

Computer Science Department
University of Twente.

Research Self-Evaluation 2003-2008

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Preface

The organizational unit¹ described in this self-evaluation is the Computer Science Department of the Faculty of Electrical Engineering, Mathematics, and Computer Science (EEMCS), University of Twente (UT). The department consists of nine Research Groups² (of which eight take part in the current self-evaluation). Each Research Group performs research on one or more coherent Research Themes.³

Version: 15 October 2009

¹ Called *Institute* in the "Standard Evaluation Protocol 2003-2009 for Public Research Organizations", VSNU, 2003.

² Called *Programmes* in the VSNU protocol.

³ Called *Sub-programmes* in the VSNU protocol.

Part A

Name: Computer Science Department

Date of establishment: September 1981

Institutional affiliations and formal responsibilities: All research in the Department is part of the Centre for Telematics and Information Technology (CTIT), a research institute of the UT.

Research area and mission: The department performs technical research on Information and Communication Technology (ICT). Its research mission is to perform multidisciplinary technical research in ICT related to applications that are relevant for society.

Formal cooperation and relations with other national and international research establishments: NIRICT, ESI, National Research Schools ASCI, IPA, SIKS.

1. Mission statement

The mission of the Department is to provide excellent academic education and to perform high-level multidisciplinary technical research in ICT related to applications in society.

Academic education relates education to research and technology and fosters a critical attitude of students. We provide academic education at the undergraduate and graduate levels.

Technical research in ICT is research in which ICT systems are designed, built and investigated. In the context of the CTIT our research is multidisciplinary. In line with our university mission of an entrepreneurial university, we aim at producing results that are relevant for problems and applications in society.

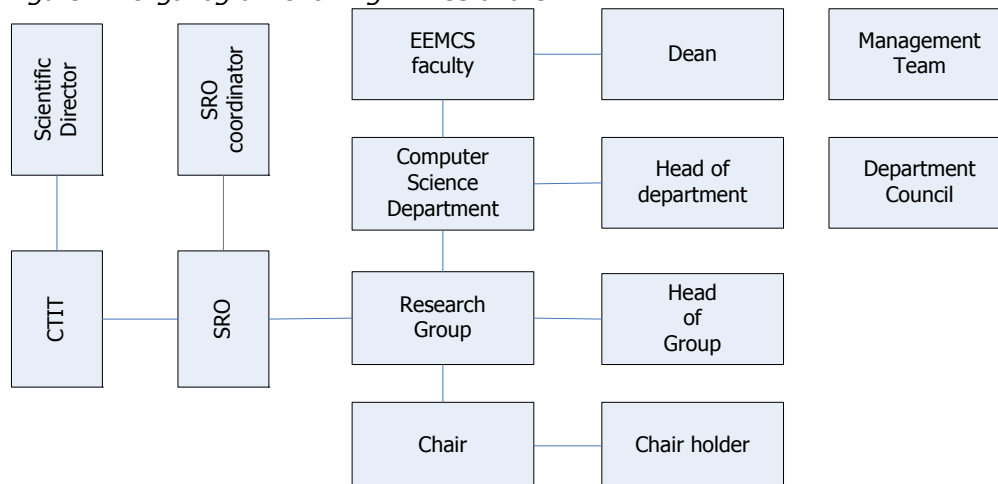
2. Leadership and management

Figure 1: The nine research groups in the Computer Science Department. CAES also participates in the Electrical Engineering Department and takes part in their assessment, rather than that of the Computer Science Department.

	Dean prof. dr. ir A.J. Moutaan
Scientific Director prof. dr. P.M.G. Apers	Computer Architecture Design and Test for Embedded Systems (CAES) Prof. dr. G.J.M. Smit
	Design and Analysis of Communication Systems (DACS) Prof. dr. ir. B.R.H.M. Haverkort
	Databases (DB) Prof. dr. P.M.G. Apers
	Distributed and Embedded Security (DIES) Prof. dr. P.H. Hartel
	Formal Methods and Tools (FMT) Prof. dr. J. C. van de Pol
	Human Media Interaction (HMI) Prof. dr. ir. A. Nijholt
	Information Systems (IS) Prof. dr. R.J. Wieringa (Head of Department)
	Pervasive Systems (PS) Vacancy (appointed from 1 May 2009: prof. dr. P.J.M. Havinga)
	Software Engineering (SE) Prof. dr. M. Aksit

The Computer Science Department consists of nine Research Groups. Each Research Group consists of one or more chairs, and one of the chair holders is also the Head of Group. Each Head of Group reports directly to the Dean of the faculty. The dean is responsible for the Degree Programmes at the faculty and for managing the faculty, including personnel management. Research at the UT is organized in a number of research institutes, one of which is the CTIT. All the research of the research groups in the Computer Science Department is part of the CTIT. The structure is further explained in Figure 2.

