ES, IST

Where innovation starts

Computer Science Graduate Program

Program Guide 2015–2016

Business Information Systems
Computer Science and Engineering
Embedded Systems
Data Science in Engineering
Information Security Technology
EIT Service Design and Engineering
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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 Specification and Verification, Algorithms and Visualization, Software and Systems Engineering, Information Systems, and Security. The CS Division offers its graduate and postgraduate courses in the Computer Science Graduate Program. There are three master programs, one of which has two special tracks (extra specialization, within the master program CSE). Each of the three master programs also has a special track within EIT, the European Institute of Technology. The EIT tracks are described in a separate section (9) of this document.

- Computer Science and Engineering (CSE). This master program has a special 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 special track on Data Science in Engineering (DSE), an interdisciplinary variant in cooperation with the Mathematics Division of the TU/e.
- Business Information Systems (BIS), an interdisciplinary master program in cooperation with the Department of Industrial Engineering and Innovation Sciences (IE&IS).
- Embedded Systems (ES), an interdisciplinary master program in cooperation with the Department of Electrical Engineering (EE).

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.

The TU/e also strives to make it possible to obtain a teaching degree by taking a special 45 ECTS program from the ESoE offering as part of several "regular" masters, thus without going for a double master degree. (The current legal requirement is 60 ECTS. We will keep you informed if and when a 45 ECTS teaching degree becomes possible.)

1.1 Structure of the master programs

All programs comprise two years of study or 120 credit points (ects); 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 ECTS 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 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. For details see the agendas and calendars at `http://owinfo.tue.nl/`.

Quarter	Period
1	August 31, 2015 – November 8, 2015
2	November 9, 2015 – January 31, 2016
3	February 1, 2016 – April 17, 2016
4	April 18, 2016 – July 3, 2016
interim	August 8, 2016 – August 13, 2015

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!

1.3 Course and exam registration

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

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 OASE (`http://education.tue.nl/`) 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.

1.4 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).

1.5 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.

1.5.1 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.

1.5.2 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 study advisor.

Students coming from other disciplines at the three Dutch technical universities may be admissible after they followed a deficiency or "homologation" program of up to 30 credits. The disciplines in question are mentioned in the "3TU-doorstroommatrix", the corresponding deficiency program is constructed on an individual basis.

1.5.3 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 NUFFIC (www.nuffic.nl).

1.5.4 Polytechnic graduates (HBO)

Students who have completed a polytechnic program may be eligible to participate in the pre-master programs. 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.

1.5.5 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.

1.6 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 ECTS 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 15ects)
- Do an internship abroad (at least 15 ects, which is roughly 3 months)
- Do the graduation project abroad

Your mentor (see section 1.7) will help you in choosing the best option for you and assist you in consulting the study advisor for programmatic issues. For organizational issues, the international affairs coordinator provides assistance. The contact person is mrs Elle van den Hurk bc., Room MF 5.099, International.office.win@tue.nl.

You need to deal with practical organizational aspects yourself. The Education and Student Service desk has a handy checklist; it can be found on `http://w3.tue.nl/en/services/stu/`. In a number of cases it is possible to obtain a scholarship that helps overcome financial hurdles of going abroad. A good starting point for scholarships is `http://www.beursopener.nl/`.

1.7 Mentoring

Within the first few weeks of your study a *mentor* will be assigned to you. 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. This typically happens between the end of the second and fourth quarter. Your mentor will then help you in choosing 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 study advisor (see section 1.13).

For the academic year 2015-2016 the mentors (for all masters) from the subdepartment Computer Science of the department of Mathematics and Computer Science are:
Algorithms: prof. dr. Mark de Berg
Applied Geometric Algorithms: prof. dr. Bettina Speckmann
Architecture of Information Systems: dr. Dirk Fahland
Formal System Analysis: prof. dr. Jan-Friso Groote
Security: dr. Nicola Zannone
Software Engineering and Technology: dr. Ruurd Kuiper
System Architecture and Networking: dr. Rudolf Mak
Visualization: prof. dr. Jack van Wijk
Web Engineering: dr. ir. Joaquin Vanschoren

For Embedded Systems and Business Information Systems there may also be mentors available from the department of Electrical Engineering (for ES) and from the department of Industrial Engineering and Innovation Sciences (for BIS).

1.8 Internship

An internship is mostly performed to fulfill the international experience part of the master program. Students who already have international experience when entering the master will typically not perform an internship but complete their study program with elective courses. In some of these cases, however, an internship may be a valuable addition to the program also for students who do not need international experience in their master, provided that it enhances practical experience, provides deepening of knowledge, and contributes to the specialization. An internship takes 15 credit points as part of the electives.

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

- 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 study 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.)

1.9 Admission to seminars, capita selecta, master project

Capita selecta courses 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. The capita selecta can be followed only by permission of the responsible lecturer. Students do not have a "right" to do these courses, but they may be granted the possibility.

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 premaster. 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.

1.10 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 study 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.

1.11 Honors program

The Honors program is aimed at excellent students from one of the Master programs offered by the Computer Science sub-department: Business Information Systems, Computer Science and Engineering, Data Science in Engineering, Information Security Technology, and Embedded Systems.

The goal of the program is to give these 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 ects 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.

Note that the Honors program is done on top of the regular Master program, that is, the 12 ects do not count towards the 120 credits you need to accumulate for your Master program. 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.

More information about the honors program can be obtained from the honors program coordinator prof.dr. Mark de Berg, e-mail m.t.d.berg@TUE.nl.

1.12 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 followup 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 examinations 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 examinations committee.

1.13 Study advisor

The master study advisor for all programs is dr. Peter Veltkamp.

Office:	MF 5.102
E-mail:	j.p.veltkamp@tue.nl
Phone:	040 247 2763
Consulting hours:	Monday, Tuesday and Thursday from 17:00 to 18:00 (or later if necessary) based on appointments (see below). Walk-in hour without appointment is often possible on Thursdays from 12.30 to 13.30, except when the study advisor is not in office then (check with the Study Program Secretariat)

1.13.1 Making an appointment with the study advisor

Since the study advisor must handle all master students in all master programs from the Computer Science Graduate Program you need to make an appointment before meeting in person. This prevents long queues and waiting times.

In order to make an appointment, send your request to the Study Program Secretariat secretariaat.opleiding.win@tue.nl at least one working day before you want to come. They will send you a form in which you are asked to indicate the topic of your visit and the preferred day (see above). After returning the form you will receive a meeting request with an exact time and a time slot of 15 or 30 minutes (see below). Please decline if the time does not suit you, otherwise accept. If you are unable to come to a set appointment, please inform the secretariat as soon as possible (e-mail, decline the appointment or call either (040-)2475630 or (040-)2474501) so that the time slot can be given to someone else.

15 minute slot:	For approval of a graduation plan. Please ensure that the form is filled out completely, that you have collected all required signatures, that you have a separate problem description, and that your individual study program has been approved already.
30 minute slot:	For all other cases.

In case you are not able to visit the study advisor during his consulting hours, you can make an appointment for a meeting at another time.

1.14 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.

1.14.1 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 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 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`

1.14.2 PhD programs

When pursuing an academic career, the first step is to obtain a doctorate. A PhD program is an individual four year program, dedicated to sharpen your research 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.

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 Computer Science and Engineering

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

Quarter	Code	Unit	ECTS
1	2DL10	Premaster calculus and probability	5
1 or 2	2IT60	Logic and set theory	5
2	2ID50	Datamodeling and databases	5
2 or 4	2IT70	Automata and process theory	5
2	2IV60	Computer graphics	5
1, 2, 3 or 4	9ST14A	Academic skills in English 1	5

Students taking the pre-master program are required to include some units of the Bachelor College as homologation units in the elective part of the master program:

Quarter	Code	Unit	ECTS
3	2IL50	Data structures	5
4	2IC60	Computer networks and security	5

2.2 Data Science in Engineering

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

Quarter	Code	Unit	ECTS
1	2DL10	Premaster calculus and probability	5
1 or 2	2IT60	Logic and set theory	5
1	2WS30	Mathematical Statistics	5
2	2ID50	Datamodeling and databases	5
2	2IV60	Computer graphics	5
1, 2, 3 or 4	9ST14A	Academic skills in English 1	5

Students taking the pre-master program are required to include some units of the Bachelor College as homologation units in the elective part of the master program:

Quarter	Code	Unit	ECTS
3	2IL50	Data structures	5
4	2IC60	Computer networks and security	5

2.3 Business Information Systems

The pre-master program consists of the following units:

