Recommendations for Setting Up Consecutive Bachelor's and Master's Programs in Informatics at Universities

Resolution passed by the Plenary Session
of the German Council of Informatics Departments
(Fakultätentag Informatik, FTI)
in Cottbus on 19 November 2004

The Study Commission of the German Council of Informatics Departments (Franz-Josef Brandenburg, Passau; Hans Decker, Dortmund; Walter Dosch, Lübeck; Jürgen Ebert, Koblenz (Chair); Peter Forbrig, Rostock; Uwe Kastens, Paderborn; Helmuth Partsch, Ulm; Wolfgang Reisig, HU Berlin; Gerhard Zimmermann, Kaiserslautern) was asked to draw up recommendations for setting up **consecutive Bachelor's and Master's programs** in informatics (computer science). The Commission's initial draft version of these recommendations was sent to all informatics faculties/departments in summer 2004 with a request for comments. There was a substantial amount of feedback, especially from the informatics departments of the TU9 Group (German Institutes of Technology). A new, revised version taking into account the suggestions made was discussed and adopted at the Council's Plenary Session in Cottbus.

The idea was to develop a solution for **universities** only, i.e. it was expressly decided **not** to strive for comprehensive – e.g. *Gesellschaft für Informatik* – guidelines, which would require coordination between universities and universities of applied sciences (Fachhochschulen).

The recommendations are divided into three sections:

- General Recommendations for Introducing the Programs
- Educational Goals
  specifying the knowledge and skills that graduates of the consecutive programs can be expected to possess, and
- Course Content in the Bachelor's Programs
  giving an overview of the content of courses offered in the curriculum. There is no such list for the Master's programs because of the wide range of specializations offered there.

Section 1: General Recommendations

1. Preliminary Remarks

All the points made in this paper should be regarded as **recommendations**. It is **not** our intention to draw up a binding examination regulations framework.

The **objective** is to:

- **help** FTI members in the process of introducing consecutive Bachelor's and Master's programs
- **curb** the **proliferation of variants** in the study programs
- harmonize the practice at different universities and thus – as with the previous agreement on the mutual recognition of interim degrees – promote the **comparability** of informatics programs at German universities
- facilitate **accreditation.**

In many areas (e.g. specific details or prioritizations), there is **scope** for the faculties/departments to **develop their own profile**. There are also other differences due to the differing **regulations in Germany's various federal states** (e.g. regarding final degrees, admission requirements for Master's programs, the number and scope of examination achievements or possible sanctions).

The recommendations outline a **basic concept** rather than addressing the details of examination or study regulations. The discussion was based initially on the two study programs in Paderborn[1] and Ulm[2].

2. Fundamental Questions

Premises

The Bachelor's and the Master's program are two consecutive but self-contained programs. The Bachelor's program aims to provide students with a broad-based knowledge of the essential fundamentals of informatics, which can subsequently be built on in the Master's program or the graduates' later professional work. The Master's program aims to broaden and deepen students' knowledge of informatics and teach the skills needed for self-reliant scientific work. A Master's degree is generally required for admission to a PhD program.

The programs are foundations- and method-oriented. Together, they equip students with the knowledge and skills they need to conduct self-reliant and research-oriented scientific work and to make well-informed decisions and judgments. Another important goal is to provide students with methods and system competence and the ability to adopt different scientific perspectives – prerequisites for self-reliant research work. They should be taught how to tackle complex problems and solve them using scientific methods, even where this means extending the current limits of knowledge.

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[1] Further information available at
`http://wwwcs.uni-paderborn.de/cs/studium`

[2] Further information available at
`http://www.informatik.uni-ulm.de`

The standard degree in this concept is the Master's degree, which is at least equivalent to the previously awarded *Diplom*.

Duration of Studies

The Bachelor's program will normally last 6 semesters, and the Master's program 4 semesters.

Final Degrees

Students who successfully complete the programs will be awarded the degrees "Bachelor of Science" and/or "Master of Science" without any additional title.