Figure 2. Organogram showing EEMCS and CTIT.



EEMCS management

Computer Science is one of the three departments in the faculty EEMCS (the others being Electrical Engineering and Mathematics). The three Heads of Department and the Dean form the core Management Team of the faculty, which is assisted by the Managing Director and the Financial Controller of the faculty. In the MT meetings all issues regarding personnel appointments, budgets, teaching programmes, investments and organizational topics are discussed. According to the Law on Higher Education, the Dean has the decisive vote and is responsible for all formal decisions. The minutes of the MT meetings are available on Intranet to all staff. The Extended Management Team of the faculty additionally includes the Course Leaders of the Degree Programmes for which EEMCS is responsible. The Dean also regularly consults the Faculty Council, consisting of staff and students, which formally approve and advise in relation to decisions of the MT.

In case of important events, information meetings for all staff of EEMCS are organized, with a minimum of one such meeting every year. Once every quarter all Chair Holders and Course Leaders within EEMCS have a dinner meeting to discuss more general topics important for the faculty.

Department management

The Heads of Group of a department in EEMCS form a Department Council. The Computer Science Department Council meets monthly with the Dean, the Managing Director and the Course Leader of the Computer Science Degree Programme, to discuss current affairs affecting the Computer Science Department and to advise the Management Team of the faculty where needed. The Head of the Computer Science Department chairs this meeting. The Head of Department also supports the Dean in personnel decisions and represents the department in external institutions like the VSNU and the NIRICT.

Research Group management

All teaching and research is done in the Research Groups. The Head of Group, who is one of the chair holders in the group, is responsible for managing the group (planning, organizing, acquiring resources including people, providing direction and leadership, and quality control).

This is done in a participatory style; in particular, the acquisition of projects and the development of new teaching are responsibilities shared with senior research staff in the group.

Every year towards the summer, a Spring management meeting takes place between the Management Team of the faculty and each Head of Group to discuss performance and plans about teaching, research output, personnel management, and finance. The Head of Group is accountable for these areas. These meetings can lead to decisions regarding the future of the Research Groups on any of these issues.

CTIT management

Research budget allocation to the Research Groups is done by the scientific director of CTIT partly based on the past performance of the groups and on the policy of CTIT. The Dean of EEMCS makes a budget allocation for education. The total of these two allocations is discussed between the Dean and the Scientific Director to see whether the allocations to the chairs sufficiently implement the goals of EEMCS and CTIT.

The research of the CTIT is organized in six strategic research orientations (SROs) to which funds are allocated. From these funds, Research Groups participating in these SROs can request budget for new (temporary) appointments, investments, and/or existing staff members to engage in new activities. SROs are coordinated by senior researchers from the Research Groups.

The CTIT Scientific Director as well as the Dean of the faculty have the right to propose new professorial positions to the Executive Board of the University. The Faculty and the Institute are represented in all appointment committees of key research staff.

The Scientific Director of the CTIT is supported by a core management team consisting of a managing director and a financial controller, and by the coordinators of the 6 SROs, and is advised by an Expertise Team consisting of researchers from the various disciplines participating in the CTIT. In addition, there is an external advisory board. The Dean of the faculty is represented in the external advisory board.

3. Strategy and policy

3.a. Strategy, policy and design in brief

Although there were some minor changes in name, all but one of the Computer Science Research Groups in 2008 were the same as those of 2003. The exception is that the groups of Application Protocol Systems and Architecture of Distributed Systems, which existed in 2003, in response to the previous research assessment were merged in 2004 into the group of Architecture and Services of Network Applications (ASNA). In 2008 this group was terminated and the Pervasive Systems group was started, to express the vision of the Department that large scale distributed systems embedded in daily life form a challenging long-term research perspective matching well with the research competences in the Department and strengthening the desired research profile of the Department. The ASNA staff members moved to other positions, both inside and outside the Department.