Quarter	Code	Unit	ECTS
1	2DL10	Premaster calculus and probability	5
1	2IP90	Programming	5
1 or 2	2IT60	Logic and set theory	5
2	2ID50	Datamodeling and databases	5
2 or 4	2IT70	Automata and process theory	5
1, 2, 3 or 4	9ST14A	Academic skills in English 1	5

Students taking the pre-master program are required to include some units of the bachelor program "Technische Informatica" as homologation units in the elective part of the master program:

Quarter	Code	Unit	ECTS
1 or 3	2IIC0 or 2IHI10	Business information systems	5
2	2DI60	Stochastic operations research	5

2.4 Information Security Technology

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

Quarter	Code	Unit	ECTS
1	2DL10	Premaster calculus and probability	5
1 or 2	2IT60	Logic and set theory	5
2	2ID50	Datamodeling and databases	5
2 or 4	2IT70	Automata and process theory	5
2	2IV60	Computer graphics	5
1, 2, 3 or 4	9ST14A	Academic skills in English 1	5

Students taking the pre-master program are required to include some units of the bachelor program "Technische Informatica" as homologation units in the elective part of the master program:

Quarter	Code	Unit	ECTS
1	2IT50	Discrete structures	5
3	2IL50	Data structures	5
4	2IC60	Computer networks and security	5

2.5 Embedded Systems

The pre-master program consists of the following units:

Quarter	Code	Unit	ECTS
1	2WBB0	Calculus	5
1	5DD17	Circuit analysis	2.5
1 or 2	2IT60	Logic and set theory	5
1	5LIQ0	Linear Systems, Signals and Control	2.5
2	5LIR0	DBL Linear Systems, Signals and Control	2.5
2 or 4	2IT70	Automata and process theory	5
2 or 4	2DL07	Statistics A	3
1, 2, 3 or 4	9ST14A	Academic skills in English 1	5

Students taking the pre-master program are required to include some homologation units offered by the department of Mathematics and Computer Science and the department of Electrical Engineering in the elective part of the master program:

Quarter	Code	Unit	ECTS
1	5LIP0	Digital Integrated Circuits: Fundamentals	2.5
1	2INC0	Operating systems	5
1	5LIS0	Embedded Programming in C and C++	2.5
1 or 3	2IL50	Data structures	5
3	2IHS10	Software specification	2.5

5LIP0 is only for students taking the Systems on Chip stream, 5LIS0 is only for students without programming experience in C and 2IHS10 is only for students taking the Embedded Networking or Embedded Software stream.

2.6 Information sources

Study advisor: dr. C.J. (Roel) Bloo, MF 5.101, phone 040 247 4496
Coordinator: ms. E. (Elisabeth) Melby, e-mail: e.melby@tue.nl, MF 5.106,
phone 040 247 5150

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.

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 study 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 3.4). 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.

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 2.1.

The admission procedure is described in Section 1.5, 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 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, CSE graduates should also be experts in the subarea of computer science that they specialize in.

3.3 Curriculum 2015

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
- Web science
- Systems science

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

Units	ECTS
Mandatory courses	25
Stream electives	25
Free electives	35
Seminar	5
Master project	30

Each stream has a number of mandatory courses, and a selected set of elective courses from which at least 25 credit points 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 (35 credit points). Within this remaining part you should include 15 credit points in international experience if you do not yet have that 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

The following table lists the mandatory courses and stream electives.

Quarter	Code	Unit	ECTS	Exam
Mandatory courses				*60*
1	2IMA10	Advanced algorithms	5	w+a
1	2IMF30	System validation	5	w+a
3	2IMP25	Software evolution	5	w+a
4	2IMW20	Database technology	5	w+a
4	2IMP20	Generic language technology	5	w+a
4 or 6		**Seminar** [1]	5	a
7 and 8	2IMC00	**Master project** [2]	30	a
Stream electives [3]				*25*
1	2IMW15	Web information retrieval and data mining	5	w+a
1	2IMN10	Architecture of distributed systems	5	w+a
1	2IMI15	Metamodeling and interoperability	5	w+a
1	2IMI25	Constraint programming	5	a
1	2IMN30	Grid and cloud computing	5	a
2	2IMP10	Program verification techniques	5	w+a
2	2IMA15	Geometric algorithms	5	a
2	2IMF25	Automated reasoning	5	w+a
3	2IMN20	Real-time systems	5	w+a
3	2IMF35	Algorithms for model checking	5	w+a
continued on next page				

Quarter	Code	Unit	ECTS	Exam
continued from previous page				
4	2IMF10	Process algebra	5	w+a
4	2IMN35	VLSI programming	5	a
4	2IMP15	Software project management	5	a
4	2IMNT2	Real-time software development	5	a
4	2IMC20	Research methods	5	w+a
Free electives (possibly including internship)				*35*

[1] *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.*

[2] *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] *You have to choose at least 25 credit points from this list*

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.

The following table lists the mandatory courses.

Quarter	Code	Unit	ECTS	Exam
Mandatory courses				*60*
1	2IMW15	Web information retrieval and data mining	5	w+a
1	2IMS25	Principles of data protection	5	w+a
2	2IMV20	Visualization	5	a
3	2IMW10	Data engineering	5	w
4	2IMW25	Adaptive web-based systems	5	w+a
4 or 6		**Seminar** [1]	5	a
7 and 8	2IMC00	**Master project** [2]	30	a
Stream electives [3]				*25*
continued on next page				

Quarter	Code	Unit	ECTS	Exam
continued from previous page				
1	2IMN10	Architecture of distributed systems	5	w+a
1	2IMS10	Physical aspects of digital security	5	w
1	2IMA10	Advanced algorithms	5	w+a
1	2IMV25	Interactive virtual environments	5	a
2	2IMS20	Hacker's hut	5	a
3	2IMW30	Foundations of data-mining	5	w+a
3	2IMI10	Business process management systems	5	w+a
4	2IMW20	Database technology	5	w+a
4	0EM110	Research Methodology for the Innovation Sciences	5	a
4	0EM190	Infonomics	5	a
4	2IMI20	Advanced process mining	5	w+a
4	2IMC20	Research methods	5	w+a
Free electives (possibly including internship)			***35***	

[1] *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. If you enroll in February, the seminars are effectively in the fourth quartile of your study.*

[2] *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] *You have to choose at least 25 credit points from this list*

3.3.3 Systems Science stream

Modern systems are defined by software. Trends include cloud platforms, consisting of large connected server farms, and Cyber Physical Systems, with a tight integration of physical system, control, communication and computation. 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 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
- understand the role of models in model-driven systems engineering, and can develop and use corresponding techniques to design systems with required qualities
- are capable to perform research on processes and tools, as well as on new emerging technologies.

The following table lists the mandatory courses.

Quarter	Code	Unit	ECTS	Exam
Mandatory courses				*60*
1	2IMN10	Architecture of distributed systems	5	w+a
1	2IMF30	System validation	5	w+a
2	2IMF25	Automated reasoning	5	w+a
3	2IMN20	Real-time systems	5	w+a
3	2IMS15	Verification of security protocols	5	w+a
4 or 6		**Seminar** [1]	5	a
7 and 8	2IMC00	**Master project** [2]	30	a
Stream electives [3]				*25*
1	2IMI25	Constraint programming	5	a
1	2IMA10	Advanced algorithms	5	w+a
1	2IMN30	Grid and cloud computing	5	a
1	2IMS25	Principles of data protection	5	w+a
1	2IMF20	Hardware verification	5	w+a
2	5SIA0	Embedded computer architecture	5	o
2	2IMN25	Quantitative evaluation of embedded systems	5	w+a
2	2IMV20	Visualization	5	a
3	2IMF15	Proving with computer assistance	5	w+a
3	2IMP25	Software evolution	5	w+a
3	2IMF35	Algorithms for model checking	5	w+a
3	5LIE0	Multiprocessors	5	a+o
4	2IMF10	Process algebra	5	w+a
4	2IMN35	VLSI programming	5	a
4	5LID0	Systems on silicon	5	w+a
4	2IMP20	Generic language technology	5	w+a
4	2IMC20	Research methods	5	w+a
Free electives (possibly including internship)				*35*

[1] *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.*

[2] *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] *You have to choose at least 25 credit points from this list.*

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 5 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 25 credit points 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 25 credits in stream electives plus 35 credits in free electives you then take only 15 credits in electives from your chosen stream plus 45 credits 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.

Some 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 1.8. (This does not apply to students taking the teacher training.)