Professional Qualification

The Bachelor's and Master's programs offer different levels of professional qualification. The expression "providing a professional qualification" is interpreted as meaning "qualified for employment" and "qualified to enter the labor market", corresponding to the term "employable" used in the Bologna Declaration.

In the Bachelor's program, students receive a foundations- and method-oriented education and are trained in scientific working methods. This ensures that they acquire the lasting ability to adapt to new technologies.

The Master's program is designed to enable graduates to directly assume high-level positions requiring self-reliance and initiative in industry, management, science and research. Graduates should in particular be capable of subsequently performing leadership functions.

In the Bachelor's program, students acquire the relevant practical basic skills they will need in their future work, e.g. professional programming as well as the foundations of software engineering and database systems. The Master's program equips students with a broader range of basic skills, deeper knowledge and greater scientific maturity.

Graduates of the Bachelor's and Master's programs will, however, generally still need to adjust to and familiarize themselves with their new working environment. Graduates possess the skills they need to familiarize themselves with the specific tasks they will be required to perform. Graduates' professional qualifications are further enhanced by training in the so-called "key skill areas" and through the General Studies section of the program.

The training in key skill areas is ensured by means of specific courses, or integrated with technical courses, or through study and lab projects. Such training should preferably be linked with the teaching of specialized course content.

Credit Points

Based on the European Credit Transfer and Accumulation System (ECTS), 60 credit points (CP) are awarded per year. One CP corresponds to 30 hours of work for the average student, assuming a total annual workload of 1,800 hours per student.

The criterion for the award of credit points is the amount of work performed by the student. It *is* possible, for many courses, to roughly convert the number of weekly hours per semester (SWS) into credit points, but these are then adjusted depending on the amount of work the respective course involves.

Modularization

The programs are modularized. This improves the comparability of achievements if students change universities and when designing examinations.

There is a great deal of diversity in the definition of modules. 4-9 CP is regarded as a suitable size for a module but larger modules are also possible (e.g. in the case of project lab work).

Module Handbook

A module handbook is a useful instrument to ensure that students are properly aware of course admission requirements, content and goals. It also helps lecturers at the same university to coordinate course content and serves as a basis for agreements between universities. The module handbook must be regularly updated to take account of changes in the study programs.

Cross-Disciplinary Studies

Cross-disciplinary course content is available to all students in the form of integrated application subjects or minor subjects.

Credit points from other General Studies subjects and other “key skill areas” can also be taken into account.

Courses Taught in English

It is recommended that some lectures and seminars be held in English, though German will remain the normal language of instruction.

Transcript of Records

It must be possible to keep track of individual students’ achievements in the form of a transcript of records. These data are used for supervision and counseling purposes.

Required Achievements

The Study and Examination Regulations should specify that students are required to obtain a minimum number of credit points over a fixed period or by set deadlines (e.g. within certain study phases or before beginning the final thesis).

Grading

There are various different ways of calculating the final grade. The recommended method is to work out a grade point average weighted by credit points, possibly with a lower rating of the early semesters in the Bachelor’s program. In addition, the certificate **must** show the weighted grade point average of all graded courses.

The method used to calculate the grades should be described comprehensibly in the transcript of records.

Examinations

Examinations are held parallel to courses, i.e. a certificate of achievement is issued on successful completion of each module. Most of these certificates should be graded. Students must also be examined orally.

Students must have regular opportunities to take – and if necessary retake – examinations to enable them to complete their studies within a reasonable period of time. Deadlines for the grading of examinations should be set accordingly.

Mechanisms enabling students to improve their grades, such as grade compensation or retaking examinations, should be provided.

Start of Programs

It is recommended that the Bachelor's program begin in the winter semester because of its highly structured form. Students should be able to begin the Master's program in both the winter and summer semesters.

Quality Assurance

The quality of the programs should be monitored by continuous evaluation of courses in the form of student questionnaires. The feedback should be evaluated and discussed with students and teachers. A commission should be set up to constantly update the organization and content of studies.

