

Centre for Telematics and Information Technology

ANNUAL REPORT

1998

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1 CTIT's First Term (1994-1998)

In 1998 the Centre for Telematics and Information Technology (CTIT) concluded its fifth year of operation. In these five years, CTIT went through a substantial growth of research activities. Telematics became in 1996 one of the four spearheads of research at the University of Twente. Through extra budgets it was possible to invest substantial in the Telematics Systems area with four full-time and three part-time senior researchers. CTIT research groups participated in a large number of national and European projects. CTIT also was actively involved in the preparations of the research programme of the national technological institute '*Telematica Instituut*' (TI), founded in 1998, also located in Enschede. It now actively participates in eight of its projects, and expects to enhance this cooperation, since CTIT and TI are natural partners in research. Other initiatives lead to the foundation of the *Telematics Graduate School (TGS)* at the end of 1997, aiming at educating Ph.D. students, able to respond effectively to the challenges of telematics. Also, major contributions have been made to the development of a telematics undergraduate curriculum and a telematics Masters of Science curriculum at the University of Twente.

In 1999, CTIT will extend the scope of its research activities to deal with the challenges posed by E-commerce. E-commerce is of strategic importance for CTIT. It will be a major research area within the scientific programme of the second term, for which additional staff will be attracted.

Telematics as an area of research is rapidly expanding, attracting companies to establish R&D centres near the university. Enschede is well on its way to become the centre of telematics expertise within the Netherlands!

1.1 Telematics research in 1998

CTIT research focuses on the design of complex telematics and information technology systems. It comprises not only research on the technical aspects of these systems, but also on the complex issues of how to successfully introduce and use these systems in organizations, business and private life. Six departments of the University of Twente (technical and non-technical disciplines) collaborate in this institute.

The CTIT research programme, which has a scope of five years, provides a framework that serves as a long-term strategic reference for all multidisciplinary research activities within CTIT. It describes the concrete research issues that will be addressed and offers a structure for all projects carried out, such as ACTS and ESPRIT projects, projects within the framework of the 'Telematica Instituut', individual Ph.D. projects and other externally funded projects.

The nucleus of CTIT is formed by the cluster of research areas 'Telematics Systems', which comprises the areas Communication Systems, Systems Management and Application Systems. Closely interacting with this cluster are the area Design Methods and Concepts, and the areas researching application domains within the user environment. The other research areas/clusters are information technology as enabler of telematics systems.

In 1999 CTIT will extend the scope of its research activities to deal with the challenges posed by E-commerce. This will open new opportunities for collaboration within the 'Telematica Instituut'.

Research Projects

As in the previous years, CTIT was successful in the acquisition of new projects. The number of projects increased from 17 at the beginning, to 29 in the course of the year; 11 projects came to a conclusion in 1998.

In 1998, eight projects of different size and duration, were started as part of the cooperation within the 'Telematica Instituut':

- AMIDST (Application of MIDDLEware in Services for Telematics)
- DMW (Digital Media Warehousing)
- DRUID (Multimedia Indexing and Retrieval on the Basis of Image Processing and Language and Speech Technology)
- ImpacT (Information Management Project Twente)
- INTESP (Internet Economics and the Strategy Development of Service Providers)
- MERITS (Managing Company Expertise with Visual Telematics Services)
- SVC (Systems Validation Centre)
- U-WISH (Web-based Services for Information and Commerce: User-centred Design Principles, Methods and Applications)

The turnover of these projects amounted to 2.2 Mfl in 1998. Another project, Internet Next-Generation, is ready to start early 1999.

CTIT started research in another five new projects:

- *Accounting Management* (Ph.D. project within the Dutch Foundation of Informatics Research SION)
- *FLAMINGO* (Multiwavelength Optical Local Access Network Supporting Multimedia Broadband Services; Dutch Foundation of Technical Sciences)
- *OLIVE* (Development of a Multilingual Indexing Tool for Broadcast Material based on Speech Recognition; Telematics Applications Programme)
- *PRISMA* (Photonic Routing and Interactive Services for Mobile Applications; ACTS Programme)
- *Q-Bone* project (Internet 2 Differentiated Services Testbed; cooperation in a world-wide consortium of universities and companies on the 'Next Generation Internet').

In 1998 eleven projects were successfully concluded

- *BELSIGN* (Behavioural Design Methodologies for Digital Systems; Human Capital and Mobility Programme).
- *INSIGNIA* (IN and B-ISDN Signalling Integration on ATM Platforms; ACTS Programme)
- *MESH* (Multimedia Services on the Electronic Super Highway; funded by the Ministry of Internal Affairs)
- *POP-EYE* (Development of a Multilingual Continuous Video Disclosing Tool, Subtitle-based Indexing and Partial Translation; Telematics Applications Programme)
- three SURFnet funded projects on *Infrastructure*, *Network Management* and *Tele-Education*
- *Testbed* (development of architectural and automated support for the modelling and (re-)design of business processes; funded by the Telematics Institute).
- *TOBASCO* (TOwards Broadband Access Systems on CATV Optical networks; ACTS Programme)
- *TWENTY-ONE* (Development of a Multimedia and Multilingual Information Transaction and Dissemination Tool; Telematics Applications Programme)

The external funding has grown by a factor 2.2 with respect to 1997 (3.067 Kfl versus 1.385 Kfl). Sixty-nine percent of the budget of the autonomous part of the institute is now funded externally. At the end of 1998, 40 fte staff was employed within the autonomous part of the institute, 35.6 fte scientific staff members and 4.4 fte supporting staff members. This number will increase in 1999.

Standardization

The CTIT plays an active role in international standardization bodies, e.g., the IETF (Internet Engineering Task Force), W3C (World-Wide Web Consortium) and OMG (Object Management Group). In 1998 CTIT became member of W3C and OMG.

Networks

The CTIT is a member of the steering committee of EUNICE (European Committee Networks of Universities and Companies in Information and Communication Technologies), under the auspices of the European Union. EUNICE organizes a Summerschool for Ph.D. Students every year. CTIT will host the Summerschool in the year 2000.

A detailed overview of all CTIT research results is given in a separate report: "CTIT Scientific Results 1997-1998" (to appear in September 1999).

1.1.1 CTIT evaluation

The research of CTIT was evaluated in October 1998. Members of the evaluation committee were: Ir. P.P. 't Hoen (Lucent Technologies, Huizen; chairman), Prof. dr. A.E. Mante (University of Utrecht/KPN Research), and Dr. I. Schieferdecker (GMD Fokus, Berlin). The evaluation covered the period 1994-1998.

The evaluation committee perceived a positive attitude within the CTIT towards multidisciplinary and cooperative research, opening new ways of looking at problems, creating new research directions, making methods and tools available and applicable in areas for which they were not originally designed, and giving inspiration to define new research questions. The increase in Ph.D. dissertations, as well as the quality of the research as reflected in VSNU visitation reports was judged positively. The growth of funds over the years was regarded substantial, thus confirming the support of the institute by third parties, including industry.

The evaluation committee recommended a further strengthening of the participation of non-technical disciplines within CTIT, for example law and economics, which are vital for research into commercial, transactional oriented telematics applications. Cooperation with other universities could fill this gap. They also suggested to enhance and strengthen the CTIT Distinguished Visitors Program and exchange programs with other national foreign

institutes. These recommendations will be considered within the framework of a new research plan of the institute.

1.2 CTIT's participation in the 'Telematica Instituut'

The *Telematica Instituut* is a unique collaboration between major Dutch companies and research institutes within the area of telematics. The institute is funded by three parties: the government, industry and the participating research institutes. It started its activities in October 1997.

The University of Twente, through CTIT, contributes 1Mfl per year to the Telematica Instituut. For CTIT, participation in this institute is of major importance: it reinforces CTIT's position as the centre of academic expertise in the field of telematics in the Netherlands. The research scope of both institutes only partly overlaps: in fact, they are more complementary than competing. CTIT and the Telematica Instituut as a combination, guarantees that a substantial part of telematics research in the Netherlands is taking place in Enschede. This combination has already proven to be successful in attracting companies to open R&D centres in Enschede, in particular Lucent Technologies, TNO and KPN.

The research within the Telematica Instituut consists of a mix of basic research, generally of long-term duration with a strategic character, and market-driven research, which is closely linked to the needs of industry, mostly of short-term duration. The institute strives to achieve a balance between this basic research and market driven research.

CTIT is a natural partner in research on many subjects addressed within the 'Telematica Instituut'. This is reflected in the participation within a wide range of projects: from collaborative support (MERITS project), to digital multimedia warehousing (DMW project), language engineering (DRUID), validation (Systems Validation Centre), and design of middleware platforms (AMIDST / FRIENDS). A project on Next Generation Internet technology (ING project) starts early 1999.

1.2.1 The GigaPort Programme

GigaPort is a research programme of the Dutch government on Next-Generation Internet in the Netherlands. The aim is to achieve a leading position within a new world-wide economy, in which information and communication technology (ICT) play a major role. It is an initiative of the Ministries of Economic Affairs, Transport and Communications, and Education, Culture and Sciences. Within GigaPort, Dutch and international companies, universities and research institutes cooperate. Through a mix of government and private funding the GigaPort budget amounts to 162 Mfl for a period of four years.

The programme consists of two parts: *GigaPort Network* and *GigaPort Applications*. *GigaPort Network* (coordinated by SURFnet) concerns mainly the construction of a next-generation Internet infrastructure: the upgrading of the national research network and the international connections to Gigabit-speed. The aim of *GigaPort Applications* (coordinated by the Telematica Instituut) is to acquire a lead in the field of Internet applications in order to give the Dutch business sector a competitive edge. CTIT researchers will be involved both in the GigaPort Network and the GigaPort Applications programme, through the Internet Next Generation and FRIENDS projects, to start in 1999.

