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Integrated Multimedia-Based Distance Teaching of Information Technology

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Abstract: An integrated set of four subsequent single semester courses is being developed covering information technology in great width and with strong links to technical applications. The courses will become integral parts of a distance teaching university's curricula. Combining short phases of presence with interleaved media-based self study blocks, they are also especially well-suited for continuing education. An innovative approach is taken by integrating all course elements -- acoustic and written information, diagrams and figures, animations, simulations, video clips, and laboratory exercises -- in a single electronic document. Whereas up to now all this information is only accessible on different storage media, the new multimedia teaching programmes even replace printed material.
Key Words: information technology, computer engineering, distance teaching, multimedia, integrated electronic documents
Category: H.5

1 Introduction

FernUniversität is the only German language institution of higher distance education at the university level, i.e., granting doctoral degrees and habilitations. It has students in almost all countries on earth. Engineering curricula are offered by the Faculties of Informatics and Electrical Engineering with some 8000 or 3000 students enrolled, respectively. After a vocational or another academic training, most of these students have a job and, in parallel, are further educating themselves by a study at FernUniversität. They are motivated by both wishing to update their knowledge and to enhance their career opportunities by obtaining a (higher) academic degree (Diplom-Ingenieur, Dr.-Ing.). To this end, they either enroll in continuing education modules consisting of a number of courses whose successful completion is certified, or by following an entire study. In the latter context the very successful supplementary curriculum in electrical engineering is to be particularly mentioned, providing engineers having graduated at Fachhochschulen (polytechnics) with the opportunity to earn an university diploma in a shortened study period.

In 1993, contents and examination regulations of both the normal and the supplementary curriculum in electrical engineering were revised fundamentally. In the course of this, the increased requirements of electrical engineers in computing knowledge and industry's need in demand-oriented training were particularly taken into account. The latter imply rather low interest in theoretical and esoteric topics as often dealt with in informatics, but more in those relevant to actual engineering work.

2 Course Objectives

According to this need, an integrated set of four subsequent single semester courses was defined covering information technology in great width and with strong links to technical applications. The courses are integral parts of the mentioned curricula offered by FernUniversität. Combining short phases of presence (e.g., weekend seminars) with interleaved media-based self study blocks, they are also especially well-suited for continuing education.

For the development of this course package, all course elements -- acoustic and written information, diagrams and figures, animations, simulations, video clips, and laboratory exercises -- are to be integrated on a single electronic storage medium in order to fully exploit the possibilities of contemporary teaching and learning technology and to lead corresponding practices far into a new -- partially still unknown -- area. Phases of conveying factual knowledge and of laboratory exercises in a very technical discipline are to be interleaved by integration into the medium computer and to allow for a maximum extent of interactive exposure to the teaching material. This innovative approach is not without risks and, thus, has to be carefully accompanied with methods of empirical pedagogics.

The disadvantage of combined media introduced several decades ago was that their single elements could only be made accessible on different storage media (study texts, audio cassettes, movies, video tapes, video disks, diskettes) each -- except the texts -- requiring a special device for replay. Therefore, it was practically difficult to have the complete volume of information at one's disposal, and its manageability was particularly cumbersome. This made it advisable to keep the interleaving of the information offered on the different media rather limited. The older multimedia concepts tried to overcome this shortcoming, at least a little bit, by "programming" the linkage of the still separated media and, thus, realising an integrated sequence control.

Our approach takes a decisive step ahead: information (text, sound, picture, movie etc.) hitherto separated by different media is integrated on a single, qualitatively as well as quantitatively high performance storage medium. Complete availability of all information is always ensured, and in combination with hypermedia techniques high flexibility is given for accessing different information. Furthermore, multimedia offer a great potential for technology transfer, since information can always be communicated in the most suitable form.