Student Counseling and Supervision

In addition to the general student counseling service, each student should be assigned a personal mentor to supervise his or her progress. The mentors should, for example, help students in the choice of compulsory electives.

Alumni Statistics

Graduates' further careers should be monitored, as far as allowed by data protection laws.

3. Bachelor's Program

Goals

The Bachelor's program in informatics offered by universities is foundations- and method-oriented. It provides a broad basic knowledge of the subject and is designed to ensure that students possess the competence and skills required for mastering a subsequent broader and deeper treatment of the subject and for specializing in certain areas of it. In particular, it prepares students for the Master's program. The Bachelor's program should enable students not only to apply the knowledge and skills they have acquired but also to quickly master new, more complex problems in a lifelong learning process. Graduates of the program are able to enter specific sectors of the labor market or continue their studies elsewhere.

It should be ensured that students embarking on the Bachelor's program have a sufficient command of written and spoken German as well as an adequate knowledge of mathematics.

Organization of Studies

The Bachelor's program is divided into different phases:

- The first studies phase (1st - 4th semester) consists mainly of compulsory courses.
- The second studies phase (remaining semesters) builds on the first phase and mainly comprises elective and compulsory elective courses.

Structure of the Program

The Bachelor's program is designed to equip students with a basic knowledge of their subject as well as with the required methodological skills and professional qualifications. Bachelor's programs may vary in the way they are structured.

The Bachelor's program includes a minor subject or an integrated application subject[3] worth a minimum of 16 CP.

Projects and Internship

The program must contain at least one project course and one seminar. In the project, students work in teams to develop a software system. In the seminar, students are required to work on and present a topic self-reliantly.

The program may include an informatics oriented internship of at least two months, which students complete during the semester vacation and for which no credit points are awarded. Care should be taken to ensure that this does not interfere with examination arrangements.

If an external internship project alternatively is taken into account in overall grading, it should last at least 12 weeks and be worth a maximum of 15 CP. It must deal with topics of relevance to the study program and allow individual monitoring of students' performance.

Bachelor's Thesis

The Bachelor's thesis, including an oral presentation and discussion in the form of a colloquium, is worth 15 CP.

Changing Universities

Students should be able to change universities during the Bachelor's program. The mutual recognition of achievements between universities based on the transcript of records makes this possible.

4. Master's Program

Goals

The Master's program in informatics at universities is research-oriented. It broadens and deepens students' knowledge of the subject, teaches them to work self-reliantly, equips them with the knowledge and skills they need to extend the bounds of their subject and prepares them for admission to a PhD program. In particular, it prepares students to assume leadership functions involving personal responsibility and provides them with the required skills for self-reliant and research-oriented scientific work and for making well-informed decisions and judgments.

Besides broadening and deepening students' knowledge, the Master's program provides the opportunity for specialization. It should offer students a wide range of choices here. The consecutive nature of the programs, with the Master's program building on the Bachelor's program, makes it possible for students to attain a suitable depth of knowledge.

Admission to the Master's Program

The faculty/department must define qualitative criteria for admission to the Master's program. These criteria should be based on the quality of the degrees obtained in the preceding Bachelor's program. Admission based purely on grades is not recommended. Every qualified gradu-

[3] GI recommendations to make university *Diplom* programs in informatics more application-oriented
`http://www.gi-ev.de/informatik/beruf_studium/index.html`

ate of a university's Bachelor's program should be entitled to enter its Master's program. There should not be a quota system for transition to the Master's program.

Graduates of Bachelor's programs offered by other faculties/departments represented at the FTI which follow these recommendations should be treated in the same way as graduates of the faculty's/department's own Bachelor's program.

For the research-oriented Master's program, it is important to ensure that the previously awarded Bachelor's degree meets the subject's requirements in terms of its research orientation. Otherwise applicants may be turned down or additional achievements may be required.