Quarter	Code	Unit	ECTS	Exam
1	2IMS10	Physical aspects of digital security	5	w
1	2IMW15	Web information retrieval and data mining	5	w+a
1	2IMN10	Architecture of distributed systems	5	w+a
1	2IMI15	Metamodeling and interoperability	5	w+a
1	2IMI25	Constraint programming	5	a
1	2IMA10	Advanced algorithms	5	w+a
1	2IMN30	Grid and cloud computing	5	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	9ST14A	Academic skills in English 1[1]	5	w+o
2	2IMS20	Hacker's hut	5	a
2	2IMP10	Program verification techniques	5	w+a
2	2IMA15	Geometric algorithms	5	a
2	2IMN25	Quantitative evaluation of embedded systems	5	w+a
2	2IMV20	Visualization	5	a
2	2IMF25	Automated reasoning	5	w+a
2	9ST14A	Academic skills in English 1[1]	5	w+o
3	2IMI30	Business process simulation	5	a
3	2IMW30	Foundations of data-mining	5	w+a
3	2IMW10	Data engineering	5	w
3	2IMF15	Proving with computer assistance	5	w+a
3	2IMI10	Business process management systems	5	w+a
3	2IMA20	Algorithms for geographic data	5	a
3	2IMN20	Real-time systems	5	w+a
3	2IMP25	Software evolution	5	w+a
3	2IMV10	Visual computing project	5	a
continued on next page				

Quarter	Code	Unit	ECTS	Exam
		continued from previous page		
3	2IMF35	Algorithms for model checking	5	w+a
3	2IMS15	Verification of security protocols	5	w+a
3	2MMD30	Graphs and algorithms	5	w
3	9ST14A	Academic skills in English 1[1]	5	w+o
4	2IMW25	Adaptive web-based systems	5	w+a
4	2IMW20	Database technology	5	w+a
4	2IMP20	Generic language technology	5	w+a
4	2IMF10	Process algebra	5	w+a
4	2IMI20	Advanced process mining	5	w+a
4	2IMN35	VLSI programming	5	a
4	2IMP15	Software project management	5	a
4	2IMV15	Simulation in computer graphics	5	a
4	2IMNT2	Real-time software development	5	a
4	9ST14A	Academic skills in English 1[1]	5	w+o
		***Courses at Utrecht University**[2]*		
1	2IUU10	Intelligent agents	7.5	w
2	2IUU15	Multi-agent systems	7.5	w+a
2	2IUU20	Computer animation	7.5	a
2	2IUU25	Computer vision	7.5	w+a
4	2IUU30	Games and agents	7.5	a
		***Seminars**[3]*		
4	2IMS00	Seminar information security technology	5	a
4	2IMA00	Seminar algorithms[6]	5	a
6	2IMG00	Seminar applied geometric algorithms	5	a
6	2IMI00	Seminar architecture of information systems	5	a
6	2IMW00	Seminar web engineering	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**[4]*		
	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
	2IMN05	Capita selecta systems architecture and networking	5	a
	2IMV05	Capita selecta visualization	5	a
	2IMW05	Capita selecta web engineering	5	a
	2IMI05	Capita selecta architecture of information systems	5	a
	2IMC10	Internship[5]	15	a

[1] *Intended for foreign students, and for students who have completed a polytechnic (HBO) programme of computer science.*

[2] *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.*

[3] *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.*

[4] *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.*

[5] *The internship can be followed only after having obtained permission of the internship coordinator.*

[6] *The Seminar algorithms is given in quarter 4 only in 2015-2016. After this academic year it moves to quarter 6 like most other seminars.*

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.

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. 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 1.10). The form must be accompanied by a project description and signed by you, your supervisor, the head of the relevant specialization and the study 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 credit points (whichever is lower) have not been completed, such permission will not be granted. In other cases (no more than two courses or 10 credit points 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 study advisor.

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 graduation regulations can be found on the website.

3.4.3 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 website.

3.4.4 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 (DSE) 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 actionalble 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 DSE 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 DSE master associated with either the CSE or the IAM master diploma. This document only describes the Computer Science stream of the DSE 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 study 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 not 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 DSE 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 1.5, 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 DSE

- 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 2015

The Master track Data Science in 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 DSE curriculum contains courses from computer science and mathematics (and optional courses also from industrial engineering). The DSE curriculum is structured in *streams*, which provide an organized set of courses in particular subject areas within data science. This document only covers the computer science stream which leads to a diploma of CSE.

The overall structure of the DSE master is summarized in the following table.

Units	ECTS
Mandatory and core courses	30
DSE-specific electives	15
Free electives	40
Seminar	5
Master project	30

The following table lists the mandatory courses, core courses, seminar and master project with their scheduling information.

Quarter	Code	Unit	ECTS	Exam
(3) Mandatory and (3 out of 4) Core courses			*65*	
1	2IMA10	Advanced algorithms (core)	5	w+a
1	2IMW15	Web information retrieval and data mining (core)	5	w+a
1-2	2MMR10	Professional Portfolio (mandatory)	5	a
2	2IMV20	Visualization (core)	5	a
2	2MMS20	Statistics for big data(mandatory)[1]	5	w
3	2DI70	Statistical learning theory (mandatory)	5	w+a
4	2IMI20	Advanced process mining (core)	5	w+a
4 or 6		**Seminar** [2]	5	a
7 and 8	2IMC00	**Master project** [3]	30	a

[1] *2MMS20 Statistics for Big Data is not mandatory for students that started in 2015-2016 and have followed all four core courses.*

[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. If you enroll in February, the seminars are effectively in the fourth quartile of your study.*

[3] *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.*

Note that the Professional Portfolio course in the DSE program is a course shared by the computer science and the mathematics version (stream) of the Data Science in Engineering master and it taken from the Industrial and Applied Mathematics master. It consists of lectures during quarter 1 and 2 and a "Modeling Week" with a "Data Challenge" assignment. In the modeling week and data challenge students

- gain experience in solving real-life problems
- should report back their findings to the problem owner
- learn to work in groups/teams
- learn how to capture the essence of a practical problem in terms of a mathematical model
- learn how to extract value from mathematical modelling
- develop a professional attitude when dealing with problems

Every DSE (CS) student must take at least three courses from the list of DSE elective courses below. (Additional core courses from the list above may also be chosen.) It is recommended to take more than three but the remaining credit points may also be taken with courses from the CSE program or from any other master program at the TU/e.

Quarter	Code	Unit	ECTS	Exam
DSE elective courses				*15*
1	1BM05	Business process Management	5	w
1	2IMV25	Interactive virtual environments	5	a
1	2IMS25	Principles of Data Protection	5	w+a
1	2MMS10	Probability and stochastics 1	5	w?
2	2MMS30	Probability and stochastics 2	5	?
3	2IMI30	Business process simulation	5	a
3	1BM56	Business intelligence	5	w+a
3	2IMA20	Algorithms for geographic data	5	a
3	2IMV10	Visual computing project	5	a
3	2IMW10	Data engineering	5	w+a
3	2IMW30	Foundations of Data Mining	5	w+a
4	2IMV15	Simulation in Computer Graphics	5	a
4	2DD23	Time-series analysis & forecasting	5	a+o
4	5P480	Knowledge systems and applications	4	o
4	0EM110	Research Methodology for the Innovation Sciences	5	a
4	2IMW20	Database technology	5	w+a
4	5N520	Statistical bioinformatics	2	w
Free electives				*40*

[1] *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.*

[2] *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] *You have to choose at least 25 credit points from this list*

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.

Some 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 1.8. (This does not apply to students taking the teacher training.)

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. 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 1.10). The form must be accompanied by a project description and signed by you, your supervisor, the head of the relevant specialization and the study 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 credit points (whichever is lower) have not been completed, such permission will not be granted. In other cases (no more than two courses or 10 credit points 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 study advisor.

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 graduation regulations can be found on the website.

4.4.3 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 website.

4.4.4 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 DSE 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 DSE master. The TU/e strives to have this become sufficient to obtain a teaching qualification without doing a double degree DSE 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 program is a joint master program between the TU/e and the Radboud University (RU). These universities have joined their forces with respect to security education. This joint master program is called the "TRU/e Master in Cyber Security" (see `http://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 study 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, he or she 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;

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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 1.5, 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 2015

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. It is only possible to enter the program in September. 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

5.3.1 Core program

The mandatory part of the program contains the following courses:

Quarter	Code	Unit	ECTS	Exam	Location
1	2MMC10	Cryptology	5	w+a	Eindhoven
1	2IMS25	Principles of Data Protection	5	w	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+a	Eindhoven
3-4	2IRU25	Advanced network security	5	w+a	Nijmegen
3-4	2IRU30	Privacy seminar *	6	a	Nijmegen
4	2IMS00	Seminar Information Security Technology *	5	a	Eindhoven
7-8	2IMC00	Master project **	30		

*) Either 2IRU30 or 2IMS00 should be followed but not both. **) 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 credits 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	ECTS	Exam	Location
1-2	2IRU35	Law in cyberspace	6	w+a	Nijmegen
2	2IMS20	Hacker's hut	5	a	Eindhoven
2	2DMI10	Applied cryptography	5	a	Eindhoven
3	2DMI00	Cryptographic protocols	5	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.