It is our mission to integrate technical ICT research with applications that are relevant for society. The CTIT supports this by defining Strategic Research Orientations (SROs) that are relevant for the technical as well as social sciences. Every four years the SROs are evaluated by the Expertise Team of the CTIT on their scientific results. Based on this evaluation, SROs can be terminated, redirected, or continued.

The most recent SRO evaluation took place in 2006. Based on the quality, the progress and the international position of the SROs, and taking into account the national and international developments, it was decided to redefine or reorganize some of the SROs and to concentrate in the period 2007-2012 on the SROs listed in the first row of Figure 3.

Figure 3: The CTIT SROs and participation by Computer Science Research Groups.

	1. Applied Science of Service for Information Technology (ASSIST)	2. Dependable Systems and Networks (DSN)	3. Wireless and Sensor Networks (WiSe)	4. Natural Interaction in Computer-mediated Environments (NICE)	5. Integrated Security in a networked World (ISTRICE)	6. Industrial Engineering and ICT (IE&ICT)
CAES		X	X			
DACS		X	X		X	
PS			X			
DB	X			X	X	
DIES		X			X	
FMT		X				
HMI	X			X		
IS	X				X	X
SE	X	X				

Many of the projects done in the SROs focus on particular application domains relevant for the CTIT. These are Well-being & Healthcare, Mobility and Logistics, Safety and Security, Energy and Sustainability, and Education and the Creative Industry. These application domains are a source for problem statements and for validation cases of our technical solutions.

If a Research Group participates in an SRO, this means that it performs research in this area and that it can request funds from the SRO budget to perform research together with one or more other CTIT research groups. Usually the funds are spent on temporary staff but in some cases, permanent staff is funded partly from an SRO to do research relevant for that SRO. It is CTIT policy to strengthen an SRO research theme by funding projects that bring participating Research Groups in a good position to acquire external funding on that theme.

3.b. Future developments

We believe our structure of research groups and SROs as shown in figure 3 is stable, for the following reasons. First, the list of research groups in the leftmost columns shows that we have a stable covering of the field. From the top down, our research groups cover the following parts of the field:

- **ICT systems.** ICT itself is the subject the CAES, PS and DACS research groups, which study architectures for embedded, ad hoc and large-scale networks and distributed systems.
- **ICT system interactions.** Interaction of ICT with people and organizations is covered by HMI, IS and DB.
- **ICT system aspects.** The remaining groups study aspects that cut across several layers of abstraction of ICT systems. SE, FMT and DIES study software engineering, correctness, and security properties of ICT, respectively.

Second, this stable structure of research groups is complemented by the more flexible structure of SROs. SROs have proven to be a successful tool to focus our research on stable and challenging topics, yet responding to changing needs in society. The CTIT will continue to use SROs as a tool for resource allocation and will continue to evaluate them every 4 years to see if any changes are called for. The next evaluation is planned for in 2010.

Looking once more at figure 3 we see very roughly along the diagonal from top left to bottom right that the department has three research foci. The three ICT systems groups work on *wireless & sensor networks*; the three systems interaction groups work on *interactions & services* provided by ICT systems; and all groups, in particular the three methodological groups, work on *dependability and security*.

To embed this in long-term developments in the ICT field: We see a long term trend towards "context-rich computing," in which computing systems are ever more tightly integrated with their natural and social context. Embedded and pervasive computing are two long-term trends towards integration with the natural (physical) context; molecular and quantum computing are other examples of this same trend (not pursued in our department). Interactive computing, multimedia and service orientation are examples of long-term trends towards integration with the social (human) context. This tight interaction between computing and its context motivates our attention of methodological issues such as quality, dependability and security. In the context of these long-term trends we think our covering of the field is stable for the next five or even ten years. However, the next Mid-Term Review in 2012 will be an occasion to reflect on our long-term goals.

For example, in the long-term strategy of ICT research and innovation currently being developed by *ICT Regie*, an advisory organ to the Dutch government, themes such as dependability and security, business processes, sustainability by ICT and sustainable ICT, and e-science are listed as being of long-term relevance for society. With our mix of research groups and SROs we are well-positioned to provide a significant contribution to these themes.