Certainly it makes no sense to offer large quantities of written information for perception via a computer screen. Therefore, in general FernUniversität's learning programmes do not present larger quantities of text. This is achieved by either selecting for programmes such topics which require only little text, or by letting programmes accompany printed course material, or by adding supplementary written information to programmes. Hitherto, teaching software mainly concentrated on functions which cannot or which can only inappropriately be fulfilled by written courses, such as to present and deal with processes of all kinds or to support active perception of the material. However, after it is now technically possible to integrate acoustic information including spoken texts into teaching programmes, the latter cannot only accompany and supplement printed courses but, in principle, also replace them. Thus, electronic courses become possible as integrated multimedia programmes. The most striking characteristic of our approach is to overcome combined media by integration and completely relinquishing printed media. Combined with hypermedia techniques complete integration offers hitherto not yet sufficiently explored possibilities for dynamic adjustment of the teaching material to the students' progress of learning as well as to their specific ways of learning.

Teaching media designed as self-instructing materials -- this is the case for all distance education materials -- can, in principle, be used in three forms of teaching and study organisation: as studying materials at an institution of higher distance education, as studying materials in a single phase of distance studies organised by an institution of presence education or by a distance learning institution in co-operation with an institution of presence learning, or as self-studying materials at institutions of presence education in order to supplement or to replace lectures. The multimedia learning programme "Information Technology" is designed to be employed (entirely or in defined parts) in all these areas.

3 Didactic Features

The project's most striking characteristic is overcoming combined media by real, physical and complete integration and the total renunciation of printed media. This approach contains considerable potential for innovation. It requires to further develop didactic-methodical concepts of distance teaching, and of media-based learning in general. Thus, the main question is: with which didactic-methodical concept and with which practical implementation technique can a modern electronic course be developed that gets by without printed media and combines different information elements such as text, sound, picture, and movie, that are hitherto stored on separate media, in a single electronic document?

In particular, the didactic-methodical concept has to contain suggestions, how the different elements, mainly acoustic and written information, can be optimally co-ordinated for the presentation of the material itself and of exercises and problem sets. The concept's realisation and its validation are carried out step by step (formative evaluation). It is hoped that the optimum co-ordination will have been found by the end of the project.

The electronic courses are conceived in such a way that they may be used not only for distance learning, but also as self-studying materials. To this end, the material is structured in modules. In the course of the project it will become clear, whether this goal can be achieved.

In pursuing the objectives stated above, it is looked into the question how teaching of a quite technical subject with corresponding laboratory phases can be interleaved by integration in the medium computer. How to explain and to accustom students with the function of a physical device when there are no laboratory sessions? As now common in science, it is not dealt with the real world, but components up to computer cores are simulated. Acceptance and range of this virtual world are to be investigated in the particular subject area of information technology. Basic digital circuits and electronic gates, for instance, are represented graphically in diagrams -- the input values can be assessed by students. Simulation programs then provide the same values at the outputs like in a real circuit.

A central item of the courses is a simulation program for an easily programmable digital computer [see Fig. 1]. This hypothetical computer does not match with any really existing computer. On the one hand, it is so powerful that it possesses the most important properties of digital computers dealt with in the course. On the other hand, it is so simple that it dispenses with all further special features that might be disturbing while demonstrating the basic properties of a computer. This computer shows the contents of its memory and the most important registers on its graphical user interface and is programmable with the help of a set of 20 instructions. The execution of a program can be performed either in step mode or in free running mode, as desired.

With these simulated circuits and computers, first the mode of operation of systems can be demonstrated with examples, especially the basic working method of a digital computer and its programming. Furthermore, students are given the opportunity to work actively on the problems dealt with in the course and to develop practical experiences in the handling of systems. Finally, the simulated devices are at disposal for free experimenting, which might lead to new questions and the search for own answers.

In the project it is investigated, whether so the need of practical experiences in the subject of information technology can be covered completely, in how far this offer is accepted and how it is assessed.