Structure of the Program

The Master's program is designed to equip students with the knowledge and skills they need to use the scientific methods of informatics, to develop them further in selected areas and to act responsibly by taking into account the impact of technological change. The Master's program is at the same time intended to prepare particularly qualified students for PhD studies.

The program should be organized in such a way that the modules are integrated into larger thematic units, ensuring sufficient breadth and depth of the range of topics studied. Topics covered in the Bachelor's program cannot be taken into account again in the Master's program.

The program should contain a project and seminars. Master's students should be able to continue studying the minor subject from the preceding Bachelor's program.

Master's Thesis

The Master's thesis is worth 30 CP. It should include an oral presentation with subsequent discussion.

Examinations

As in the Bachelor's program, examinations are held parallel to courses. It is also possible to hold integrative examinations covering the entire material of several modules. These should, in general, be oral examinations.

Section 2: Educational Goals

1. General Educational Goals

The consecutive Bachelor's and Master's programs are **scientific, research-oriented programs** geared to the teaching of fundamental knowledge and methods. This orientation toward fundamental knowledge provides graduates with a sound and lasting foundation for their future work: Course content is not restricted to current topics and trends but offers a thorough theoretical treatment of concepts and methods that will be of benefit to them throughout their careers.

Students are taught the fundamental **principles, concepts and methods** of informatics: Graduates of the program should in particular be able to use the means and instruments of informatics to tackle problems in a variety of application domains and under existing technical, economic and social constraints, as well as developing suitable systems, and leading projects. They should acquire the ability to apply the concepts and methods they have learned to future developments. The minor subject is designed to provide insight into typical application problems.

Problem-solving competence: Students should learn to specify complex problems systematically using informatical methods, to design workable and reliable solutions and validate them. If problems arise, they should be able to take the necessary measures to resolve them. Students should acquire practical experience in constructively tackling problems that appear unmanageable by making effective use of the systems and techniques provided by informatics.

Key skills and interdisciplinarity: Besides acquiring technical competence, students should learn to communicate concepts, methods and results and work in teams. They should be able to gain facility in dealing with application-specific concepts and terminology in order to cooperate across discipline boundaries. They should gain experience in project management and acquire leadership and management skills.

The impact of informatics: Students should learn to assess the impact of informatics on society in its social, economic, psychological and legal dimensions and in terms of how it affects the organization of work. They should be familiar with the ethical guidelines for their profession[4].

There are differences between the Bachelor's and Master's programs in the extent to which the above-described educational goals are attained. These differences are quite marked with regard to graduates' problem-solving and leadership skills. This implies that there will also be differences in the sort of functions graduates can be expected to assume in industry after completing their respective degrees.

2. Educational Goals of the Bachelor's Program

Skill Profile

Graduates of a university Bachelor's program in informatics should have the following skill profile:

1. They have a good command of the mathematical and informatical methods needed to analyze problems thoroughly.
2. They have a good command of the informatical methods needed to develop abstract models.
3. They have learned to formulate problems and work on the resulting tasks self-reliantly in meaningfully organized teams, incorporating the results of other team members and communicating their own results.
4. They have acquired the method competence needed to successfully tackle programming problems, taking equal account of technical, economic and social constraints.
5. They are aware of the diverse security problems entailed by the use of information systems, especially when networked; they are familiar with the methods and techniques for securing such systems.
6. They have gained familiarity with selected typical application domains and have the competence needed to apply their basic knowledge of informatics to application problems.

[4] Ethical Guidelines of the *Gesellschaft für Informatik*
`http://www.gi-ev.de/verein/struktur/index-ethik.html`

7. They have acquired competence in typical areas outside their own subject and are aware of the non-technical and “soft” skills required in industrial practice.
8. The program’s orientation to fundamental knowledge prepares them well for lifelong learning and working in a variety of professions.

What we have, then, is a foundations- and method-oriented skill profile that differs distinctly from an application-oriented skill profile. This distinction must be reflected in the structure of the first study phase, which culminates in the Bachelor’s degree.