In the near future, the Head of Group of HMI will retire, and we have started preparations for finding a successor. The HMI group will continue to play an important role in the department. They are responsible for a Master Degree Programme in HMI and play an important role in our new bachelor in Creative Technology. They have a proven track record in project acquisition and in answering to a continuing and growing need for technical research in human-computer interfaces.

Most of the externally funded projects require the design and development of software prototypes to validate the ideas and to show the feasibility of a certain approach. There is now a strong emphasis on making this software available via the web and sources of public domain software, so others can continue building on our results. Besides the traditional ways of making the results visible via scientific publications and PhD theses, the department makes all its publications available on the world-wide web (via the e-prints system), as well as substantial amount of software prototypes, as indicated in sections B.7.a on external validation.

3.c. Cooperation with other technical universities in the Netherlands

The three universities of technology in the Netherlands, TU Delft, TU Eindhoven, and UT, have excellent cooperation in several areas, including ICT. This has resulted in the start of NIRICT, the Netherlands Institute for Research in ICT, which is part of the 3TU.Federation. NIRICT brings together over 70 research groups from the disciplines Computer Science, Electrical Engineering, Mathematics and several ICT application domains, which makes NIRICT an important academic research partner in the Netherlands. NIRICT is governed by the Deans of EWI from TU Delft and UT and the Dean of EE TU/e. Peter Apers is the scientific director of NIRICT.

NIRICT's research program consists of a Long-Term Research Agenda (LTRA), a Strategic Research Agenda (SRA), and an Innovation Agenda (IA). The first topic of the LTRA, Dependable ICT systems, led to the recently founded 3TU Centre for Dependable ICT Systems (CeDICT). The goal of CeDICT is to develop and apply methods and techniques to make dependable ICT systems a reality. As a concrete means to achieve this goal, six new chairs have been appointed, of which three in the Computer Science departments of the universities involved: Dependable Multimedia Processing (TU Delft), Formal Methods and Tools (UT), and Embedded Systems Security (TU/e).

The SRA themes of NIRICT are:

- Broadband Communication Systems
- Computer Networks

- Multimedia and VR Systems
- Ambient Intelligence
- Security
- Enterprise Information Systems

These themes are closely linked to the national and international research agendas.

To implement the Innovation Agenda the joint 3TU.NIRICT Research Laboratories have been founded: the Laboratory for Quality Software (LaQuSo; Radboud University Nijmegen also participates in this lab), the Smart Environments Laboratory, and the Design Laboratory. All labs have facilities at the three locations and are supported from the CeDICT program.

In December 2008, the 3TU.Federation signed the "Joint Research Unit for Embedded System Engineering", a collaboration agreement with the Embedded Systems Institute (ESI) in Eindhoven. The aim is to collaborate more closely within Dutch and European research programs/projects.

3.d. Embedding and relations with external parties

National research consultation takes place in a number of ways: scientific meetings, project meetings, collaborative activities, etc. A formal forum is the *Informatica-kamer* (Informatics Chamber) of the VSNU, where Department Heads and/or Deans of all Dutch universities with a Computer Science department meet and discuss issues of mutual interest. A second important forum is the Informatics Platform Netherlands (IPN), which advises government policy makers and the NWO funding agency about computer science research.⁴ All computer science researchers participate in national research schools, which facilitate and provide PhD level teaching to PhD candidates in the Netherlands. The scientific directors of these schools participate in IPN. The three technical universities coordinate their computer science research through NIRICT as explained in section 3.c. As a result of this consultation national research programs are run by NWO, STW, and SenterNovem, which have a strong participation from the UT. Examples are programs like Sentinels, Freeband and SmartSurroundings.

At the international level most research groups have a strong to very strong presence in European (FP6 and 7) projects. The lists of projects in part B give details. Some groups also have projects funded by multinational companies operating from the Netherlands or elsewhere.

4. Researchers and other personnel

Research staff

The following table gives an overview of the research staff employed at the Department, not including the CAES group.