1.3 Advanced Network and Technology Centre (ANTC)

ANTC (Advanced Network and Technology Centre) is CTIT's expertise centre and research laboratory on advanced networks and applications (network technology, measurements, and management). ANTC operates as a partner in leading network systems research, through which CTIT's cooperation with industry get shape. This liaison role yields valuable knowledge related to the design of complex multi-service network systems as well as the deployment of advanced networking technology in these systems.

ANTC has a well equipped laboratory with state-of-the-art networking technology and measurement tools, and well trained staff. It concluded partnerships with leading vendors

of advanced networking technology, in particular Cisco, FORE, and Torrent. The expertise is focused on three areas:

- design of complex multi service network systems,
- deployment of advanced networking technology in these systems, and
- performance and conformance analysis of these systems.

1.4 Distinguished Visitors Programme

CTIT has introduced a "Distinguished Visitors Programme", through which leading scientists are invited to visit CTIT on a temporary basis, in order to give an impulse to specific research areas. Under this programme, the following guests visited CTIT in 1998:

- Arantza Anton Gil, Ericsson Spain (3-28 August 1998), BELSIGN project.
- Prof. Eugenio Villar Bonet, Microelectronics Engineering Group, University of Cantabria (3-28 August 1998), Work: ADA specification of AAL protocols.
- Dr. Vidyadhar Kulkarni, University of North Carolina, Chapel Hill, N.C., Professor of Operations Research (22-23 June 1998), Talk: " Bounds for second order fluid models"
- José Bidarra de Almeida (CENTED-Universidade Aberta, Lisbon; educational sciences; November 1998 - March 1999),
- Agus Rahardja (University of Singapore, educational sciences, 6 March 1998 - 6 June 1998)
- Florin Popentiu (University of Bukarest; software engineering).

2 Telematics Graduate School

At the end of 1997, the Telematics Graduate School (TGS) was established; in May 1998 it received official recognition from the Dutch Academy of Sciences. TGS is complementary to CTIT and is intended for graduate students who want to obtain a Ph.D. degree in telematics. The research of the TGS Ph.D. students falls within the CTIT research programme. The director of CTIT, Prof. Ignas Niemegeers, is also director of TGS. However, CTIT and TGS are not completely equivalent: some CTIT research groups participate in other, more discipline oriented, graduate schools: IPA (software algorithms), SIKS (knowledge-based systems), BETA (business engineering and technology application), MRI (mathematics), COBRA (communication technology and opto-electronics), and ICO (educational sciences). The *multidisciplinary* orientation of its research clearly distinguishes TGS from these other graduate schools.

2.1 TGS Educational Programme

The educational programme of TGS is intended to offer the students a broad knowledge on telematics at a non-expert level, but with the depth needed for being professionally active in the multidisciplinary telematics area, as well as expert in-depth professional knowledge and skills within one of the telematics disciplines. TGS has a four-year programme that reflects both the content-specific and professional objectives of the graduate school.

Main elements in the educational programme are:

- *Core modules*, relating to particular core research areas in telematics, for instance network technology, telematics applications, educational technology or human factors. The objective is to get familiar with key-concepts, methods and theory in a discipline at a level that is appropriate for operating and working in a multidisciplinary research team.
- *Advanced modules*, relating to the telematics discipline that is the particular focus of the Ph.D. dissertation. The objective is to acquire in-depth knowledge, skills and expertise within the specific discipline.

- *Workshops*: every half a year a workshop is organized on a specific research topic within telematics. During these workshops, Ph.D. students can present their work and take part in discussions.

2.2 TGS Students

At the start of TGS, 49 Ph.D. students were enrolled from four faculties, CTIT and the Telematics Institute.

Faculty	total end 1998	graduated in 1998	appointed in 1998
CTIT autonomous	15	0	9
Computer Science	19	4	1
Electrical Engineering	6	2	1
Mathematics	2	0	0
Educational Science and Technology	3	2	0
Telematica Instituut	4	2	0
TOTAL fte	49	10	10

Figure 1: Ph.D. students per faculty / research institute in 1998

3 Overview of 1998 research

3.1 Structure of the research programme

CTITCTIT Research Programme is structured into research areas and clusters of research areas. The choice of areas is motivated by the external (societal and economic) relevance of the areas, thus reflecting the external orientation of CTIT research. Consequently, research of individual groups can be programmed under more than one area. Area clustering reflects CTIT's view on telematics: some areas are concerned with the primary goal of telematics research, i.e., designing telematics systems or user environments; other areas are concerned with the design methods and techniques for this; and yet other areas are concerned with the enabling technologies.

The following figure gives the structure of the research programme:

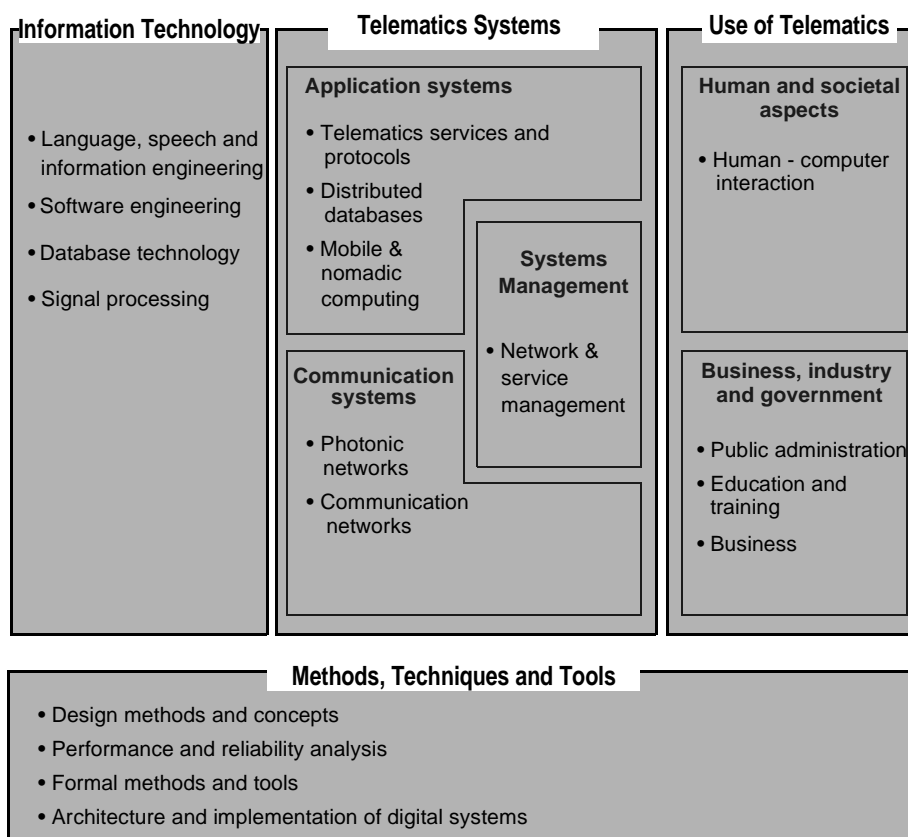


Figure 2: Structure of CTIT Research Programme

3.2 Overview of the Research Areas

In this section we give a short overview of the research areas defined in CTIT research programme. For each area we give a short description, indicate who is responsible for this area and give a short overview of the major projects that address this area.

3.2.1 Information Technology

This cluster is concerned with the development of technologies that enable the engineering of telematics systems and user environments. The cluster consists of the following areas:

- I1: Language, speech and information engineering.
- I2: Software engineering.
- I3: Database technology.
- I4: Signal processing.

3.2.1.1 Area I1: Language, speech and information engineering

Area leader: Prof. dr. F.M.G. de Jong

Applications enabled by the technology corresponding to Language, Speech and Information engineering are conceivable and/or currently developed for domains where there is a need for information content processing, for easy access to information sources, and for man-machine communication. Electronic information content has become a key element in everyday life. Natural language, the basic carrier of information, can have many different realizations. It comes as speech and as text. Automating the process of written and spoken language understanding requires the availability of various technologies, including text processing, speech processing, and techniques for the handling of context dependent aspects of language, such as knowledge engineering, and expertise on handling meta-information. By focusing on these technologies the area addresses the needs following from the ICT functionality required by service providers, professional content providers and document production departments. The area makes the linguistic knowledge available that supports document-intensive processes in distributed enterprises and that helps to consoli-

date distributed knowledge into collaborative document spaces. Moreover, it provides tools for the use, reuse and commercial exploitation of digital information among the general public.

Projects

TWENTY-ONE (Telematics Applications Programme / 1996-1998; CTIT involvement: 0.75 fte/year) aims at the improvement of the distribution and use of multimedia documents. The tools developed facilitate access to information for readers who are not native speakers of the language in which the documents are written. The technology developed by the project is domain independent. At a technical level, improved document access is achieved by use of approved natural language processing technology, knowledge-based image analysis, and telecommunication-based information technology, as developed in earlier national and European projects. The technology not only makes use of the current infrastructure and de facto IETF standards, but also contributes to standardisation within the new generation of internet tools and applications.