Educational Goals

Modeling and Formalization: Students should be able to “think in concepts” and describe situations in informatical terms. To do so, they must be familiar with the standard techniques, notations and system models of informatics and be able to select from them the best-suited for the respective case. This involves not only recognizing fundamental structures in problems but also the ability to apply formal methods or adapt them to new problems. In particular, students should be able to structure problems and their solution, formulate them at suitable levels of abstraction and communicate them. They should also have a firm command of basic proof and analysis techniques.

Algorithms: Students should be able to analyze and describe problems, develop algorithmic solutions for them and evaluate these in terms of their quality, in particular their efficiency. This means they must not only have a good knowledge of basic algorithms, e.g. for graph, geometry, coding, communication and optimization problems, but also be able to classify problems according to their computability and complexity, develop efficient algorithms for them and analyze them in terms of correctness and efficiency. In addition, they should be capable of selecting and combining suitable algorithms and adapting the algorithms and data structures to the respective requirements.

Software Development: Students must be familiar with the life cycle of the software and the processes and methods of software development. They should be able to select and use suitable methods and processes to structure and coordinate the design of complex systems. In particular, they should be conversant with the principles and methods for estimating the effort and for planning projects. Students should understand the concepts of software development tools and be able to use standard programming environments and familiarize themselves with the use of new tools. In particular, they should be able to make proper use of software libraries, extend them and adapt them to the respective requirements. They should be conversant with the most important standards.

Languages and Programming Methods: All students must be familiar with and have used several programming languages, have a firm command of at least one of them and have gained practical experience in software development in projects. They should also know all the important language paradigms and concepts so that they can learn new languages on their own, assess languages in terms of their suitability for specific application domains and effectively map software designs to programming concepts.

Information Systems: Students should adopt a data- and information-centered approach, such as is needed for managing and using very large databases over lengthy periods. To do so, they must acquire a sound knowledge of database and knowledge base modeling and of data structures and languages for efficiently managing and accessing them, as well as learning how to meaningfully implement database accesses in application programs (in distributed scenarios, too). They should also be familiar with the importance and principles of transaction-oriented processing in multi-user mode and its correct implementation.

IT Security: Students should be sensitized to the problem areas of IT security and data protection and be familiar with typical attacks on computer systems and information, whether local or in the Internet. They should have a sound knowledge of the standard techniques, methods and infrastructure measures used for achieving security goals. And they should be made aware of the fact that a system's security features must be taken into account as early as the requirements engineering phase and not implemented as add-ons at a later stage.

Embedded Systems, System Software, Computer Networks: Students should understand the way hardware and software interact at various levels and how distributed and networked system work. They should also be aware of the importance of efficient and secure resource management. They should be able to develop complex systems and check their correctness. To do so, they must have a good command of the required fundamentals of digital and continuous systems.

Human-Computer Interaction: Students should be familiar with the interactions between users and technical systems and able to assess them. They should be able to design user interfaces, have a good command of the modern techniques used in audiovisual media and be able to implement the requirements of software ergonomics. In addition, they should be conversant with the fundamentals of computer graphics, visualization and image processing.

3. Educational Goals of the Master's Program

Skill Profile

Graduates of a university Master's program in informatics will have a skill profile with the following additional features:

1. They have transcended the educational goals of the Bachelor's program in a lengthy process in which they have matured and acquired greater competence in using and applying their technical and non-technical skills.
2. They have acquired a profound knowledge of a chosen specialization area of informatics.
3. They possess knowledge of sufficient breadth and depth to enable them to swiftly familiarize themselves not only with future developments in their own field but also with its fringe areas.
4. They are able to successfully apply the informatical methods they have learned to specify and solve complex research and development problems in industry or research institutions, as well as making a critical assessment of them and developing them further if required.
5. They have acquired a variety of technical and social skills (ability to abstract, system analysis skills, team and communication skills, international and intercultural experience, etc.) preparing them to assume leadership functions.
6. They are very well trained, not only to assume R&D functions but also for other demanding tasks, especially leadership functions in the business and administrative sectors.