Some 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 1.8. (This does not apply to students taking the teacher training.)

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 1.10). The form must be accompanied by a project description and signed by you, your supervisor, the head of the relevant specialization and the study 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 credit points (whichever is lower) have not been completed, such permission will not be granted. In other cases (no more than two courses or 10 credit points 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 study advisor.

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 graduation regulations can be found on the website.

5.4.3 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 website.

5.4.4 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 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 and application of quality business information systems and technology for 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 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 study 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

A Bachelor degree in Computer Science or in Industrial Engineering obtained at a Dutch university provides direct admission to the BIS 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.

The admission procedure is described in Section 1.5, and the requirements are listed in the Teaching and Examination Regulations (see Appendix A.2).

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 2015

The Master program Business Information Systems 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 in either semester; however, starting in September is preferred. The program is full time.

The BIS curriculum is structured in *streams*, which provide an organized set of courses in particular subject areas within computer science and industrial engineering. 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 BIS master you should choose a stream right away because this determines the list of stream electives and the assignment of a mentor. The streams are:

- Logistics
- Information management

- Business process intelligence

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

Units	ECTS
Mandatory courses	30
Stream electives	20
Free electives	40
Master project	30

The above table shows that there is great flexibility in defining your individual study program fas there are 35 credits in free electives. Within this part you should include 15 credit points in international experience if you do not yet have that 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.

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	5	a
3	2IMI10	Business process management systems	5	w+a
4	2IMW20	Database technology	5	w+a

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.

Logistics. The logistics stream is aimed at students interested in logistical systems, not only from an managerial, but also from a mathematical point of view. Topics that are addressed are accounting and finance, supply chain management, constraint-based optimization and distributed systems. The goal of this stream is for students not only to understand the complexity of logistical systems, but also to be able to develop solution architectures for supporting logistical systems while focusing on optimality of the provided solutions.

Information Management. 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.

Business Process Intelligence. The business process intelligence stream aims at the more technical side of business information systems. The focus of this stream is on the analysis of

models and other sources of information such as event logs, using techniques and insights from metamodelling, process mining, visualization, and business intelligence.

The stream courses can be found in the table below.

Quarter	Code	Unit	ECTS	Exam
		Business Process Intelligence		
1	2IMW15	Web information retrieval and data mining	5	w+a
2	2IMV20	Visualization	5	a
3	1BM56	Business intelligence	5	w+a
4	2IMI20	Advanced process mining	5	w+a
		Information Management		
1	2IMI15	Metamodelling and interoperability	5	w+a
2	1BM70	Healthcare business networks	5	a+o
4	1BM65	IT-governance	5	w+a
4	1BM20	Software requirements management	5	w+a
		Logistics		
1	2IMI25	Constraint programming	5	a
2	2DI66	Advanced simulation	5	a
3	1CM22	Integrated financial & operations management	5	w
4	1CM100	Multi-Echelon Inventory Management	5	w+a

6.3.2 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 addition to the courses from this list we also recommend 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 lists given 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.

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. 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 1.8. (This does not apply to students taking the teacher training.)

Quarter	Code	Unit	ECTS	Exam
1	0LM120	Perspectives on medical technology	5	o
1	2IMN10	Architecture of distributed systems	5	w+a
1	1CM120	Advanced Maintenance and Service Logistics	5	w
2	1ZM20	Technology enterpreneurship	5	w+a
continued on next page				

Quarter	Code	Unit	ECTS	Exam
		continued from previous page		
2	2IMV20	Visualization	5	a
2	2IMP10	Program verification techniques	5	w+a
2	1CM40	Retail operations	5	w+a
2	1CM10	Modeling and analysis of manufacturing systems	5	a
3	2IMW30	Foundations of data mining	5	w+a
3	1CM36	Game theory with applications to supply chain management	5	w
4	2IMW25	Adaptive web-based systems	5	w+a
4	1CM05	Design of operations planning and control systems	5	a
4	2IMP20	Generic language technology	5	w+a
		Seminars[3]		
4	2IMS00	Seminar information security technology	5	a
4	2IMA00	Seminar algorithms[4]	5	a
6	2IMG00	Seminar applied geometric algorithms	5	a
6	2IMW00	Seminar web engineering	5	a
6	2IMI00	Seminar architecture of information systems	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
	1BM95	Literature study for BIS-students[1]	5	a
		Capita selecta[2]		
	2IMS05	Capita selecta security	5	a
	2IMW05	Capita web engineering	5	a
	2IMF05	Capita selecta formal system analysis	5	a
	2IMI05	Capita selecta architecture of information systems	5	a
	2IMA05	Capita selecta algorithms	5	a
	2IMG05	Capita selecta applied geometric algorithms	5	a
	2IMN05	Capita selecta systems architecture and networking	5	a
	2IMP05	Capita selecta software engineering and technology	5	a
	2IMV05	Capita selecta visualization	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.

[4] The Seminar algorithms is given in quarter 4 only in 2015-2016. After this academic year it moves to quarter 6 like most other seminars.

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	ECTS	Exam
2	2DI60	Stochastic operations research	5	w

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

Quarter	Code	Unit	ECTS	Exam
1	2IBP90	Programming	5	w+a

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 8.1 and Section 8.2, 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 1.10). The form must be accompanied by a project description and signed by you, your supervisor, the head of the relevant specialization and the study 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 credit points (whichever is lower) have not been completed, such permission will not be granted. In other cases (no more than two courses or 10 credit points 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 study advisor.

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 graduation regulations can be found on the website.

6.4.3 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 website.

6.4.4 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.

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 study 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 7.4). 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.

The Embedded Systems program focuses on the design of efficient and reliable systems. In order 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 masters degree program in Embedded Systems is a joint program of the 3TU federation. The programs offered at each location share the common core part (25 credits). Furthermore, some specialisation courses are exchanged by 3TU telefacilities.

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 2.5.

The admission procedure is described in Section 1.5, and the requirements are listed in the Teaching and Examination Regulations (see Appendix A.3).

7.2 Learning outcomes

Graduates from the Embedded Systems master program

- are qualified to degree level in the domain of science, engineering and technology;
- are capable of acquiring knowledge independently;
- are capable of critical thinking, can reason logically and form opinions;
- have design skills, presentation skills, and communication skills;
- have a holistic view on embedded systems, their development, and their embedding in larger systems;
- are able to master complex embedded systems;
- can describe and study structure and behaviour of embedded systems;
- possess knowledge of contemporary techniques;
- are proficient in the Design of embedded systems;
- possess knowledge of requirement engineering, modelling, testing and implementation techniques;
- have a flexible and inquisitive mind with regard to developments in the field;
- invent own specific tools, theories and techniques if unavailable;
- are aware of their own position and that of embedded systems in society;
- can present and communicate their ideas and visions on embedded systems;
- can work in a multidisciplinary design team.

7.3 Curriculum 2015

The Master program Embedded Systems 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 curriculum consists of courses offered by the Computer Science division of the department Mathematics and Computer Science and the department of Electrical Engineering This section describes the curriculum at the TU/e; the programs of the two partner universities can be found in the program guides of the TUDelft and the University of Twente.

The ES curriculum is structured in *streams*, which provide an organized set of courses in particular subject areas within Embedded Systems. The purpose of 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 ES study program.

When you enroll to the ES master you should choose a stream right away because this determines the list of stream courses and the assignment of a mentor. The streams are:

- Systems on Chip
- Embedded Software
- Embedded Networking
- Cyber-Physical Systems

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

Units	ECTS
Mandatory courses	25
Stream courses	15
Stream electives	20
Free electives	20
Master thesis preparation	10
Master project	30

Each stream has a three mandatory courses, and a selected set of elective courses from which at least 20 credit points should be chosen. The remaining part of your individual study program can be used for free electives, i.e., courses taken from any master program offered at the TU/e. We give some recommendations in Section 7.3.6. In addition you may also choose courses from the ES programs in Delft or Twente, 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. Within your study program you should include 15 credit points in international experience if you do not yet have that and are not 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. 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	ECTS	Exam
1	2IMF30	System Validation	5	w+a
2	5SIA0	Embedded Computer Architecture	5	a+o
2	2IMN25	Quantitative Evaluation of Embedded Systems	5	w+a
3	2IMN20	Real-time Systems	5	w+a
4	5LIB0	Embedded Systems Laboratory	5	a+o
5-6	2IMC05/5T514	**Preparation graduation project ES**[1]	10	a
7-8		**Master thesis project**	30	

[1] *Preparation for graduation project ES consists of a literature survey and feasibility study for the graduation project. The preparation has to be finished and graded before the start of the final project.*

7.3.2 Systems on Chip stream

Modern chips are rapidly evolving into complete systems on chip (SoCs). Heterogeneous SoCs with one or more general-purpose embedded processors (e.g., ARM cores), dedicated accelerators, reconfigurable fabric, and advanced memory and interconnect structures are typically used in devices where energy efficiency and performance are both important. Homogeneous SoCs are characterized by replication of regular structures, leading to multi- and many-core architectures that target high-performance computing. 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.