POP-EYE (Telematics Applications Programme / 1997-1998; CTIT involvement: 0.75 fte/year) built a demonstrator of a multilingual film and video indexing system. Pop-Eye used natural language processing to index and partially translate text captions that were used to subtitle audio-visual programmes. These multilingual indexes can be used within broadcasting companies, across the internet, or via an intranet, to help producers to locate and retrieve video fragments to be used in new television productions.

DRUID (1998-2001; CTIT involvement: 1.75 fte/year), a project performed within the "Telematica Instituut", aims at the development of tools for the indexing and retrieval of multimedia content. The research will advance existing insights and exploit the potential synergy between technologies from various domains: language & speech technology, image processing and database technology. In terms of the objects to be made available for retrieval, the project will cover continuous objects containing text and/or speech elements (e.g., video and audio fragments), as well as static objects, ranging from paper documents

and textually annotated images, to web pages. Both fundamental research, as well as prototyping, tools testing and usability studies are part of the project.

OLIVE (Telematics Applications Programme / 1998-1999; CTIT involvement: 0.5 fte / year) is developing a system which automatically produces indexes from the sound track of a programme (television or radio). This allows archives to be searched by keywords and corresponding visual or soundtrack material to be retrieved. The system will facilitate production of broadcast material which incorporates existing radio and video material, for example, news and documentaries. It will also be a valuable tool for programme researchers designing new programmes and other content providers, such as advertisers. Through the provision of bibliographic material, transcripts and video stills, the system will save time by allowing material to be pre-viewed before it is actually retrieved from an archive.

3.2.1.2 Area I2: Software engineering

Area leader: Dr.ir. M. Aksit

This area aims at developing architectures, methods, patterns, frameworks and components for designing cost-effective telematics systems.

Application demands are continuously evolving and are very diverse. Increasingly new services are required (for example for nomadic and agent-based computing), and the fulfilment of the quality of service requirements is becoming more and more important. A traditional way of dealing with such problems is to define a set of specialized services. Implementing specialized software modules and functions may soon become infeasible, because of the large number of different modules and functions. An alternative approach is to construct software from simpler components that correspond to the fundamental aspects of applications and services. Unfortunately, the current object and component-oriented technology as exemplified by Java, CORBA, DCOM and OMG component models, is not able to support the evolving demands effectively. Constructing software systems from basic components may be problematic, because for certain aspects the software engineers may be forced to re-implement and/or modify the basic components each time a new service is

implemented. These so-called composability and/or inheritance anomaly problems are particularly evident for middleware applications and services, where software components are largely concurrent, cooperating, distributed and layered.

In 1998, a number of composability problems have been identified that software engineers may experience while construction middleware systems. This study was carried out within the context of nomadic and agent based middleware platform design. Secondly, a technique has been introduced to derive software architectures and frameworks from domain knowledge. Further, since middleware applications are largely concurrent, designing and composing concurrent components are considered essential. A mechanism has been proposed to design composable concurrent components. Here, a large set of example problems is given. Finally, to fulfil the quality of service requirements, which demand balancing various quality factors such as adaptability and performance, a new technique termed as design algebra has been introduced. Design algebra makes the quality factors explicit and introduces new ways to compare alternative implementations.

The research has been carried out in the projects:

- Application of MIDdeware in Services for Telematics (AMIDST) (Telematica Instituut / 1998-2002; CTIT involvement: 5.85 fte/year).
- Formalization of design patterns. (1 fte)

3.2.1.3 Area T2 and I3: Distributed databases & Database technology

Area leader: Prof. dr. P.M.G. Apers

The goal of this area is to control the complexity of database systems and their applications in a distributed environment. It deals with the design and performance issues of object-oriented databases to support applications domains like, multimedia, geographic information systems (GIS), and workflow management. Two subareas can be distinguished: Multimedia Databases and Models and Tools

1. Multimedia databases

In this area four projects are carried out:

- **MIRROR** (1995-1999; CTIT involvement: 1.5 fte) project deals with multimedia databases. An experimental multimedia database system has been designed and partly implemented. The design decisions are based on the similarities between multimedia and text retrieval; this resulted in an architecture to incorporate user relevance feedback, the combination of evidence from several media, and the classification of multimedia objects. Moreover, the intrinsic distributed nature of multimedia systems led to the inclusion of CORBA in the before-mentioned experimentation platform.
- **Usage of multimedia for tele-education**, a Ph.D. project within the **IDYLLE**-project (1996-2000; CTIT involvement: 5.6 fte/year) is concerned with 'Labelling of Units of Learning Material (ULMs). It focuses on reuse of multimedia learning material, which is needed to allow retrieval and which precedes reuse. It will contribute to the IDYLLE-demonstrator to be built in 1999. ULMs delivered on request by a system, are generally ranked according to estimated relevance for the user. A ranking function presupposes a distance function that computes the distance between two labelled ULMs.
- The **AMIS**-project (1998-2002; CTIT involvement: 1.2 fte) concerns multimedia query processing. The starting phase of the project was used to master the details of an experimentation platform to be used for multimedia applications. Contributions to the distributed architecture and implementation of a multimedia database system mentioned in the MIRROR project were made. The research now narrows down to optimization of image queries. This project is funded by SION. Other partners are: University of Amsterdam, CWI, and University of Utrecht.
- The **Digital Media Warehouse Systems (DMW)** project (1998-2002; CTIT involvement: 2.25 fte/year) deals with the integration of semi-structured data in the MIRROR architecture. In Internet and Intranet environments it turns out that Web pages contain a lot of inherent structure. This structure can be used to improve searching the Web. This project started mid 1998 within the framework of the 'Telematica Instituut'. The first phase of the project was focused on making a survey of research done on semi-structured

data and on implementing a first prototype. Other partners are: CWI, Telematica Instituut, KPN, and Syllogic.

- In the **MAGNUM** (1994-1998; CTIT involvement: 2 fte) project MOA, an open object data model to efficiently support database applications, was developed. Current database systems are not able to accommodate a wide variety of applications. MOA is a layer on top of the low level object server Monet, which allows for the definition of new data structures including an efficient implementation. This idea has been implemented on top of Monet, a low level object server, and tested with applications like GIS, information retrieval, and semi-structured data. Other partners are: CWI, University of Amsterdam, and TUE.

2. Models and Tools

In the area of Models and Tools there are two projects:

- The **Verdi** (VERification of Database Integrity) project is concerned with automatic control of integrity constraints in object-oriented databases. The main efforts have resulted in a theorem-prover based analysis tool used for verification of transaction safety. The tool can check whether a transaction respects consistency of the database (safety) and provides limited user feedback in the case of constraint violations. Work is also aimed at extending the tool to check commutativity of transactions. Future work will include object-oriented databases equipped with active rules as further support for integrity maintenance.
- The **QUANTUM** project is a collaboration with the Amsterdam division of Compuware. In this project the goal of the UT team is to statically check process aspects of object-oriented databases, very much like static checks of data aspects (type checking) is by now common use. As a first result a tool PAUL has been developed that does limited process checking in a general OO setting: protocol checking. The tool signals inconsistencies between protocol specifications, and provides counter-examples to help the user to resolve the error. Future work is directed to extending the process aspects that can be checked, in particular dynamic creation of objects.

Besides the above projects there is the **IMPACT** project. Its focus is on usage of parallel databases to support financial applications. There is special interest in combining OLTP and DSS-queries on one databases. An overview of OLTP has been provided. Initial ideas how to combine OLTP and DSS are being developed.

3.2.1.4 Area I4: Signal processing

Area leader: Dr. ir. C.H. Slump

The focus of the research is on applications of signal processing for telematic systems. The scope is wide and comprises the full design trajectory: from the research and development of signal processing algorithms, the real-time implementation on DSPs or programmable hardware including embedded systems, design and realization of hardware PCBs, to the design and realization of real-time signal processing ASICs. In many cases the functionality added to an application can be characterized as computational intelligence (adaptive signal processing, neural networks, fuzzy reasoning etc.). Topics include: acoustic and line echo cancelling, adaptive equalization in mobile communications, spatial equalization in DECT systems, mobile communication (speech and data) for public safety (TETRA), speech processing and compression, video processing and compression, processing for binaural hearing, audio and video processing for multi-media applications (reproduction and display improvement), and processing for DAB.

3.2.2 Telematics Systems

The Telematics Systems cluster is concerned with the design of telematics system infrastructures and consists of the following subclusters:

- Application systems, which addresses the (infra-) structures for access to, use of, and interworking between applications. Three areas are defined:
 - T1: Telematics services and protocols
 - T2: Distributed databases (see description under 2.1.1).
 - T3: Mobile and nomadic computing.

- Communication systems, which addresses the infrastructures for information exchange. Two areas are defined:
 - T4: Photonic networks.
 - T5: Communication networks.
- System management, which addresses management of services, networks and network elements. A single area is defined:
 - T6: Network & service management.

3.2.2.1 Area T1: Telematics services and protocols

Area leader: Dr. ir. M.J. van Sinderen

The area Telematics services and protocols aims at the development of advanced telematics services and protocols. Telematics services directly support the actual tasks of the end-users of telematics systems; the protocols (often referred to as application protocols) that provide telematics services operate over a communication infrastructure. This area therefore bridges the gap between communication networks and telematics applications. Important qualitative characteristics to be pursued in this area are ‘openness’, ‘portability’ and ‘transparency’ with respect to distribution aspects. The research is directly linked to the development of standards for telecommunications/telematics services and distributed computing services in multi-vendor environments.

The research topics in this area are grouped into three sub-areas:

- *application protocol engineering*: this research is concerned with concepts, methods and techniques that can be used in the application protocol design process;
- *multimedia telematics services*: this research is concerned with application protocols that address the integration of multiple media in a single telematics service;
- *QoS (Quality-of-Service) in telematics services*: this research is concerned with the matching of application QoS requirements with network QoS capabilities.