Another question concerning the complete integration and the relinquishment of written media arises because of the commonly held estimation that it is not useful to offer extensive written information for reading on a monitor. Admittedly, longer linguistic passages usually do not take up a central position in the passing on of technical contents, but they do have their status in the field of information technology, e.g., in introductions into a subject, in motivations for a problem or in supplementary remarks about the reference to practice or the like. But since the integration of acoustic information is realisable technically now, it is possible -- and in the sense of easing the visual channel even desirable -- to offer such information as spoken texts. A typical example for this type of information in the programme "Information Technology" is made up by a historical look back at the development of calculators. In the style of a sound-slide-show, a detailed spoken description of the development is given together with several pictures of inventors and their historical machines [see Fig. 2].

The concept of the integrated information is in essential parts superior to conventional presentations in study texts, lectures or films. As there is no longer a limitation to the respectively small presentation facilities, it is now possible to present any content in its optimal form. As examples that are of special importance in the field of information technology the picture-sound-sequences are to be cited, well-known from educational films, i.e., sequences of diagrams, formulae etc. that are accompanied by sound commentaries. Thus, gradual developments and processes, like e.g., the construction of a complex diagram, the deduction of a mathematical formula [see Fig. 3] or -- especially in computer engineering -- the demonstration of the operation mode of algorithms [see Fig. 4] or circuits [see Fig. 5], can be presented graphically by picture sequences, and -- in contrast to written material -- explained at the same time in an optimal way. In contrast to educational films, the speed of the process can be determined by the user himself.

Of even greater importance as for the presentation of the subject are the aspects of new presentation and individual usage facilities in the field of the use of computer programs. With the help of simulated circuits and devices, now -- conventionally only in the context of a special practical instruction -- the gaining of practical experiences is possible. The passing on of the syllabus and the practical exercises can be interconnected in a way chosen by the student himself.

Completely new is also the approach to provide the student with an interactive environment of software tools. This surrounding offers the opportunity to deepen the understanding of the learned terms, the writing and the principles of software engineering by means of trial and error. Thus, e.g., the working method of circuit nets, digital circuitry, finite automata, algorithms or complete computer architectures can be illustrated by animation, interaction, colour and sound accompaniment. A further feature of the software environment is the opportunity to adapt and expand the functionality of the tools correspondingly to the user's learning process.

In addition to the advantages of the concepts of integrated information, that are to be found in representing and operating the single information elements, there is a further crucial advantage that is based in the overall structure of the teaching programme: a computer teaching programme is able to overcome the presentation that is ordered linearly and to be passed through sequentially, as it is given in books or study texts, lectures and films. With such a suitable structure, on the one hand the individual student can be provided with essentially better opportunities to go through the subject in a way that is in accordance with his individual background knowledge and learning experiences, on the other hand a large, even quite heterogeneous range of persons can be addressed.

The students that are addressed by the teaching programme "Information Technology" have the most different background knowledge and learning experiences. This is valid for the students of FernUniversität, among which there are students with modest school knowledge, practitioners with the most different abilities, and university graduates of a related field, and it is even more valid, if a further range of students, e.g., at other universities or in the field of continuing education, is addressed.

The requirements for teaching materials suitable for such a wide range of addressees and at the same time effectively manageable for the single one, is only hard to meet by a linearly presented syllabus (book, lecture, video clip): a clearly and strictly presented subject is only ascertainable in an optimal way for a range of learners with certain background knowledge and learning abilities, whether a syllabus that is provided with many learning aids is confusing and only ponderously manageable for the individual person.

A computer program, however, offers the chance to provide an amount of learning aids, and, furthermore, to structure this offer in such a way that the learner effectively can make his choice that is in accordance with his individual needs. It is our approach to make a strict distinction between the contents to be passed on -- e.g., the definitions, propositions, methods, algorithms or descriptions of devices or circuits -- that are compulsory for everyone, and the didactic elements -- introductions into a subject, motivations, explanations, examples, demonstrations, exercises, lists of teaching aims, provision of background knowledge from mathematics and electrical engineering -- that are only offered optionally.