Educational Goals

For the Master's program, it is, understandably, impossible to list specific subjects and topics. This is due on the one hand to the varying profiles of the universities offering such programs in informatics, which allow for a range of different specializations, and on the other to the aim of providing in-depth training through specialization.

One major objective of the Master's program is to broaden students' professional skill base. The program should be designed to equip Master's students with the knowledge and skills they will need to assume high-level functions in the area of development. Another important objective is to broaden students' knowledge of the foundations of informatics and its applications.

A further essential element of the Master's program is specialization in a specific area of informatics. This specialization process culminates in the Master's thesis, which requires self-reliant scientific work and is well above the level of the Bachelor's thesis. The subject of the thesis should preferably be linked to the minor subject or address the solution of an application-related problem.

Section 3: Course Content in the Bachelor’s Programs

The following list comprises the **topics** that Bachelor’s students should normally have a command of after completing the program. They are grouped in clusters worth an (estimated) minimum of 4 CP, the intention **not** being to list specific courses but merely to give an overview of course content. The topics listed could well be **differently organized and prioritized** in the program. No such list is given for the Master’s section because the curriculum will vary from university to university.

A number of important topics are **not evident** in this list because they only become clear if the goals for which specific topics are taught are included. For instance, topics like real-time systems, mobile computing etc. are not mentioned because they only become evident by subsuming certain subtopics under a specific goal.

The content is divided into three blocks: Foundations of Informatics, Informatics of Systems and Mathematics. In each case a compulsory subject section is defined, and in some cases an (incomplete) list of elective or compulsory elective subjects is given. This may contain further subjects, depending on the specialization areas offered by the respective faculty/department.

Foundations of Informatics (minimum of 35 CP)

Compulsory Subjects

- Automata Theory, Formal Languages and Complexity
  Grammars and automata models, Chomsky hierarchy, algorithm, computability and decidability, complexity, NP-complete problems
- Logic
  Boolean logic, resolution, compactness theorem, predicate logic, models, nondecidability and incompleteness, fundamentals of logic programming
- Formal Systems
  Induction and recursion, graphs and trees, term algebras and abstract data types, rewriting systems, networks
- Modeling
  Principles, entity-relationship models, state transition, control flow and data flow models, UML, Petri nets, metamodeling, model transformations
- Programming
  Basic elements and concepts of imperative and object-oriented languages
- Programming Paradigms
  Object-oriented, functional, logic and parallel programming concepts
- Data Structures and Algorithms
  Basic data structures, sorting and searching, search trees, hashing, simple graph and geometric algorithms, algorithmic principles, verification and complexity analysis of algorithms

Informatics of Systems (a minimum of 50 CP from the compulsory and electives sections)

Compulsory Subjects

- Foundations of Operating Systems
  Tasks and architecture, UNIX, processes, concurrency, synchronization and communication, files, protection mechanisms, system calls, shells, utilities
- Foundations of Software Engineering
  Software process models, project management, requirements analysis, design methods, specification, implementation techniques, testing, integration, maintenance, documentation, CASE, quality assurance, configuration management, reengineering
- Database Systems
  Structure of database systems, entity-relationship model, relational model, normal forms, relational algebra, SQL, query calculi, implementation techniques, query processing and optimization, transactions, synchronization and data security
- Computer Networks or Distributed Systems
  Services and protocols, communication architectures, OSI reference model, Internet protocols, network management, wide area networks, local networks
- Foundations of Digital Technology
  Boolean algebra, combinational and sequential logic, combinational and sequential circuits, minimization, elementary components and function blocks, implementation of logic functions, validation
- Computer Systems
  Number notations and computer arithmetic, assembler programming and its use for implementing high-level programming languages, structure of arithmetic logical units, microarchitecture of a processor, command interpretation, command pipeline, memory hierarchies, I/O
- Security
  Dependability of information systems, risks, security problems, attack scenarios; cryptography: techniques, protocols, software, hardware, infrastructures; access control, information flow, models and mechanisms; security policies, security management, data protection