This area contributed to research and development in the projects Mesh, Idylle and Amidst (see below), and was instrumental in the demonstration of the Mesh middleware platform (e.g., at the Mesh closing ceremony, December 2nd, in Enschede).

Projects

This area has contributed to the following projects:

- **AMIDST** (Telematica Instituut / 1998-2002; CTIT involvement: 5.85 fte/year) has been defined and initiated in the reported period with contributions from this area. Initial state-of-the-art studies have been performed on middleware technologies and QoS issues in the middleware context.
- **IDYLLE**-project (University of Twente / 1996-2000; CTIT involvement: 5.6 fte/year). A part of the Idylle project is concerned with the development of a flexible educational infrastructure that enables educational actors to plan, perform and evaluate courses. This area contributed to the prototyping of the planning support part of this infrastructure.
- **MESH** (Ministry of Economic Affairs / 1997-1998; CTIT involvement: 4.5 fte/year). In this project a TINA-based middleware platform has been developed in collaboration with other Mesh partners. The platform has been implemented and demonstrated, and will be used as the basis for an integrated engineering and deployment platform in a future project (Friends).

3.2.2.2 Area T3: Mobile and nomadic computing

Area leader: Prof. dr. S.J. Mullender

Mobile Computing has evolved as a consequence of miniaturization and ever decreasing power consumption of components. The technology used in mobile telephony can be combined with those for hand-held and notebook computers to produce powerful devices that can be used in a wide variety of applications. Important usage areas are: sharing information with the work place while on the road, multimedia person-to-person communication, electronic shopping, electronic contract exchange, navigation. Achieving this requires

research in the areas of overall systems architecture, power-management architecture, security architecture, and communication architecture. The Huygens Laboratory for Systems Research has concentrated its effort on two areas of research: low-power mobile computing and operating-system support for real-time systems in particular for multimedia. Huygens hosts a number of closely related projects.

Projects

- **Moby Dick project** (Esprit Long Term Research / 1997-1998, CTIT involvement: 1.5 fte/year) addresses the design of hand-held computers, requiring power-saving capabilities and operating-system-software to exploit this. The dynamics of such a mobile system requires reconfigurable hardware and a Quality-of-Service driven operating system. The underlying architectural model consists of a switching fabric interconnecting system parts. To transfer data between devices and memory, Moby Dick uses virtual circuits to interconnect processors, devices and memory. A connection-oriented switch has been designed and tested. Adaptive wireless communication for multimedia traffic is another issue in the project. Under design is an energy-efficient MAC protocol and data link layer that is amenable to Quality-of-Service requirements. A reconfigurable processor suitable for fast, low-power encoding/decoding operations on data streams has been designed. Its built-in security module is an important contribution.
- **Pegasus II** (Esprit Long Term Research / 1996-1999) Project partners are: Universities of Cambridge and Glasgow, the Swedish Institute for Computer Science and APM Ltd. Pegasus II is a follow-up project to Pegasus I which ran from 1992 to 1995. Pegasus has been a very successful project resulting in a number of international publications and an operating system called Nemesis. Nemesis will be made available outside the project in 1999. The Huygens Lab worked particularly on the Nemesis mixed-media storage system, Clockwise. Clockwise is a storage server that can combine hard real-time traffic with best-effort traffic, guaranteeing real-time deadlines while providing low-latency to best-effort traffic. Clockwise will be finished in 1999 and then it will be made available both on Nemesis and on Unix systems.

- **Amis** (1998-2002) is a Dutch national collaborative project supported by NWO. Participants are the Universities of Amsterdam and Utrecht, CTIT (two groups) and CWI, the Centre for Mathematics and Computer Science. The Huygens Laboratory is building a combined secondary/tertiary high-performance media data store which is being based on Clockwise. Amis started in 1998, so results will not be forthcoming until the second half of 1999.

There are two other ongoing activities. The **Helicon project** investigates possibilities of systems in and around home networks. The **Tukker project** is on fundamental issues for schedulability analysis in real-time and multimedia kernels. These projects have led to a series of external publications and have drawn attention of external researchers of industry and academia.

3.2.2.3 Area T4: Photonic networks

Area leader: Prof. ir. A.M.J. Koonen

This area focuses on broadband (all-)optical multipoint networking (especially at the lower network levels like MAN/LAN/residential access), exploiting the unique characteristics of the fibre (low attenuation, huge bandwidth) in a multi-dimensional way (switching and routing in the wavelength, time and space dimension). A specific topic is the disclosure of the wavelength domain for additional networking flexibility in combination with innovative (hybrid network) management and control concepts.

Projects

- **Optical Packet- and Circuit-switched Optical Ring Networks employing Multi-Wavelength Techniques** (IOP Electro-Optics projects IEO 94100 and IEO 96101 / 1995-1999; CTIT involvement: 3.2 fte/year). In 1998 a large part of the laboratory demonstration of an all-optical multiwavelength ring network has been realized, including a

home-built optical fibre amplifier, some optical transmitters and receivers, and the network control- and management system. Part of the measurements has been done at the KPN Research labs in Leidschendam. Furthermore, the behaviour of Erbium-doped fibre amplifiers in ring networks was theoretically investigated by means of numerical simulation. Ton Koonen has continued his chairmanship of the overall IOP Electro-Optics Cluster 1 Programme.

- **FLAMINGO** (Multiwavelength Optical Local Access Network Supporting Multimedia Broadband Services; STW / 1998-1001; CTIT involvement 2.2 fte) One of the research activities concern the design methodology and performance analysis of the Physical Layer for Flexible Multiwavelength Optical Local Access Network, focusing on non-ring network topologies. A start has been made with a refinement of the problem formulation, and an identification of the physical building blocks needed. Cooperation has started with the Applied Mathematics faculty concerning wavelength routing algorithms.

In the European ACTS projects **AC028 TOBASCO** and **AC349 PRISMA** (report: see under T5 Communication networks), Ton Koonen has acted as project manager.

3.2.2.4 Area T5: Communication networks

Area leader: Dr. Ph.F. Chimento

The communication networks area has, as its main study, network control in all of its aspects. What we mean by network control is just this: a set of concepts algorithms, protocols, formats, and messages, all of which are used to provide, in real time, the services of the network, and which control the network itself and the communication between end-users that the network provides. This is dedicated to the control of lines, switches, buffers, frequencies, wavelengths, bandwidth, error rates, CPU cycles, in short, all the physical resources that the network comprises.

Projects

- **BELSIGN** (Behavioural Design Methodologies for Digital Systems; Human Capital and Mobility Network / 1994-1998; CTIT involvement: 1 fte/year). Active research took place in the area of high-speed network architectures. This resulted in the design and specification of a high performance and parameterizable architecture for sending and receiving multiple ATM adaptation layer protocols. A very important achievement was the specification of the transmitting entity in ADA. All this work was carried out in close cooperation with the University of Cantabria.
- **INSIGNIA** (Intelligent Network and B-ISDN Signalling Integration on ATM platforms; ACTS / 1996-1998; CTIT involvement: 2 fte/year). CTIT part of this project focused on two areas: first, the area of performance analysis of the Intelligent Network nodes in the system which was performed by the Quantitative Methods discipline group. The Communication Systems discipline group focused on the measurement of the prototype system by various means, including specialized measurement instruments developed by project partners.
- **TOBASCO** (TOwards Broadband Access Systems on CATV Optical networks; ACTS / 1996-1998; CTIT involvement: 0.75 fte/year). The major goal of this project is to provide broadband interactive services by using a hybrid fibre CATV network in combination with High-Density Wavelength Division Multiplexing (HDWDM) technology.
- **PRISMA** (Photonic Routing and Interactive Services for Mobile Applications: ACTS / 1998-2000; CTIT involvement: 1.5 fte/year). The objective of the project is to develop strategies for dynamic reconfiguration of fibre-wireless networks by means of HDWDM techniques for the support of UMTS and MBS application.
- **FLAMINGO** (Multiwavelength Optical Local Access Network Supporting Multimedia Broadband Services; STW / 1998-1001; CTIT involvement 2.2 fte). The major objective of the project is to investigate promising technological advances in the area of Gb/s throughput optical telecommunications regarding their capabilities to support broadband multimedia services in optical local access networks. This project addresses important

design problems in WDM-based optical networking, ranging from the design of integrated optical components to network and protocol issues.

- **SURFnet Infrastructure** (SURFnet / 1998; CTIT involvement: 0.4 fte). During 1998, the SURFnet4 projects included experiments with SURFnet, the University of Utrecht, and with the TF-TEN group on the ATM Private Network-Network Interface (PNNI). In addition, we broadened the focus of the SURFnet4 work to include a number of IP experiments which were run together with the SURFnet Expertise Centre, the University of Utrecht and SURFnet. These included experiments with RSVP and IP Integrated Services, IPv6. We performed a joint experiment with KPN research and SURFnet on measurements for evaluating dynamic connection admission control and finally we did a series of short reports on measurements in IP with the Network Management discipline group of CTIT.
- **Internet Next Generation** (Telematica Instituut / 1999-2003; CTIT involvement: 8 fte) focuses on the development and introduction of Quality of Service (QoS) mechanisms for the Internet. Important topics of this project are the development of a new Internet Management Architecture and an Accounting Architecture. The project has the following partners: CTIT, TI-CO, Ericsson Business Mobile Networks BV (EMN), Ericsson Telecommunications BV (ETM) and KPN Research. The project plan has been defined in 1998 and the project starts on 1-1-1999.
- **Q-Bone** - CTIT, jointly with SURFnet and Northwestern University iCAIR has recently become a participant in the initial phase of QBone, the **Internet 2 Differentiated Services Testbed**. A great many questions about the provision of differentiated service in the Internet remain to be answered, but foremost among those questions is how the concatenation of heterogeneous networks (and indeed, the concatenation of heterogeneous routers along a path) affect the character of the service being provided. CTIT's activities fall into four areas: Measurement, Mechanisms, Policy and Management. The activities are carried out under the 'Internet Next Generation' project (see above).