Quarter	Code	Unit	ECTS	Exam
Mandatory courses				*65*
1	2IMF20	Hardware verification	5	w+a
3	5LIE0	Multiprocessors	5	a+o
4	5LID0	Systems on silicon	5	w+a
Stream electives [1]				*25*
1	5LIN0	Video processing	5	?
1	5LIL0	Intelligent architectures	5	?
2	5LIH0	Digital integrated circuit design	5	?
2	5LIF0	Advanced digital circuit design	5	?
2	2IMF25	Automated reasoning	5	w+a
2	2IMNT1	Embedded computer architectures 2	5	w+a
2	5KK07	Energy efficient embedded systems	5	?
2	5LIG0	Applied combinatorial algorithms	5	?
3	5LIM0	Parallelism, compilers and platforms	5	?
3	5SIB0	Electronic design automation	5	?
3	5LIJ0	Embedded control systems	5	?
4	2IMN35	VLSI programming	5	a
6	2IMF00	Seminar formal system analysis	5	a

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

7.3.3 Embedded Software stream

The behaviour and functionality of embedded systems is largely determined by the software that it runs. This software must be of excellent quality because embedded systems must often perform safety critical tasks without human supervision for long periods of time with guaranteed performance. Parallelism (in tasks, data and instructions), distribution, and reactivity pose additional challenges. As the software generally outlives the hardware, the software must be such that it is easily maintainable and adaptable to always changing circumstances. Model-driven design, formal proof and advanced code generation techniques are very important to achieve this.

Quarter	Code	Unit	ECTS	Exam
Mandatory courses				**65**
2	2IMF25	Automated reasoning	5	w+a
3	5LIM0	Parallelism, compilers and platforms	5	?
4	2IMP20	Generic language technology	5	w+a
Stream electives [1]				**25**
1	5LIN0	Video processing	5	?
1	2IMN10	Architecture of distributed systems	5	w+a
1	2IMA10	Advanced algorithms	5	w+a
1	5LIL0	Intelligent architectures	5	?
2	2IMP10	Program verification techniques	5	w+a
2	5LIG0	Applied combinatorial algorithms	5	?
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	?
4	2IMN35	VLSI programming	5	a
4	2IMNT2	Real-time software development	5	a
4	5LIK0	Embedded signal processing systems	5	?
6	2IMF00	Seminar formal system analysis	5	a
6	2IMN00	Seminar systems architecture and networking	5	a

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

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.

Quarter	Code	Unit	ECTS	Exam
Mandatory courses				**65**
1	2IMN10	Architecture of distributed systems	5	w+a
1	5LIC0	Networked embedded systems	5	a+o
2	2IMN15	Internet of things	5	?
continued on next page				

Quarter	Code	Unit	ECTS	Exam
continued from previous page				
Stream electives [1]				**25**
1	2IMA10	Advanced algorithms	5	w+a
1	2IMN30	Grid and cloud computing	5	a
1	2IMF20	Hardware verification	5	w+a
2	5LIH0	Digital integrated circuit design	5	?
2	5LIF0	Advanced digital circuit design	5	?
2	2IMF25	Automated reasoning	5	w+a
2	5KK07	Energy efficient embedded systems	5	?
2	2IMS20	Hacker's hut	5	a
3	5SIB0	Electronic design automation	5	?
3	2IMS15	Verification of security protocols	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	?
6	2IMF00	Seminar formal system analysis	5	a
6	2IMN00	Seminar systems architecture and networking	5	a

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

7.3.5 Cyber-Physical Systems stream

Cyber-Physical Systems (CPS) are characterized by a tight coupling between embedded computer (cyber) systems and physical processes, monitored and controlled by those computer systems. Next generation embedded systems in automotive, professional printing, electron microscopy, semiconductor lithography, and medical imaging, are rapidly evolving into CPS. CPS require integral, multidisciplinary design, involving computer engineering, control, mechatronics, networking, signal processing, and mathematical modeling. Embedded-system design needs to take into account constraints and requirements from other domains; cross-domain design paradigms are needed to optimize the embedded system in combination with the monitored and controlled system.

Quarter	Code	Unit	ECTS	Exam
Mandatory courses				**65**
2	2IMN15	Internet of things	5	?
3	5LIJ0	Embedded control systems	5	?
4	5LIK0	Embedded signal processing systems	5	?
Stream electives [1]				**25**
1	2IMN10	Architecture of distributed systems	5	w+a
1	2IMA10	Advanced algorithms	5	w+a
1	2IMN30	Grid and cloud computing	5	a
1	5LIC0	Networked embedded systems	5	a+o
1	5LIL0	Intelligent architectures	5	?
1	2IMF20	Hardware verification	5	w+a
2	5LIF0	Advanced digital circuit design	5	?
2	2IMNT1	Embedded computer architectures 2	5	w+a
2	5LIG0	Applied combinatorial algorithms	5	?
continued on next page				

Quarter	Code	Unit	ECTS	Exam
continued from previous page				
3	2IMP25	Software evolution	5	a
3	5LIE0	Multiprocessors	5	a+o
3	5LIM0	Parallelism, compilers and platforms	5	?
3	5SIB0	Electronic design automation	5	?
4	2IMP20	Generic language technology	5	w+a
4	5LIA0	Embedded visual control	5	a
4	2IMN35	VLSI programming	5	a
4	2IMNT2	Real-time software development	5	a

[1] *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. 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 10 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 1.8.

7.3.7 Homologation units

Students entering Embedded Systems program have very diverse backgrounds. When you are admitted to the program, or directly at the start of the program, it will be evaluated to what extent you satisfy the BSc-level knowledge and skills required for the Embedded Systems master program in general, and the stream of your choice in particular. Deficiencies should be repaired by taking one or more homologation modules. Homologation packages may consist of one or more homologation modules and may comprise at most 10 EC in total. The credits obtained for homologation modules will count as free electives in your study program. We may prescribe homologation modules, depending on your background knowledge and skills and the stream of your choice.

We will offer the homologation modules below. You will generally be expected to do the homologation modules by self-study, with some guidance by a responsible lecturer. In most cases, the homologation modules are associated with existing BSc-level courses, so that you can attend lectures, tutorials and lab sessions if needed.

Quarter	Code	Unit	ECTS
1	5LFK0	Circuit analysis	2.5
1	5LIQ0	Linear Systems, signals and control	2.5
1	5LIS0	Embedded programming in C/C++	2.5
1	2IHT10	Logic and set theory	2.5
1	5LIP0	Digital integrated circuits: fundamentals	2.5
2	5LIR0	DBL Linear Systems, signals and control	2.5
3	2IHS10	Software specification	2.5

If you feel that you lack knowledge and skills not addressed by one of the homologation modules above, then contact the study advisor.

7.3.8 Seminars, Internship and multi-disciplinary design project

Since the master project can already 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 1.8 for details on internships. Instead of an internship, a multi-disciplinary design project (code 2IW70 or 5KK05) 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	ECTS	Exam
		Seminars		
4	2IMS00	Seminar information security technology	5	a
4	2IMA00	Seminar algorithms[3]	5	a
6	2IMG00	Seminar applied geometric algorithms	5	a
6	2IMW00	Seminar web engineering	5	a
6	2IMI00	Seminar architecture of information systems	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	2IMA00	Seminar algorithms	5	a
		Capita Selecta		
	2IMS05	Capita selecta security	5	a
	2IMW05	Capita selecta web engineering	5	a
	2IMF05	Capita selecta formal system analysis	5	a
	2IMI05	Capita selecta architecture of information systems	5	a
	2IMA05	Capita selecta algorithms	5	a
	2IMN05	Capita selecta systems architecture and networking	5	a

Quarter	Code	Unit	ECTS	Exam
		continued from previous page		
	2IMP05	Capita selecta software engineering and technology	5	a
	2IMV05	Capita selecta visualization	5	a
		Internship / Multi-disciplinary design project (second year)		
	2IMC10/5L990	Internship[2]	15	a
	2IMC25/5KK05	Multi-disciplinary design project[4]	10	a

[1] *Offered as a tele-lecture by Delft University of Technology.*

[2] *Note that only one of these may be chosen, and that the Internship requires permission of the coordinator. See Section 1.8 for the details.*

[3] *The Seminar algorithms is given in quarter 4 only in 2015-2016. After this academic year it moves to quarter 6 like most other seminars.*

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 8.1 and Section 8.3, 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.