Compulsory Electives

- Artificial Intelligence
  Knowledge representation, search algorithms, non-classical logics, theorem provers, learning and planning, fuzzy knowledge, robotics, natural language processing multi-agent systems
- Compiler Construction
  Syntax, semantics, lexical analysis, parsing, context-sensitive analysis, code generation, code optimization, generators, program analysis
- Human-Computer Interfaces
  Software ergonomics, user interfaces, usability engineering, designing workflows
- Simulation
  Equation-based modeling vs. agent-based modeling, simulation of continuous, discrete

and hybrid processes, event-oriented simulation, agent-based simulation, simulation of evolutionary and learning processes, genetic algorithms, neural networks; applications of simulation in the natural and social sciences

- Computer Graphics
  Fundamentals of rasterization, algorithms for scan conversion and clipping, 3D transformations, camera transformation, orthographic and perspective projection, lighting simulation, parametric curves

- Computer Vision
  Pattern recognition methods, image processing, projective geometry, camera models, classifier design

- Informatics and Society
  Moving toward the "information society": globalization, new business models, mobile and globally networked communication; control and regulation problems: access, competence ("digital divide"); data protection; proprietary rights for content, tools and products; application areas: eCommerce, eGovernment, ePrivacy

- Foundations of Electrical Engineering
  Direct and alternating current circuits, reactive systems, fundamentals of system theory (time and frequency range, sampling theorem, z-transformation), fundamentals of communications engineering, semiconductors, transistors, integrated circuits

- System Software
  Machine-oriented programming, assembler programming, procedure calls, stack and heap management, garbage collection, processes, interrupts, synchronization, memory management, I/O systems, compilers, binders and loaders, runtime systems, communication networks, ISO/OSI layers, TCP/IP protocols

- Embedded Systems
  Specification of embedded systems, hardware platforms, real-time operating systems, real-time scheduling, hardware/software codesign, validation of embedded systems, performance evaluation, energy efficiency, simulation, digital signal processing, communication protocols, machine vision, robots, mobile computing

Mathematics (minimum of 25 CP)

Compulsory Subjects

- Mathematics – Calculus I
  Rational, real and complex numbers, sequences, series, convergence, continuity, functions of one variable, differentiation, integration, asymptotics, iterations, fix points

- Mathematics – Calculus II
  Differential and integral calculus of multiple variables, Fourier series, elementary vector analysis

- Mathematics – Linear Algebra
  Systems of linear equations, vector spaces, basis, dimension, linear mappings, matrices, determinants, eigenvalues

- Mathematics – Discrete Structures
  Sets, relations, graphs, terms, groups, rings, fields, finite combinatorics, basic concepts of number theory

Compulsory Electives

- Mathematics – Probability Theory
  Probability spaces, Laplace experiments, conditional probabilities and independence, random variables and their distributions, central limit theorem, random numbers
- Statistics/Stochastics
  Probability, distribution function, important distributions (uniform distribution, normal distribution, χ^2 distribution, beta distribution, Erlang distribution), foundations of sampling theory, foundations of test theory (errors of first and second kind, significance level), stochastic processes, Markov property
- Numerical Algorithms
  Floating-point arithmetic, rounding, condition, stability. Interpolation and quadrature (polynomials, splines, FFT), systems of linear equations, iterative processes (linear and nonlinear), ordinary differential equations (e.g. Euler, Runge-Kutta)

Overall, these recommendations result in the following minimum requirements being defined for the Bachelor's program:

Foundations of Informatics	35 CP
Informatics of Systems	50 CP
Mathematics	25 CP
Bachelor's Thesis	15 CP
Subsidiary/Minor Subject	16 CP

Further compulsory program elements are a project and a seminar.