3.2.2.5 Area T6: Network and service management

Area leader: Dr. ir. A. Pras

Systems management is concerned with the initialization, monitoring and modification of the operation of communication networks, network applications and telematics services. Until recently, systems management has been performed in an ad-hoc and enterprise specific manner. This is not adequate anymore for management of future telematics systems, which can be characterized by fast growing numbers of users, frequent configuration changes and multi-vendor equipment, and which demand management solutions that are scalable, flexible and open.

This area focuses on management solutions which are open (multi-vendor) and easy to adapt. The research is not restricted to the management of networks and network elements, but also covers the management of provided services, collaboration between multiple management domains, and customer control over their network view. New approaches based on WWW and CORBA technologies will be investigated. Specific research topics are: design and implementation of network management platforms and protocols, distribution of management functionality, accounting, management of transport networks, and management of network applications.

Results

This area contributed to research in the projects "Management of ATM networks", "INTESP", and "Internet Next Generation" (see below). Next to these projects, the area contributed to the IETF working group on Distributed Management, as well as the IRTF research group on Service Management, for which membership is by invitation only. The area also contributed to the BEAM group, a collaboration between the TU Braunschweig, EPFL (Lausanne), University of Pisa, IBM and the UT; this group is trying to establish a new IRTF research group on network management.

The "**SimpleWeb**" (<http://wwwsnmp.cs.utwente.nl/>), a web server that provides links and information on network management, is maintained as part of this area; the SimpleWeb server has nearly 4000 hits per day. Another webserver for which this area has (joint) responsibility (part of the editorial board), is the "**SimpleTimes**", which is an openly-available publication devoted to the promotion of the Simple Network Management Protocol. The SimpleTimes has more than 4000 subscriptions, and the server has 750 hits daily.

The area contributes (part of the editorial board) to the "Handboek Netwerk Management", a publication by tenHagenStam Uitgevers. Researchers within this area are member of the "Integrated Management '99" (IM99) Programme Committee, as well as the Technical Programme Committees of the EUNICE'98 and EUNICE'99 Summerschools. Contributions were made to the panel session of the fifth international conference on Intelligence in Services and Networks (IS&N'98). Finally researchers within this area are member of the SION Steering Committee on the Digital Information Super Highway programme.

Projects

- **Management of ATM networks** (SURFnet b.v. / 1998; CTIT involvement: 0.3 fte) investigates the management issues associated with the dutch SURFnet4 ATM research network. Activities that have been performed in 1998 include a state-of-the-art study on performance measurement techniques and tools, as well as the further development of the UTopia ATM management tool. This tool makes the creation and maintenance of cross connects in ATM switches easier, is web based, provides an easy to use user interface and includes different drivers to access ATM switches from multiple vendors.
- **INTESP** (Telematica Instituut / 1998; CTIT involvement: 0.05 fte consultancy) focuses on Internet Economics and the strategy development of Internet Service Providers. Members within INTESP are the Central Organization of TI (TI-CO), KPN Research, CTIT and WIK (Wissenschaftliches Institut für Kommunikationsdienste).
- **Internet Next Generation** (Telematica Instituut / 1999-2003; CTIT involvement: 8 fte) is a new project of the TI that focuses on the development and introduction of Quality of Service (QoS) mechanisms for the Internet. Important topics of this project are the devel-

opment of a new Internet Management Architecture and an Accounting Architecture. The project has the following partners: CTIT, TI-CO, Ericsson Business Mobile Networks BV (EMN), Ericsson Telecommunications BV (ETM) and KPN Research. The project plan has been defined in 1998 and the project started on 1-1-1999. This area provides the project coordinator, as well as a number of Work Unit leaders.

3.2.3 Use of Telematics

This cluster is concerned with the environment of the telematics system user and consists of the following subclusters:

- Human and societal aspects, which addresses the human behaviour in interactions with telematics systems, and the embedding of telematics systems in society. Two areas are defined:
 - U1: Human-computer interfaces.
 - U2: Models for human collaboration.
- Business, industry and government, which addresses the organisation and needs of specific user environments that (plan to) embed telematics systems. Four areas are defined:
 - U3: Public administration.
 - U4: Education and training.
 - U5: Business

3.2.3.1 Area U1: Human computer interaction

Area leader: Prof. dr. A. Nijholt

During 1998 CTIT research in the area of human-computer interaction was done at the Faculty of Computer Science (Language, Knowledge & Interaction), the Faculty of Philosophy and Social Sciences (Philosophy of Science and Technology, Systematic Philosophy) and the Faculty of Educational Science (Ergonomics and Educational Instrumentation).

The HCI research at the Faculty of Computer Science focused, as in previous years, on the role of speech and language in dialogue systems. Modest investigations in multimodality and virtual reality have now become important research issues in the group. The HCI related research topics in the Faculty of Philosophy and Social Sciences can be characterized as approaches to ethical, social, and political dimensions of information technology. In particular attention has been given to the role of virtual reality. At the Faculty of Educational Science HCI research took place in the Ergonomics group and the group Educational Instrumentation. It focused on theory, methods and design for computer-supported communication and collaboration. Moreover, work was carried out in the area of virtual coaches.

Below the main research efforts are summarized:

- Theoretical research on syntax (grammar learning, efficient and robust parsing), semantics (semantics of dialogue utterances) and management of dialogues continued. A start was made with an attempt to use formal methods from computer science (CSP) to model aspects of human-computer interaction.
- Theoretical research has been integrated in practical systems for WWW based information and transaction services. Ongoing research on a natural language dialogue system has been embedded in a virtual environment where multi-modal accessible intelligent agents assist users to obtain information and to perform tasks.
- A video communication system (GAZE) was developed that conveys gaze direction in multiparty communication by capturing looking behaviour of individual users using advanced eyetracking technology, and representing it as angular movement of user representations in a virtual world.
- Theoretical work based on the idea that communicative acts result in cognate meaning. A general theory of human action (semiotics) has been adjusted to formulate a particular theory ('Significant Communication') on human communicative actions. The design space for flexible work environments was studied in relation to technological developments, as well as the consequences for design methods and practice. A start has been made with the development of an evaluation tool for human-display interaction, based on this work.

Projects

- **Overheidsloket 2000** (Dutch Ministry of Home Affairs; CTIT involvement: 1.6 fte/year). In this project a public counter was set up and evaluated by means of user studies. The project was concluded in 1998. See also: area U3.
- **MEWO** (University of Twente / 1996-1998; CTIT involvement: 0.8 fte/year). In this project, it was investigated how methods can be designed for influencing the direction of scientific research by its societal aspects. The emphasis in the project has been on case studies:
 - user-centered design
 - the development of digital cities
 - design of a public counterThe project was concluded in 1998.
- **U-Wish** (Telematica Instituut / 1998-2001; CTIT involvement: 2 fte/year) stands for "Usability of Web-based Information Services for Hypermedia". In this project general design principles will be developed to attune web-based user interfaces to the user tasks and abilities. The principles will be based on experiments addressing the information transfer for three different applications. Subsequently, the principles will be integrated into a design method consisting of techniques and tools for the specification and assessment of web-environments. Finally, the method will be applied and evaluated for a new application. This research has started in the Autumn of 1998.

3.2.3.2 Area U2: Public administration

Area leader: Prof. mr. dr. H.M. de Jong

The research-area Telematics and Public Administration deals with seven specific issues: political-administrative relations, integration of service-delivery, information privacy in the health sector, institutional redesign of the welfare state, methodology of the social sciences, interactive policy making and the economy of public enterprise.

Projects

- **Informatisation and political-administrative relations**

The objective of this research project is empirical as well as normative. On the one hand the project aims to analyse the effects of the process of informatisation and the increased uses of computerised information systems in political-administrative relations. On the other hand the normative implications for the legal and organisational design of these relations in the light of the principle of separation of powers are taken into account. The year 1998 was devoted to developing a theoretical framework for analysing the empirical effects of informatisation. For this framework the theory of institutional change of Elinor Ostrom has been used. A distinction is being made between the direct effects of informatisation on the characteristics of the decision-making arena, and the indirect effects on the institutional rules governing the decision-making arena (position rules, authority rules and information rules).

- **Overheidsloket 2000** (Dutch Ministry of Home Affairs/Municipality of Enschede; CTIT involvement: 1.6 fte/year). The goal of the government project Public Counter 2000 is to use information technology to improve the delivery of the services provided by the local government to the citizens. A way to achieve this goal is to integrate services of the municipal government. In this project several pilot-studies have been conducted. The researchers of CTIT produced a third manual in the series of the research program of Public Counter 2000; “Deel III: Monitoren van geïntegreerde dienstverlening” (“Part III: Monitoring integrated service delivery”). In addition to this manual (on CD-ROM) three software programs have been produced: an electronic desklog, a program for performing and processing surveys and a program for analysing log files at a webserver.