In the programme "Information Technology", the contents to be passed on are decomposed in small sections that are offered in linear order [see Fig. 6]. To each of these content sections a set of didactic elements is allocated that can be chosen as required via a selection menu. Thus, e.g., a student repeating the course will mainly go through the content elements before an examination and only rarely take advantage of supplementary information, whereas a beginner in this subject possibly falls back on most of the aids. Thus, an offer arises, that on the one hand copes with the diverse needs of learning support, and on the other hand is simply and clearly to handle and -- especially with the help of the lists of teaching aims and self-test exercises offered in every section -- enables an effective and object-oriented working on the syllabus.

4 Course Development

The project work consists of development activities that are directly followed by testing activities. The former can be subdivided into teaching (selection and restriction of material, definition of preconditions and expected performance, standards of grading, etc.) and presentation activities (didactics of the media, design of teaching media, technology of teaching and learning, etc.). As far as the testing activities are concerned, we distinguish between (further) teaching (organisation of the situation of teaching and learning, selection of parts to be tested, assessment of the evaluation results, etc.) and research activities (formulation of hypotheses and questions, selection of testing instruments, assessment of testing results, etc.). The sequencing of development and testing phases characterises the project's schedule:

- development of the pilot unit,
- testing of the pilot unit,
- development of the first half and important parts of the second half of the course package,
- testing of the first half of the course package,
- further development of the second half of the four courses,
- testing of the second half of the course package; adding of testing results,
- completion of the course package.

5 Course Assessment

Empirical pedagogics distinguishes between formative and summative evaluation. Whereas the latter investigates the prepared course, i.e., the developed *product,* the former focuses on the development *process.* As in the present project, formative evaluation is always selected when a *new type* of a teaching medium is to be developed. Therefore, testing phases are scheduled within the development period as formative evaluation. This will concentrate on structure, contents, and methodics of the course package. The main questions aim at clarity and consistency of the course structure, the optimal proportion of informative, activating, and testing contents, the optimal balance of sound, text, pictures, films, and simulations, and if the teaching programme is reliable and easy to handle. Needless to say, formative evaluation is to detect and remove errors.

The schedule provides three phases of formative evaluation, with the first one serving for the better formulation of hypotheses and questions, whereas the second and third phases are totally aimed to gain more knowledge. The first phase will be carried out using the pilot unit with just a few students in class at FernUniversität. Owing to the objectives and the low number of participants, in this phase it is tried to obtain first results by observations and (group) discussions. It is not sensible to use interviews and questionnaires before the second and third evaluation phase, following the first one with a distinct delay. The evaluation sites will partly move to the students' homes, in order to meet the conditions of distance learning. It is envisaged to include up to 50 participants into these tests. They will be questioned following a structured programme.