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 1.10) 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 study 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 credit points (whichever is lower) have not been completed, such permission will not be granted. In other cases (no more than two courses or 10 credit points 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 study advisor.

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 graduation regulations can be found on the website.

7.4.3 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 website.

7.4.4 Checklist

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

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8
Research groups

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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.

8.1 Research groups in the CS department

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

8.1.1 Algorithms

Contact person: prof. Mark de Berg

The creation, storage, analysis and manipulation of spatial data plays a central role in robotics, computer graphics, geographical information systems, and other areas of computer science. In all these areas, there are many challenging algorithmic questions. For example, a typical problem in robotics is to compute efficient routes for a robot moving through a factory building while avoiding all obstacles in its way. A typical problem in geographic information systems could be to find a good location of a new airfield, say the location such that the region in a 20-mile radius around it is the least populated. Such problems form the focus of this specialization: we study techniques and concepts for the design and analysis of efficient algorithms and data structures, with emphasis on algorithms for spatial data. Typical master projects are either experimental or theoretical in nature, depending on the interests of the student.

Relevant courses are:

- ▶ Algorithms for geographic data (2IMA20)

- ▶ Advanced algorithms (2IMA10)
- ▶ Geometric algorithms (2IMA15)
- ▶ Seminar algorithms (2IMA00)
- ▶ Capita selecta algorithms (2IMA05)

Other relevant courses:

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

8.1.2 Applied Geometric Algorithms

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 nonspatial 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 (2IMA20)
- ▶ Advanced algorithms (2IMA10)
- ▶ Geometric algorithms (2IMA15)
- ▶ Seminar applied geometric algorithms (2IMG00)
- ▶ Capita selecta applied geometric algorithms (2IMG05)

Other relevant courses:

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

8.1.3 Architecture of Information Systems

Contact person: dr. Natalia Sidorova

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)
▶ Contraint programming (2IMI25)
▶ Business process simulation (2IMI30)
▶ Seminar architecture of information systems (2IMI00)
▶ Capita selecta architecture of information systems (2IMI05)

8.1.4 Formal System Analysis

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)

8.1.5 System Architecture and Networking

Contact person: dr. Rudolf Mak

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.

Relevant courses are:

- ▶ Real-time systems (2IMN20)
- ▶ Architecture of distributed systems (2IMN10)
- ▶ VLSI programming (2IMN35)

- ▶ 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)
- ▶ Adaptive web-based systems (2IMW25)
- ▶ Seminar information security technology (2IMS00)
- ▶ Principles of data protection (2IMS25)
- ▶ Web-based interactive systems (2IMW30)
- ▶ Advanced algorithms (2IMA10)
- ▶ Generic language technology (2IMP20)
- ▶ System validation (2IMF30)

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 and, more recently, lighting. 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.

8.1.6 Security

Contact person: prof. Sandro Etalle

The interconnectivity and pervasiveness of computers and of embedded systems like PDAs and smart phones is not only determining new functionalities, but is also opening the way to increasingly sophisticated attacks. Indeed, in the last years the field of security has become one of the main focuses of computer science research around the globe. The recently established security group aims at contributing to a comprehensive framework for the engineering, the deployment and the maintenance of secure distributed systems, in which existing and new techniques are harmonized and integrated. The group focuses on distributed system security: a broad area that deals with the security of embedded systems as well as of the ICT infrastructures. Prominent subfields are: the specification and the enforcement of usage policies of critical systems, verification of security protocols, trust management.

The group cooperates actively with the Radboud University in the TRU/e cyber security master.

Relevant courses are:

- ▶ Seminar information security technology (2IMS00)

- ▶ Verification of security protocols (2IMS15)
- ▶ Principles of data protection (2IMS25)
- ▶ Hacker's hut (2IMS20)
- ▶ Cryptology (2MMC10)
- ▶ Cryptographic Protocols (2DMI00)
- ▶ Applied Cryptography (2DMI10)
- ▶ Physical aspects of digital security (2IMS10)
- ▶ Software evolution (2IMP25)

8.1.7 Software Engineering and Technology

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)
- ▶ Seminar Software Engineering and Technology (2IMP00)
- ▶ Capita Selecta Software Engineering and Technology (2IMP05)
- ▶ Architecture of distributed systems (2IMN10)
- ▶ Foundations of Data Mining (2IMW30)

8.1.8 Visualization

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 (2IMW15)

8.1.9 Web engineering

Contact person: prof. Paul De Bra

The focus of WE is on the study of concepts and technologies that are used to store, access, manage and retrieve information. Information often comes from several sources that each

contain a wealth of information of which only a small subset is of interest to any particular user or user group.

- Database systems are needed to store, maintain, and efficiently query the data; data can come in different flavors from unstructured text-data, semi-structured XML data to structured databases;

- Datamining 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.

- Adaptation, or automatic personalization, must ensure that each user is guided (automatically) to the information that is relevant to him or her, resulting in Adaptive Hypermedia systems. Adaptive Hypermedia is studied at the conceptual and the practical level: the former is done through the study of Adaptive Hypermedia Reference Models, the latter through the development of the "Generic Adaptation Language and Engine" GALE, a general-purpose web-based adaptive hypermedia system.

The WE group focuses research in these overlapping domains aimed at the efficient disclosure of large data repositories in a user-friendly manner, and on the extraction of knowledge (and value) from data.

Relevant courses are:

- ▶ Web information retrieval and data mining (2IMW15)
- ▶ Foundations of Data Mining (2IMW30)
- ▶ Database technology (2IMW20)
- ▶ Data Engineering (2IMW10)
- ▶ Adaptive web-based systems (2IMW25)
- ▶ Capita selecta web engineering (2IMW05)
- ▶ Seminar web engineering (2IMW00)

8.2 Research groups 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 8.1. In addition, a project is possible in two research groups in the IE&IS department.

8.2.1 Information Systems (IE&IS-IS)

Contact person: dr.ir. Jos Trienekens

The specializations of the Information Systems group are as follows:

- Architecture/EIS. The cluster addresses research topics that deal with design of enterprise information systems at a high level of abstraction.

- Business Process Management. The research 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.

- Cross-Organizational Information Systems. Within the cluster a number of topics related to cross-organizational information systems is being investigated.
- Process Mining. Research is concerned with the extraction of knowledge about a (business) process from its process execution logs. Process Mining strives to gain insight into various perspectives, such as the process (or control flow) perspective, the performance, data, and organizational perspective.
- Software Management. The Software Management cluster focuses on topics related to the development and implementation of (embedded) software and information systems.
- Healthcare. The focus of the Healthcare cluster is on the application of information systems in the healthcare domain, in particular to improve the safety, effectiveness, and efficiency of operational processes within and across hospitals, health and treatment centers, private clinics, and other medical institutes.

For more information see `http://w3.ieis.tue.nl/en/groups/is/`

8.2.2 Operations, Planning, Accounting, and Control (IE&IS-OPAC)

Contact person: dr.ir. Henny van Ooijen

The sub-department Operations, Planning, Accounting, and Control performs research into the control of operational processes in service and manufacturing industries. Operational processes can be manufacturing processes of all kinds, distribution processes, transportation processes, warehouse processes, retail processes, but also service processes like maintenance of equipment, health care processes and public transportation.

There are four research programs within OPAC:

- Capital Goods
- Physical Distribution and Logistics Management
- Process Industry Operations
- Healthcare Operations

For more information see `http://w3.ieis.tue.nl/en/groups/opac/` or contact h.p.g.v.ooijen@tue.nl.

8.3 Research groups 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 8.1. In addition, a project is possible in the EE department.

8.3.1 Electronic systems

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:

- ▶ Combinatorial algorithms (5MC10)
- ▶ Computer architecture (5MD00)
- ▶ Design automation (5MD20)
- ▶ Signal processing for communication (5ME00)
- ▶ Video processing for multimedia systems (5P530)

9

EIT Tracks

EIT ICT Labs 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 ICT Labs 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 ICT Labs 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 ICT Labs certificate, documenting the EIT ICT Labs specific learning outcomes on Innovation and Entrepreneurship.