- **The meaning of information privacy in hospitals**

The central question is “What is the meaning of (information) privacy in hospitals and in what way is this concept of privacy influenced by laws and regulations?” The theoretical perspective of this study is a “constitutive” approach to law, which places emphasis upon the concepts of “meaning”, “interaction” and “social norms”, whereby social context of action is taken as point of departure. This calls for a method in which detailed observational data are collected and attention is focused on individual “accounts” and

“actions”. In 1998 a start has been made with the empirical research. Five hospitals have been selected that differ in size and in character. The selection encloses a university hospital, a large urban hospital, a small urban hospital, a large regional hospital and a small regional hospital. Thusfar, two case-studies have been completed.

3.2.3.3 Area U3: Education and training

Area leaders: prof. dr. Jef Moonen and prof. dr. Betty Collis, Faculty of Educational Science and Technology, Division Instrumentation Technology (ISM)

This area comprises the instrumental support of processes that result in learning, communication and information acquisition. The support is being realized via media, in particular media based on ICT. This leads to educational instrumentation in the form of electronic educational material and educational environments. The characteristics of these media are the subject of research. The knowledge and skills needed to perform this research cross traditional disciplinary boundaries.

The application of advanced telematics systems and services to the educational delivery of the University of Twente itself is an area of considerable activity. Members of the group, in particular, prof. dr. B. Collis as Professor of Tele-Learning at the University of Twente, have participated in a Task Force on Telematics Applications in Education, have represented CTIT in the ECIU, UNISCENE, and EUNICE European consortia, and in various advisory roles at the university level (as well as external to the university). The group also stimulated the participation of CTIT in the "Web University" based in CERN, in Switzerland.

Results

In the Area U4 the major activities in 1998 have occurred (a) in the context of the IDYLLE Project, (b) in the context of the MESH Project, (c) in the preparation of project proposals

for submission in 1999, and (d) in various activities within the University of Twente relating to the applications of telematics to education.

Projects

- **IDYLLE** (University of Twente / 1996-2000; CTIT involvement: 5.6 fte/year).
 - Preliminary results of the project were presented at two (inter)national conferences (Onderwijsresearchdagen 1998, Enschede; Annual meeting van de 'Gesellschaft für Medien in der Wissenschaft', Dresden).
 - Several workflow experiments were completed and presented at international conferences in Gothenburg (CALISCE'98) and Paris (FORTE/PSTV '98).Also, IDYLLE worked cooperatively with the Educational Centre (OC) of the University of Twente to sponsor two one-day conferences during 1998.
- **MESH** (Ministry of Economic Affairs / 1997-1998; CTIT involvement: 4.5 fte/year). The particular contribution to MESH included the evaluation of the different tele-application scenarios and key participation in the tele-education scenario. Prof.dr.J.Moonen was project leader for WP 2 of MESH, responsible for all four pilot scenarios.
- **WAWS**. Together with Ericsson Business Mobile Networks B.V. a project relating to wireless access to WWW-based course-support environments has been defined (the WAWS-project). The final project proposal will be submitted in 1999.

3.2.3.4 Area U4: Business

Area leaders: Dr. V.M. Jones and Dr. P.M. Wognum

More and more companies are forced to collaborate with other companies with complementary skills to react flexibly to changing market demands, the introduction of new technology and globalisation of markets. Collaboration is often organised in collaborative projects of networks of organizations. Such networks exist only for the duration of one project. Shared goals and shared responsibilities are essential aspects of such networks. The temporary organisation of collaborative networks that collaboratively perform a product development

project (both tangible and non-tangible) is called a virtual enterprise. Collaboration with others, however, is not without problems. Especially the management and co-ordination of the tasks to be performed in a collaborative project present many challenges. The major challenge is to develop methods, tools, and techniques to support management and co-ordination of tasks in a collaborative project. These methods, tools, and techniques should incorporate not only the process aspects of a virtual enterprise but also the aspects related to people, means, and organisational arrangements. Concurrent Engineering is viewed as a framework that can improve the way of working within organisation with the goal to achieve shorter time-to-market, lower costs, and higher quality. To achieve the same goals in virtual enterprises, Concurrent Engineering principles have to be extended to Concurrent Enterprising principles.

Research at the Department of Technology and Organisation of the Faculty of Technology and Management Developments and results Research in the Faculty of Technology and Organisation is structured in three research programmes: **ConcERT** (Concurrent Engineering Research Twente), **ContINeth** (Continuous Improvement), and **OiN** (Enterpeneurship in Networks). The research builds on the innovation and organisation models developed in previous research. In 1998, the Faculty of Technology and Organisation has been involved in several European projects, working groups, and networks.

3.2.4 Methods, Techniques and Tools

This cluster is concerned with the development of methods, techniques and tools that support the design of telematics systems and user environments. The cluster consists of the following areas:

- M1: Design methods and concepts
- M2: Performance and reliability analysis
- M3: Formal methods.
- M4: Software tools.
- M5: Architecture and implementation of digital systems

3.2.4.1 Area M1: Design methods and concepts

Area leader: Dr. L. Ferreira Pires

The distributed systems of interest for telematics (business processes and telematics systems) have intrinsically complex functional requirements. This implies that their development process is intricate, such that it can only succeed if abstractions of these systems are applied in their development, according to precise design guidelines (methods and techniques). Adherence to standards may also be required especially for telematics systems, since it makes it possible for different manufacturers to produce these systems. This implies that abstractions and guidelines used in the development of standards also have to be internationally agreed in case the systems are subject to standardization.

The area contributed to research in the projects Testbed, Mesh and Amidst (see below). The area has also participated in the organising committee of the Middleware'98 conference (Windermere, UK), through C. Vissers and L. Ferreira Pires. Participants of this area contributed to the IDMS'98 conference in Oslo, Norway, and the Workshop on Software Architecture in Newcastle, UK.

Projects

This area has contributed to the following projects:

- **Testbed** (Telematica Instituut / 1996-1998; CTIT involvement: 1.55 fte/year). In this project the area has contributed to the improvement of the causality-based design model (related to Quartel's PhD Thesis) and applied this design model in case studies of business process modelling (related to de Weger's PhD Thesis).
- **MESH** (Ministry of Economic Affairs / 1997-1998; CTIT involvement: 4.5 fte/year). In this project a design methodology has been investigated based on viewpoints for the development of telematics systems in a TINA-based architecture. The methodology has been applied in the development of the Mesh platform architecture.

- **AMIDST** (Telematica Instituut / 1998-2002; CTIT involvement: 5.85 fte/year) This project has been defined and initiated in the reported period. Initial state-of-the-art studies have been performed on middleware architectures and related design models.

3.2.4.2 Area M2: Performance and reliability analysis

Area leader: Dr. V.F. Nicola

The deployment of modern telecommunication networks, such as broadband integrated service networks, mobile and wireless communication systems, poses numerous issues that need to be investigated. Efficient use of network resources should be achieved while providing the quality of service (QoS) required by the end-user applications.

The objectives of the research in this area are:

- To support the design of telematics applications and the underlying communication networks and infrastructures;
- To develop new performance evaluation methodologies;
- To build tools for the evaluation of performance and dependability of communication networks and telematics systems.

Within this area the Telematics Systems and Services (TSS) / faculties of Computer Science and Electrical Engineering and the Stochastics and Operations Research (SOR) / faculty of Applied Mathematics cooperate.

Achievements

- A dissertation was completed on the analysis of fluid models which are important for the modelling of telecommunication systems.
- Asymptotic analysis and/or efficient simulation (based on importance sampling) of queueing models have been considered for the prediction of quality of service (QoS) measures in telecommunication systems.

- Other efficient simulation techniques based on splitting methods (RESTART) have also been investigated. For some systems and/or measures, these techniques may prove to be easier to use and more robust than importance sampling methods.
- Applications of importance sampling for the estimation of bit error rate (BER) in mobile communication systems and WDM optical networks has been considered.
- New theoretical results are obtained for the analysis of job completion time in a failure-prone environment. Methods for the numerical inversion of transform results are being investigated.
- Performance aspects, such as scalability and the integration of mobile services, in intelligent networks have been investigated.
- Approximate queueing models are used for the performance analysis and comparison of access mechanisms in optical slotted ring networks.
- Experimental studies on traffic characterization and the impact of basic network functions has been performed using data from real sources.

Projects

- **INSIGNIA** (Intelligent Network and B-ISDN Signalling Integration on ATM platforms; ACTS / 1996-1998; CTIT involvement: 2 fte/year). The research of the TSS/QAM group focused on the area of performance analysis of the Intelligent Network nodes in the system.

3.2.4.3 Area M3: Formal methods and tools

Area leader: Prof. dr. H. Brinksma

There is an increasing need for reliable software, which is especially critical in areas such as communication protocols, distributed systems and real-time systems. Reliability can only be achieved through the use of rigorous design techniques. This has motivated a large

amount of research on design and implementation methods, and tools that support both the design and implementation phase.

The goal is to design and realise notations, methods and provide the foundations for tools that are used to develop and validate system specifications, and to transform these specifications into efficient implementations. As such this area is very closely linked with that of software tools with which it has many common activities. Examples of models and theories that provide the formal underpinning for this work are transition systems, process algebras, Petri nets, extended state machines, I/O-automata, event structures, and temporal and other modal logics. Important specification formalisms and semi-formal notations that are pertinent to the work in this area are LOTOS, SDL, Estelle and TTCN.