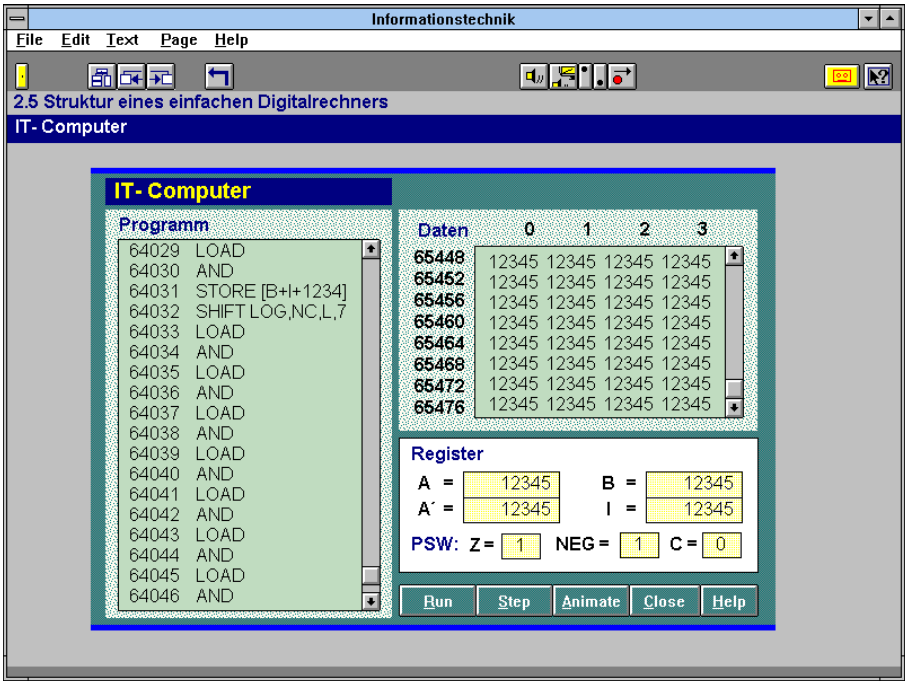

Figure 1: Simulation of an elementary digital computer

Figure 2: Historical development of computers

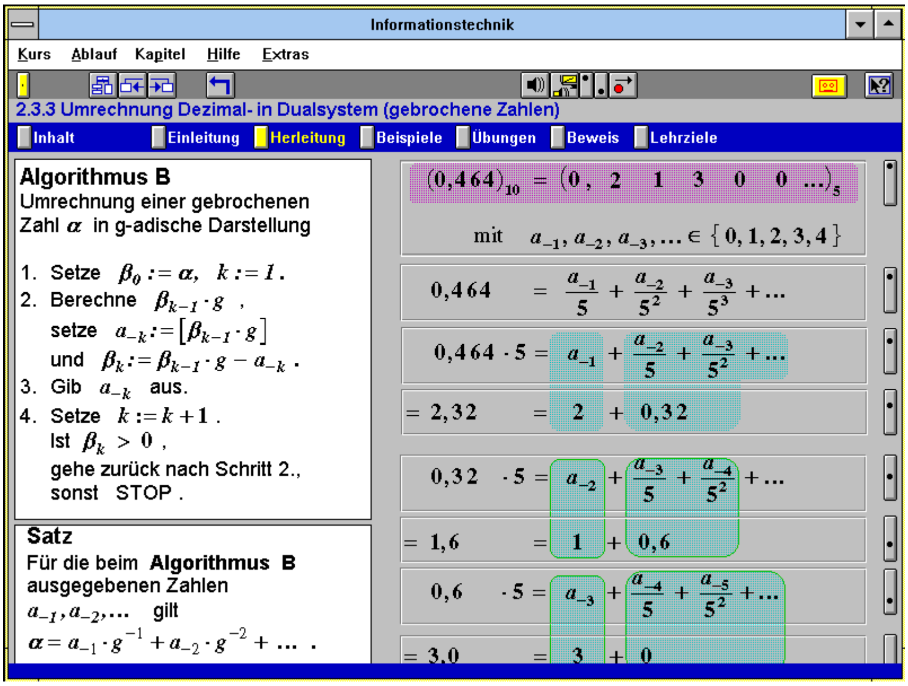

Figure 3: Deduction of a mathematical formula

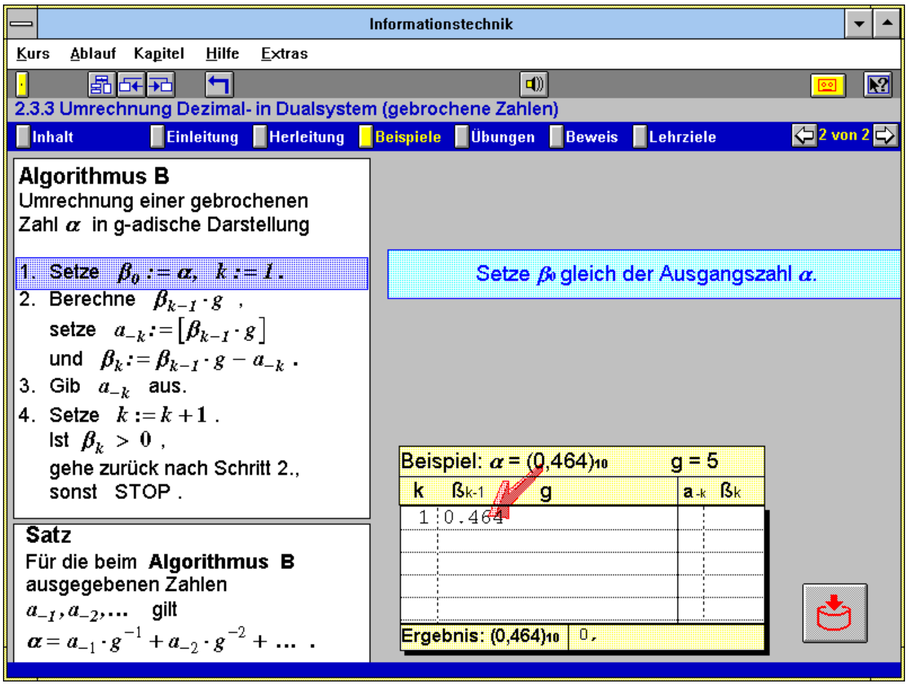

Figure 4: Demonstration of an algorithm

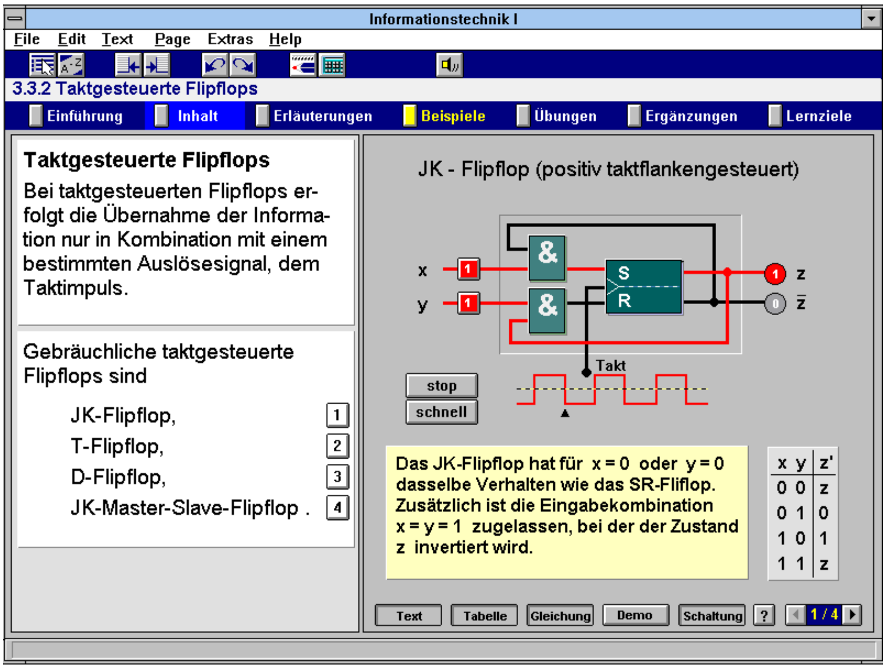

Figure 5: Demonstration of a circuit

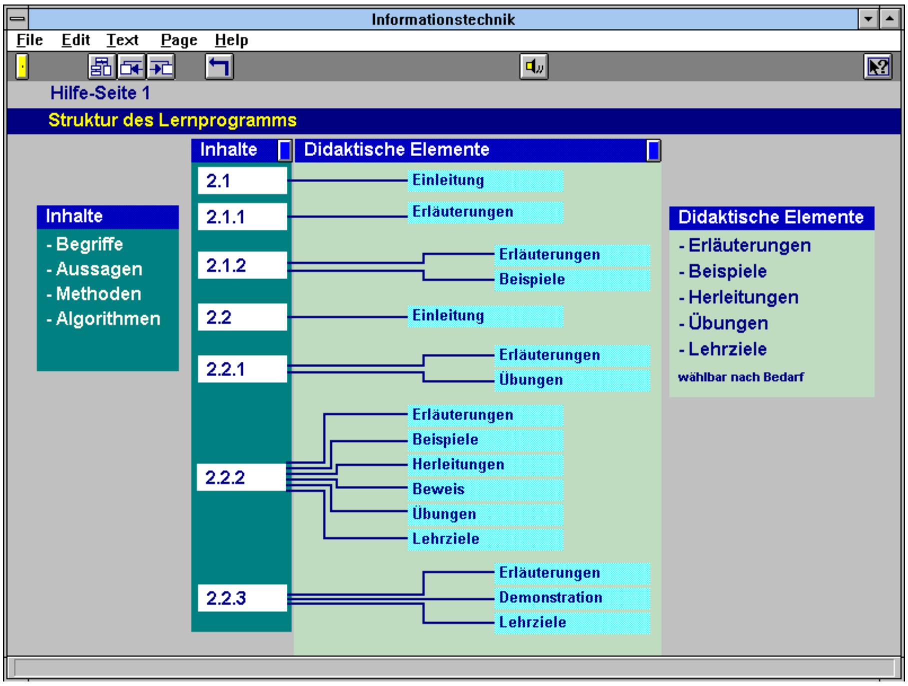

Figure 6: Selection of didactic elements

Appendix: Course Syllabus

1. Semester

- Introduction to the hardware oriented part
- – Introduction to the subject area
- – Historical development of information technology
- – Survey on the structure of digital computers
- Fundamentals
- – Digital representation of information
- – Coding of ciphers and characters
- – Polyadic number systems
- – Representation of integer and real numbers
- – Structure of a simple digital computer
- – Programming of the simple digital computer
- – Logical circuits
- – Boolean algebra
- Logical combinatorical circuits
- – Circuits with storage elements
- – Basic digital circuits

– Finite automata

2. Semester

- Processors
– Tasks and functions of a control unit
– Structure of a control unit