Three tracks

Eindhoven University of Technology offers three 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.
Service Design and Engineering:	This program will provide both the technical competence and the entrepreneurial and innovative skills needed for a successful business in the area of service design and engineering.
	At the TU/e this track leads to a degree in Business Information Systems.

9.1 Service Design and Engineering

The Master program on Service Design and Engineering (SDE) is a two-year Master program organized in the context of the EIT ICT Labs Master School. It provides both the technical competence for the design and engineering of services and skills in the area of entrepreneurship and innovation.

The first year is common for all SDE students and consists of technical courses in areas important for SDE (e.g., information systems, distributed systems, business process management and software engineering). It also includes an extensive module on entrepreneurship and innovation.

For the second year, you choose one of the following specializations: Mobile Services, Service-oriented Business Process Management, Service-oriented Social Informatics, and Distributed Service Systems.

A distinctive feature of the program is that you study at two universities in two different countries. The first year is offered at Aalto University (Finland). The university at which you do the second-year specialization, depends on the specialization of your choice:

- The specialization on Mobile Services is offered by Aalto University.
- The specialization on Service-oriented Business Process Management is offered by Eindhoven University of Technology.
- The specialization on Service-oriented Social Informatics is offered by University of Trento.
- The specialization on Distributed Service Systems is offered by a collaboration of two universities in Budapest.

The university at which you do the first year of the program is called the entry point; the university at which you do the second year specialization is called the exit point.

For details about the other specializations we refer to the website of the EIT ICT Labs Master School: http://eitictlabs.masterschool.eu/.

9.1.1 Goals

The general learning outcomes of the programme are:

- Identify and master appropriate software technologies, architectures and systems related to service-oriented computing.
- Relate business insights and behavioral, legal, and societal expertise in modern information systems and services.
- Analyze the user and organizational needs for services and their decomposition.
- Analyze different service-oriented computing approaches and open standards.
- Relate technology skills (e.g. communication, knowledge integration, engineering systems) with strategic business expertise in practicable technology and business opportunities.
- Model, design and integrate software intensive service applications and information systems considering various stakeholder requirements, their potential evolution as well as scalability, usability and security dimensions.
- Communicate complex and intangible challenges and solutions in an explicit and concrete manner with diverse professional experts.
- Co-operate in international and multidisciplinary teams and apply expertise from diverse competence domains and cultures to construct and develop concrete solutions.
- Apply state-of-the-art theories in service science in real enterprise experiences.
- Propose novel and innovative services with sustainable business models.

9.1.2 Entry point program

This program is not offered by the TU/e.

9.1.3 Exit point program

The TU/e offers an exit-point programme with a specialisation in the direction of Service-oriented Business Process Management. The specialisation will be organised by the Architecture of Information Systems group. The following table summarises the programme:

Quarter	Code	Unit	ECTS
1	1BM10	Electronic business	5
1	2IMI15	Metamodeling and interoperability	5
1	2IIC0	Business information systems	5
2	1BM05	Business process management	5
2	1BM41	Business information systems architecture	5
2-4	1ZS30	**Innovation and entrepreneurship thesis**	6
3-4	2IMC00/1BM91	**Master project**	30

Master project

The Master project will be carried out within one of the EIT ICT Labs business partners Philips and Novay. TU/e participates, together with Philips, in a research-to-business project Service Spaces for Health and Wellbeing. Together with Philips we will define graduation projects associated with that project. Note that the role of service spaces for health and wellbeing will also be addressed in the course 2IMI15 Metamodeling and Interoperability.

9.2 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.

Graduation options

The EIT 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

9.2.1 Goals

The general learning outcomes of the programme are:

- The graduate has a holistic, system-based and multi-disciplinary view on embedded systems, their development and their integration. She is able to formulate abstract views to understand embedded systems of great complexity. She is able to describe and study the structure and the behaviour of embedded systems with respect to both functional and non-functional behaviour, e.g., resource usage and dependability.
- The graduate has a thorough knowledge of contemporary techniques to realise embedded systems. She has sufficient academic background to understand and apply techniques that will become available within the next decades.
- The graduate has a sufficient basis for designing embedded systems at the required level of quality, or assessing feasibility. This supposes knowledge of requirement engineering, performance analysis, validation and testing, and implementation techniques. She is familiar with a range of realisation platforms, ranging from software to direct realisation in silicon. She knows of the life span of embedded systems, and of the role of architectures in this field. She is aware of costs and environmental issues, and capable of making optimal use of the available means.
- The graduate has a flexible and inquisitive mind. She understands the theories, techniques and tools in this field in such a way that she is able to adapt these to fit their purpose optimally. She is able to invent his own tools, theories and techniques if these are not available.
- The graduate is aware of her position and that of the embedded systems she constructs in society. She is aware of and has a responsible attitude concerning the impact of new technology on the economy, the environment, and the daily life of citizens. She is able to present and communicate her ideas and visions in a clear and concise way. She is also able to work in multidisciplinary design teams, a competence the industrial field of embedded systems is in great need of.
- The graduate has an understanding how technological innovations can be developed into successful business ideas. She is aware of the basic concepts of business organisation, product development, entrepreneurial finance, and market dynamics. She 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.

9.2.2 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
Technical common base			
continued on next page			

Quarter	Code	Unit	ECTS
continued from previous page			
1	2IMF30	System validation	5
2	5SIA0	Embedded computer architecture	5
2	2IMN25	Quantitative evaluation of embedded systems	5
3	2IMN20	Real-time systems	5
3	5LIM0	Parallelism, compilers and platforms	5
4	5LIB0	Embedded systems laboratory	5
Innovation & entrepreneurship module			
2	1ZM20	Technology entrepreneurship	5
3-4	1ZSM0	CTEM project	10
3-4	2IEIT0	Winter school	1
	2IEIT5	Summer school	4
Electives Embedded Systems			10
Electives Innovation & entrepreneurship			5

9.2.3 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
1	2IMN15	Internet of things	5
1	2IMN10	Architecture of distributed systems	5
1	5LIC0	Networked embedded systems	5
		Electives	10
	1ZS30	**Innovation and entrepreneurship thesis**	6
	2IMC00/5T746	**Master project**	30

Electives

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

9.3 Data Science

The EIT ICT Labs 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.

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

After being admitted to one of the entry nodes (TU/e, UPM Madrid or UNS Nice Sophia Antipolis), 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: Process Mining in High Tech Systems, Healthcare, Visual Analytics, or Big Software
- UPM Madrid: Internet of Things
- UNS Nice Sophia-Antipolis: Multimedia and Web Science for big data

9.3.1 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.

9.3.2 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
Technical common base			
1	2IMI35	Introduction to process mining[1]	5
continued on next page			

Quarter	Code	Unit	ECTS
continued from previous page			
1	2IMW15	Web information retrieval and data mining	5
1	2IMA10	Advanced Algorithms	5
2	2IMV20	Visualization	5
4	2MMS20	Statistics for Big Data	5
Core Electives			
2	2IMN15	Internet of Things	5
2	2IMA15	Geometric algorithms	5
3	2IMV10	Visual computing project	5
3	2IMA20	Algorithms for geographic data	5
3	2DI70	Statistical learning theory	5
Suggested Electives (on top of program)			
1	2MMS10	Probability and stochastics 1	5
1	2IMV25	Interactive virtual environments	5
1	2IMS25	Principles of Data Protection	5
2	2MMS30	Probability and stochastics 2	5
3	2IMI30	Business process simulation	5
3	2IMW30	Foundations of data mining	5
3	2IMW10	Data engineering	5
4	2IMV15	Simulation in Computer Graphics	5
4	2IMW20	Database technology	5
4	2DD23	Time-series analysis & forecasting	5
Innovation & entrepreneurship module			
2	1ZM20	Technology entrepreneurship	5
3-4	1ZSM0	CTEM project	10
3-4	2IEIT0	Winter school	1
	2IEIT5	Summer school	4
4	0LM150	Entrepreneurship and corporate social responsibility	5

[1] *Students who took the course 2IIE0 or 2IIF0 in their bachelor are not allowed to take 2IMI35 because of overlap.*

9.3.3 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
1	2IMI35	Introduction to process mining (if needed) [1]	5
1	2MMS10	Probability and stochastics 1 (if needed)	5
1	2IMS25	Principles of Data Protection	5
2	2IMI20	Advanced process mining	5
2	2IMI00	Seminar architecture of information systems, OR	5
2	2IMW00	Seminar web engineering	5
Alternatives for "if needed" courses			
1	2IMA10	Advanced algorithms	5
1	2IMW15	Web information retrieval and data mining	5
2	1ZS30	**Innovation and entrepreneurship thesis**	6
continued on next page			

Quarter	Code	Unit	ECTS
continued from previous page			
	2IMC00	**Master project**	30

[1] *Students who took the course 2IIE0 or 2IIF0 in their bachelor are not allowed to take 2IMI35 because of overlap.*

Part III

Organization and regulations

10
Academic administration

10.1 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).