Projects

- **Cote de Resyste** (STW 1998-2002; CTIT involvement: 2 fte/year). This project is carried out in collaboration with Eindhoven University, Philips Research Laboratories and KPN Research. The main goal of the project is the development of methods, techniques, and tools to support the automatic generation of tests from specifications, as well as their implementation, execution and analysis. In this first year of the project a start has been made with the design of test tools, based on existing theory. This has resulted in the tool TORCH, which is an open architecture for the integration of test tool modules. Also a start has been made with working on case studies in collaboration with the industrial partners.
- **System Validation Centre (SVC)** (Telematica Instituut / 1998-2002: CTIT involvement: 2.2 fte/year) is devoted to fundamental and applied research in the validation of telematics systems. The aim is to develop, apply, evaluate and improve validation methods and tools that are used in the (automated) analysis of the (functional) correctness of real-life specifications, designs and products. Important validation techniques that will be studied include simulation, model checking, verification and testing. The project has started in September 1998. Here we report on preparatory research before and project research after the start of the project:
 - research has been done on stochastic process algebras and methods for their analysis. For the language SPADES this has resulted in a prototype tool based on discrete event simulation.

- research on partial order models (and their quantitative extensions) to obtain efficient representations of large state spaces has been continued successfully. A start has been made with the implementation of a tool based on finite prefix theory.
- experience has been gained with the use of literate programming techniques as a modelling tool in large validation projects.
- **DISC**: the DISC project was a six month project in cooperation with Lucent Technologies. The aim was the construction of a frontend for a compiler from PROMELA into an intermediate representation for multiprocessor satellite hardware. The project has been concluded successfully.

Activities

- Co-organisation of the Schloss Dagstuhl Seminar "Test Automation for Reactive Systems - Theory and Practice", Wadern, Germany, September 7 - 11, 1998.
- Fourth Dutch Testing Day (Nederlandse Testdag 1998, 15 October)

3.2.4.4 Area M4: Architecture and Implementation of Digital Systems

This area focuses on design methodology and fault tolerance. Design methodology aims at the development of a fundamental approach to high-level digital system design and in particular at developing a transformational design methodology for digital system architecture. Fault tolerance aims at methods to develop systems which maintain their functionality in the presence of malfunctioning hardware. In this research, special attention is given to the reliability and security of storage systems in the presence of malicious faults.

Projects

- **Dependable distributed storage systems** has been completed with a Ph.D. thesis. Research in this area will be continued. Attention will be paid to autonomous dependable

systems, in which we focus on security and safety, next to reliability. The results will find applications in, among others, secure networks and authentication servers.

- Research on **design methodology**, with applications in telematics and with emphasis on transformational design, the HW/SW interface, retargetable code generation and application of VHDL in the design trajectory, continues as expected.
- **Transformational design** provides correctness by construction. The transformational design approach strongly depends on the design language and its formal semantics. A current re-design of our design language SIL, initiated from the semantical model, looks very promising and might solve the problem of transformation generation.
- **Synthesis based on VHDL** has been made possible by the construction of a compiler that semantically correctly translates almost full-fledged VHDL to a signal flow graph description. It has been show that the execution model of VHDL, which remains after compilation in the signal flow graph description, can in most cases be automatically removed by means of behaviour preserving transformations.
- A new project on **design methodology** for high throughput signal processing was started in April. In this project an existing design flow from a specification in C to a description in a signal flow graph is studied and should lead to an interactive compiler that replaces the current design trajectory. This work is funded by Philips Research.

4 CTIT Organization

4.1 Board and Management

CTIT is directed by a Board, consisting of four external members and one internal member: *Prof. Dr.-Ing. Dr. HC multi P.J. Kühn* (Chairman, University of Stuttgart, Germany), *Prof. Dr. E.J. Neuhold* (GMD-IPSI, Darmstadt, Germany), *Prof. ir. M. Antal* (Technical University of Eindhoven, NL), *Prof. ing. W. Zegveld* (Rijswijk, NL) and *Prof. dr. ir. A. Nijholt* (University of Twente, NL). The Board supervises the research policy, the institute's finances and the performed research, and assesses the five-yearly research programme of CTIT.

The Scientific Director, *Prof. dr. ir. I.G.M.M. Niemegeers*, assisted by a Management Team, is charged with the day-to-day management of the institute and determines the institute's strategy.

4.2 Organizational Structure

CTIT is one of the four major research institutes of the University of Twente. Six faculties of the University of Twente participate: Computer Science, Electrical Engineering, Educational Science and Technology, Applied Mathematics, Technology and Management, and Public Administration. At the beginning of 1998, the Cognitive Ergonomics group of the faculty of Philosophy and Social Sciences, which was involved in CTIT previously, moved to the faculty of Educational Sciences and Technology.

Participating faculties have committed for a period of five years scientific personnel and supporting staff to CTIT, to carry out its research programme. Researchers from these faculties, together with researchers employed by CTIT itself, collaborate in CTIT research projects. Research groups are represented by their area leader in the Scientific Council, an advisory body for research policy.

University of Twente

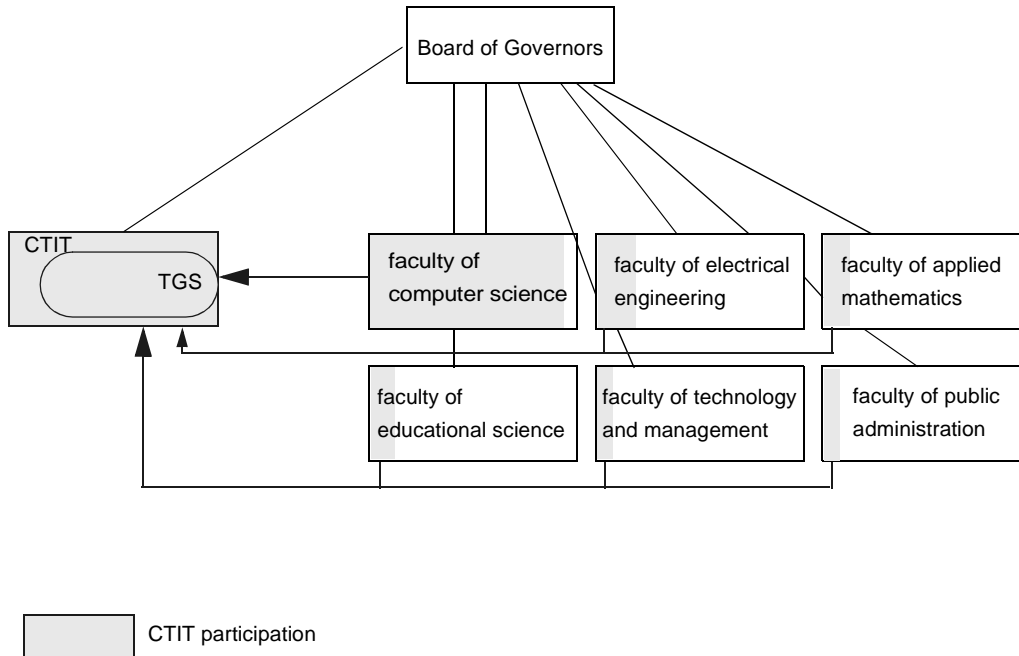


Figure 3: CTIT participation

The first period of five years ended officially at the beginning of 1999. Due to plans of the Board of Governors of the University at that time to reorganize the faculty structure of the University, it was decided to extend this period, and accordingly the commitments of the faculties, with nine months. New commitments will be made as soon as the new structure is clear (expected by September 1999).

Early 1999, it was decided to position the four major research institutes directly under the Board of Governors of the University, at the same level as faculties. This will cause major changes in budget allocations to CTIT. Also the position of personnel will change. The new status implies budget independency: budgets will be allocated directly to the institute, for which it can hire university staff from participating faculties. CTIT will have no research staff of its own anymore: all research staff will be formally appointed by faculties. The new structure will be implemented by January 1st, 2000.

4.3 Research Staff

The institute's manpower for 1998 is shown in Table 1. The units are fte's (full time equivalents, i.e., manyears).

faculty	total fte's
Computer Science	45.4
Electrical Engineering	12.6
Applied Mathematics	2.8
Educational Sciences	6.4
Technology & Management	1.0
Public Administration	1.0
subtotal	69.2
CTIT	32.8
total	102.0

Table 1: Contribution in manpower (fte's) per faculty in 1998

4.4 CTIT personnel

The number of people employed by CTIT increased further in 1998. The total number of personnel employed per 1-1-1998 was 42, per 31-12-1998 it amounted to 46 persons, in total 40 fte's (including supporting staff). In 1998 twelve employees left CTIT and sixteen new ones were appointed. The senior research staff has been increased in 1998 with the appointment of two senior researchers, one full-time position on Application Systems, and one part-time position on Mobile Communications.

It is still difficult to attract junior research staff, in view of the competition with industry. Companies are able to offer higher salaries and permanent contracts. For this reason CTIT is now attracting more and more research staff from foreign countries, especially from Eastern Europe, Latin America and Asia.

5 Institute's finances

The institute's budget in 1998 consisted for the main part of the capitalization of the commitments of the participating faculties. This budget remains under the formal control of these faculties. In addition to this budget, CTIT has its own budget. The total budget of 1998 is shown in Table 2. The units are Kfl (thousands of Dutch Guilders).