– Instructions and addressing
– Microprogramming und instruction implementation
– Program interrupts
– Tasks and functions of an arithmetic unit
– Binary adders
– Binary multiplication
– Binary division
– Binary floating point arithmetic
– Error detection and handling
- Memories
– Tasks and functions of memories
– Memories with random access
– Memories with cyclic access
– Memories with sequential access
– Organisation and structure of memory hierarchies
- Input and output
– Survey on I/O-devices
– Parallel and serial communication with I/O-devices
– Interrupts units and timers
– Direct memory access and I/O-controllers
– Keyboards, CRT-terminals, and printers
– A/D and D/A converters
- Outlook to further computer architectures
– RISC principle
– Transputer
– Distributed systems
– Parallel computers
– Unconventional computer architectures

3. Semester

- Introduction to the software oriented part
– Software in technical systems
– Design and validation of large software systems
– Quality features of Software
- Information and its representation
– Statistical information (Shannon's) theory
– Information as semantic content of messages
– Forms of representation and interpretations
– Transformations of information representations
- Fundamental mathematical notions
– Characters, strings, and formal languages

- Predicate logic
- Sets, relations, and functions
- • Data structures
- Arrays and mappings
- Sequences
- Graphs and trees
- Organisation and storage of data structures
- • Algorithms
- Basic notions
- Design and representation of algorithms
- Correctness
- Complexity
- • Syntax and semantics
- Grammars, BNF, and syntax diagrams
- Context conditions (static semantics)
- Semantical models
- Language translation

4. Semester

- • Fundamental notions of programming
- Functions
- Case selection
- Non-deterministic selection
- • State oriented programming
- On the notion "state"
- Pre- and post-conditions
- Program variables
- Iteration
- Procedures
- • Concurrency, parallelism, and distribution
- Control of technical processes
- Data parallelism
- Control parallelism
- Fair co-operation of processes
- Deadlocks
- Concurrency and synchronisation
- • Structuring of programs
- Modularity
- Stepwise refinement
- Composition of modules and processes
- Strictly and loosely coupled communication
- • Organisation of computer operation
- User and access rights
- Layers of system objects
- Memory organisation
- Process management