10.1.1 Department Board of Mathematics and Computer Science

The Department Board appoints a study-program director for the graduate program, 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 education and examination regulations (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-dean and division chairs 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. de Vlieg
Vice-deans: prof.dr. M.G.J. van den Brand and prof.dr.ir. B. Koren
Managing director: drs. P.D.M. Groothuis

10.1.2 Study-program Director

Every year the study-program director outlines in the OER 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 in charge of the development and implementation of a quality management system. The Study-program Committee advises the study-program director on his curriculum and quality plans. 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. P.M.E. De Bra
Vice-director: dr. A. Serebrenik
Program manager CSE and DSE: dr. J. Schmaltz
Program manager BIS and SDE: dr.ir. B.F. van Dongen
Program manager ES and EIT-ES: dr. S.P. Luttik
Program manager IST: dr. B. Skoric
Program manager EIT-DS: dr. F. Heidari

10.1.3 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 OER
- to annually evaluate the implementation of the OER
- 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 EIT-SDE, for the BIS program, and for the ES program including the special track EIT-ES.

10.1.4 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 ms. J.M.L.G. Sanders.

10.1.5 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/`.

10.1.6 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.

Division secretary: ms. M.M.W.G. van den Bosch-Zaat, phone number 040 247 5010
Staff members: a complete list is available on the web site

10.1.7 Department Office

The Department Board delegates day-to-day operations to the Department Office. The managing director heads the Department Office, which is sub-divided into six offices:

- Human Resource Management (HRM) Office

- Financial Services Office
- Computer Services Office — BCF (MF 3.082)
- Management Support Office
- Education Office
- Public Relations

The managing director of the Department Office is drs. P.D.M. Groothuis.

Study advisors and Education secretariat:
Bachelor study advisors: dr. C.J. Bloo (MF 5.101)
                             dr. ir. N.V. Stash (MF 7.061)

Master study advisor: dr. J.P. Veltkamp (MF 5.102)
Secretarial services: (MF 5.104b)
                         ms. G.M. van der Linden
                         ms. C.C.H. Welten-Verhulst
                         ms. P.C.J. Gudden-van den Boomen

10.1.8 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. For the most recent meeting schedule, please refer to http://www.studentenraad.org
- 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 committee (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.

10.2 Facilities

10.2.1 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.

10.2.2 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 by ms. M. de Voogd, Auditorium 2.08, telephone number (040)(247) 2645 or on e-mail zaalreserveringen@tue.nl. 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.

10.2.3 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 8.00-22.30 h. and Saturday-Sunday 10.00-22.00 h. Even longer hours apply during examination periods. For all further information about TU/e Library service go to our website: `http://www.tue.nl/library`.

10.2.4 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.

10.2.5 Computer Services Office

The Computer service office (BCF) is part of the department office. BCF is located in MF 3.083. The BCF-helpdesk is open on working days from 9.00 until 17.00 hrs, tel. (040) (247) 2802, e-mail: `wshelp@win.tue.nl`, Website: `http://www.win.tue.nl/bcf`

The tasks of the Computer Service Office (BCF) are:

- to provide computer facilities;
- to provide user support;
- to administer student accounts on the student server svstud, a Linux-server for the students of the department;
- and to manage the use of computer rooms

Students can print at printers on the third floor. 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 `http://w3.win.tue.nl/en/education/regulations/`

For problems with student e-mail accounts, please contact the ICT Information and Service Desk at LG 1.94, telephone number (040)(247) 4649. The Notebooks Help Desk is located at MF 3.083, telephone number (040)(247) 2979.

10.2.6 Conditions for computer use

The use of all computer and network facilities is subject to the rules listed in the document "Computer- en netwerkgebruik in ruimten van de faculteit W&I" (Computer and Network Use in Rooms of the Department of Mathematics and Computer Science), which can be downloaded from http://www.win.tue.nl/bcf. A copy is also available for inspection in the Computer Services Office. 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 four free printers available: one on the fifth floor and the others on the tenth floor. Usage is monitored and any student printing more than five hundred pages in any one year will be asked to explain. His or her account will be blocked if usage remains excessive and will only be reactivated on payment of 20 euros. The department considers photocopying unnecessary. Students with a PAS account can use the university printers and photocopiers. The PAS card can be topped up at the Computer Services Office in Room MF 3.083.

Any problems or technical faults with hardware or software should be reported to the Computer Services Office, as should any infractions of the rules governing the use of the computer rooms, computers and networks.

10.3 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.

10.4 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. J.P. Veltkamp
- Student Administration in room MF 5.104b (inquiries desk) or at telephone number (040)(247) 2379, 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. More information can be found on website `http://w3.win.tue.nl/en/education`
- International students coordinator: E. van den Hurk in room MF 3.068, telephone number (040)(247) 2752 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.
- Information about education in computer science is available at `http://w3.win.tue.nl/en/education/`
- Video recordings of lectures: `http://videocollege.tue.nl/`

A

Teaching and Examination Regulations

A.1 CSE

Available at the website:

A.2 BIS

Available at the website:

A.3 ES

Available at the website:

B
Graduation checklist

Graduation timeline

Year 1 | Q1 | Q2 | Q3 | Q4

form 1 — compose individual study program

Year 2 | Q5 | Q6 | graduation project

submit graduation plan — form 2

other important steps and forms (see graduation checklist)
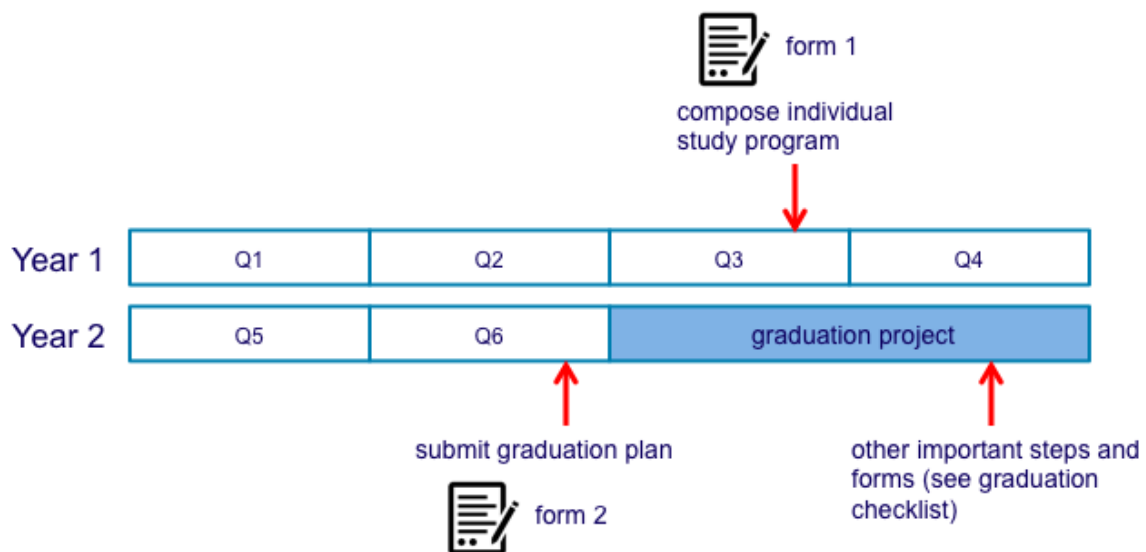
Months before you start the project

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. Submit a signed paper version at the student administration and a digital version (in Word-format, without signatures) to: studadm.win@tue.nl.

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

Register for the examination meeting at the latest four weeks in advance. Via `http://owinfo.tue.nl/`. In this meeting, the examinations committee determines whether or not you qualify for the diploma.

Compose the assessment committee at the latest 1 month before your final presentation.

Form 3: See the web version of this document.

The *graduation supervisor* must assemble the commitee according to the regulations, gather all the required signatures on the form, and submit it to the student administration.

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, your supervisor should submit your grade and an assessment report at the student administration.

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.

Send your graduation report (in PDF) by e-mail to the student administration at the latest 1 week before the examination meeting.

If your report should be confidential for 1 year or longer, have your supervisor indicate this on the graduation project assessment form. Also, if the report should be confidential for **more** than one year, you have to make both a public and confidential version. Both versions have to be submitted to the student administration.

After you completed your project

Fill out the graduation survey (only for CSE, BIS and ES students). You will get an e-mail with the link from the student administration.

Come to the **graduation ceremony**. You will get an e-mail with the invitation from the student administration.