Faculty	1 st (direct) funding	2 nd (indirect) funding	3 rd (external) funding	total
Computer Science	9.233	975	1.615	11.823
Electrical Engineering	2.994	123	610	3.727
Applied Mathematics	345	60		405
Educational Sciences + Cognitive Ergonomics	1.385			1.385
Technology & Management	191			191
Public Administration	180			180
Total Departments	14.327	1.158	2.225	17.710
CTIT	1.388	177	2.891	4.456
Total CTIT	15.715	1.335	5.116	22.166

Table 2: CTIT budget in 1998 (in Kfl)

The estimated budget for 1999 is shown in Table 3:

total depart- ments	total CTIT (excl. depart- ments)	Total CTIT
17.710	4.090	21.800

Table 3: The estimated CTIT budget for 1999 (in Kfl)

5.1 CTIT budget

The financial state of CTIT (excluding involvement of faculties) in 1998 was as follows:

Centre for Telematics and Information Technology

Specification (in Kfl)			
expenditures		budgets	
Personnel		Central Budgets	
salaries	1.963	budget changes	266
social security costs	640	allocations	1.029
expenses other departments	(198)		
indirect personnel costs	200		
Total Personnel	2.605	Total Central Budgets	1.295
Total Housing	24		
Equipment		Third Parties	
depreciation equipment	20	External contracts	
purchasing equipment	146	2nd (indirect) funding	149
		3rd (external) funding	4.268
		Mutation 'Work carried out'	
		2nd (indirect) funding	28 ¹
		3rd (external) funding	(1.376) ¹
Total Equipment	167	Total Third Parties	3.068
		others	3
		Total	3.071
Materials		Internal revenues	
collections	1	other departments	7
materials	21		
administrative means	52		
Total Materials	74	Total Internal Revenues	7
Other Expenditures		Special revenues and expenses	84
services dept. CS	563		
communication facilities	26		
travel and meeting costs	250		
(external) contract work	42		
memberships	39		
contribution Telematica Instituut	1.000		
advisory costs	14		
managerial costs	56		
Total Other Expenditures	1.949		
Total Result	(361)		
TOTAL EXPENDITURES	4.456	TOTAL BUDGETS	4.456

1. this amount was still in the procedure of payment, when drawing up the annual account 1998; work has been carried out in 1998

The University of Twente allocated the following budgets to CTIT: 200 Kfl central allocation, 250 Kfl for the IDYLLE (= Tele-Education) project, and 750 Kfl for reinforcement of CTIT key areas as part of the University's incentives policy. Compared to 1997, the total revenue from external projects increased with 1.633 Kfl to 4.219 Kfl. An amount of 1.376 Kfl was still in the procedure of being paid at the time of drawing up the annual account (thus to be accounted for in 1999). The total revenue is 3.071 Kfl.

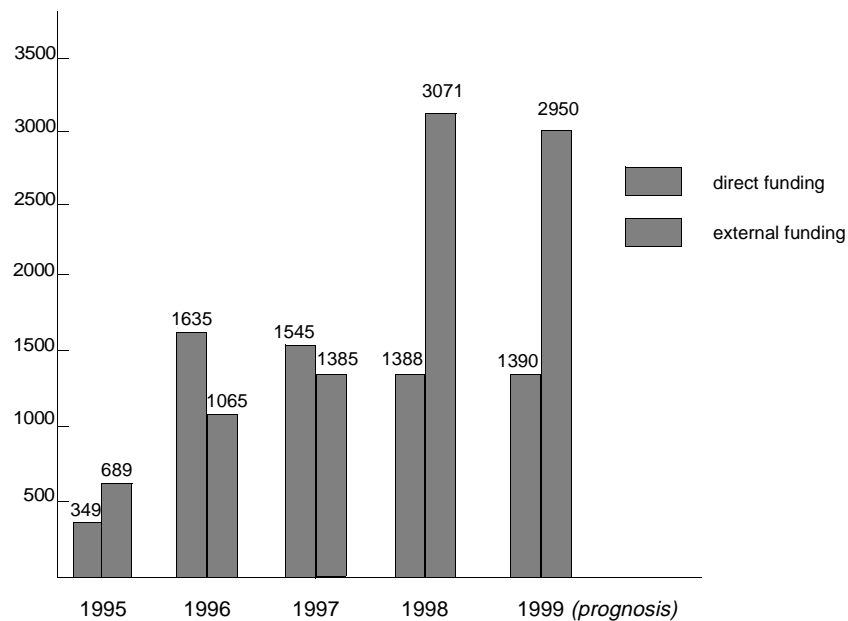


Figure 4: Annual turnover CTIT 1995-1999

Half of the external income came in 1998 from research projects within the 'Telematica Instituut'. However, there consists a ceiling of 2.3 Mfl for basic research within this institute. This ceiling has almost been reached in 1998 (2.2 Mfl); it is thus expected that the share of the TI-research on the total of external funding will decrease in the coming years as other external funding is expected to grow. Concluded projects have added 276 Kfl to the central reservations of CTIT. The year 1998 had, however, in total a negative result of 361 Kfl, to be covered from CTIT's central reservations. This negative result was caused by investments in the ANTC (Advanced Network and Technology Centre), salary costs of Ph.D.-students from budgets allocated in previous years (employment contracts do not run

in parallel with the allocation of budgets), and costs of the Service Level Agreement with the Computer Science faculty: in 1998 both the costs of 1997 and 1998 were covered.

The prognosis for 1999 is a slight decrease of income, mainly caused by a gap between projects for the European Fourth and the Fifth Framework Programmes, and the fact that research within the Telematics Institute is expected to remain limited to 2.3 Mfl.

6 Research projects

In 1998 the following projects were carried out in CTIT:

funding organization	project name	duration
European Union		
ACTS	<ul style="list-style-type: none"> - INSIGNIA (AC068) - TOBASCO (AC028) - PRISMA (AC 349) 	1995-1998 1995-1998 1998-2000
Telematics Applications Programme	<ul style="list-style-type: none"> - Twenty-One (IE21080) - Pop-Eye (LE 4234) - OLIVE (LE 4-8364) 	1996-1998 1997-1998 1998-2000
Human Capital and Mobility	- BELSIGN	1994-1998
International projects		
	Q-Bone	1998-
National projects		
Senter	<ul style="list-style-type: none"> - Optically Packet and Circuit-switched Networks - MESH 	1995-1999 1996-1998
Telematica Instituut	<ul style="list-style-type: none"> - Testbed (Business Process Re-design) - AMIDST - DRUID - DMW - Systems Validation Centre - U-WISH - MERITS 	1996-1999 1998-2002 1998-2001 1998-2002 1998-2002 1998-2001 1998-2001
HPCN (Dutch Foundation for research on High Performance Computing and Networking)	- IMPACT	1996-1999
SURFnet	<ul style="list-style-type: none"> - Management of ATM Networks - SURFnet Infrastructure - SURFnet Tele-education pilot (part of MESH) 	1994-1998 1994-1998 1997-1998
SION (Dutch Foundation of Informatics Research)	- PhD-project on Accounting Management, under its programme 'Electronic Super-Highway'	1998-2001
Ministry of Home Affairs	- Civic Center 2000	1997-1998
University of Twente		
	<ul style="list-style-type: none"> - IDYLLE (Tele-learning) - 3 Ph.D. projects 	1996-2000 1995-2000

Board

Prof. Dr.-Ing. Dr. HC multi P.J. Kühn (Chairman)

Prof. Dr. E.J. Neuhold

Prof. ir. M. Antal

Prof. ing. W. Zegveld

Prof. dr. ir. A. Nijholt

Members CTIT Scientific Council

M. Aksit (Computer Science)

P.M.G. Apers (Computer Science)

A.C. van Bochove (Electrical Engineering)

H. Brinksma (Computer Science)

Ph.F. Chimento (CTIT)

U. Faigle (Applied Mathematics)

L. Ferreira Pires (Computer Science)

B.L. de Goede (Computer Science/Electrical Engineering)

S.M. Heemstra de Groot (Electrical Engineering)

O.E. Herrmann (Electrical Engineering)

H. Johansson (Eurescom, Heidelberg).

F.M.G. de Jong (Computer Science/CTIT)

A.M.J. Koonen (Electrical Engineering/CTIT)

Th. Krol (Computer Science)

J.C. Looise (Technology and Management)

E.F. Michiels (Electrical Engineering)

J.C.M.M. Moonen (Educational Sciences)

S.J. Mullender (Computer Science)

D. Nauta (Philosophy and Social Sciences)

I.G.M.M. Niemegeers (Computer Science - Chairman)

A. Nijholt (Computer Science)

H. Pot (student)

A. Pras (CTIT)

J. Schot (Telematics Research Centre)

M.J. van Sinderen (CTIT)

J.H.A. de Smit (Applied Mathematics)

C.H. Slump (Electrical Engineering)

H. Thielmann (GMD-Darmstadt)

G.C. van der Veer (Philosophy and Social Sciences)

P.E. van der Vet (Computer Science)

Participating Groups

Faculty of Computer Science:

- Telematics Systems and Services (TSS - interfaculty group with the Department of Electrical Engineering)
- Man-machine Interaction
- Language Technology
- Knowledge-based Systems
- Databases
- DATA (Database Technology for Telematics Applications)
- Information Systems
- Software Engineering (TRESE)
- Formal Methods and Tools
- Laboratory for Systems Research (Huygens)
- Computer Architecture and Embedded Systems

Faculty of Electrical Engineering

- Telematics Systems and Services (TSS - interfaculty group with the Department of Computer Science)
- Telecommunications Engineering
- Laboratory for Network Theory

Faculty of Applied Mathematics

- Stochastic and Operations Research group

Department of Educational Sciences

- Educational Instrumentation

Department of Business and Management Sciences

- School of Management Studies

Department of Public Administration

- Management and Finance