Table 1: Research staff (fte)

Type	2003	2004	2005	2006	2007	2008
Tenured staff	20,95	20,09	19,07	17,82	16,51	16,44
Non-tenured staff	13,94	11,71	20,97	24,91	24,76	26,99
PhD Candidates	45,06	49,35	62,58	63,46	64,89	62,15
Total research staff	79,95	81,15	102,62	106,19	106,16	105,58

All research staff is employed by the faculty, not by the research institutes of the UT. UT research institutes only employ a scientific director, a managing director, and a minimum of support staff. All financial aspects regarding personnel management rest with the Dean. For positions at the Associate Professor level and beyond the final decision on promotions and appointments is made by the Executive Board of the University.

⁴ <http://www.ictonderzoek.net>.

Human resource management in the faculty takes place through annual performance appraisals between staff members and the Heads of Group. These are open discussions on all factors influencing the productivity and well-being of the staff member. Based on these meetings, a bonus can be awarded to the staff member, or steps can be agreed on by both parties to enhance performance of the staff member. If desirable, targets are agreed in a personal development plan. The personnel department discusses any issues that come out of these yearly appraisals with the group leader, who takes action if and when needed.

Job promotions require a formal assessment by the Heads of Group in the presence of the personnel officer and are based on Academic Job Ranking Criteria shared by universities in the Netherlands. Formal evaluations are done only when the employee or Heads of Group requests it. Reports of the performance appraisal meetings and of formal assessments are archived in the personnel file.

It is faculty policy that all permanent academic staff contribute to teaching *and* research. This is also true for part-time professors appointed on positions provided by industry. Full-time staff also contributes to the management activities. The actual tasks of permanent academic staff members are determined by the Head of Group in consultation with the staff. The ratio of teaching to research to management tasks may vary across people and over time.

It is faculty policy to encourage people to take study leave as well as sabbatical leave to support the dynamics in focus of research. Most senior staff members in the faculty have recently attended the Academic Leadership program facilitated by the university. New staff members follow an extensive program offered by the university, called DUIT, to enhance their teaching skills.

PhD candidates and postdocs spend most of their time doing research, but may contribute to teaching. We encourage temporary staff to enhance their research skills by following courses in national research schools and in the university.

A Head of Group must be a full-time professor appointed to an established chair. Recruitment is by rule done internationally. A description of the field of activity is made by the Dean with the chair of the Computer Science department and the Scientific Director of the CTIT. These descriptions are kept concise and relatively open-ended since it is important to attract young, eminent scientists and give them some freedom to develop their field further.

Visiting professors ("bijzondere leerstoelen") are appointed if there is a faculty/institutional interest in providing seniority for a specific sub-field for which collaboration with an external partner(s) is fruitful. These appointments are normally financed by third parties and made for a period of 3 years.

Personal chairs are awarded to existing permanent staff in sub-fields of substantial breadth and size within research groups. Candidates must be outstanding in their field.

Both the University and the Faculty EEMCS actively stimulate and support staff members to apply for the NWO 'Innovational Research Incentives' (Veni/Vidi/Vici) program. This program provides funding for both the researcher and temporary staff (PhD candidates and postdocs) in his/her research project.

Supporting staff

Technical and administrative support is organized at various levels. Each Research Group has one or more secretaries and possibly some technical staff to support research and teaching. ICT support existed at the faculty level (network management) as well as at the University level (network, infrastructure), but in 2007 all ICT support was centralized in the ICT Service Centre of the UT. It is impossible to break this down to a price per Research Group. The faculty has a financial department and a personnel department that are managed functionally from the central UT financial and personnel departments.

In 2008, the ratio of research staff (including postdocs and PhDs) to support staff was somewhat over 4:1 in the faculty EEMCS, compared to 17:10 in the university.

4.a. PhD programs and policies

Short introduction on PhD policy and program.

Standard PhD candidates in the Department are temporary employees on a four-year contract. Funding comes from external sponsoring, either from governmental research funding ("second money flow") or from contracts with industry ("third money flow"). A few PhD candidates are directly funded by the university through the CTIT ("first money flow"). In all cases there is a project plan before the PhD candidate is hired. Based on the background of the PhD candidate, an educational program is set up consisting of courses necessary for the PhD research. These courses are provided by the university, national research schools and through International Summer Schools. PhD candidates are also offered general courses, such as professional effectiveness, technical writing and presenting, and career orientation. In addition, English and Dutch language courses are offered. Presently, about 58% of the PhD candidates originate from outside the Netherlands. This creates an international atmosphere that benefits the candidates.

Starting in 2009, the university will establish a Graduate School that offers combined Master's and PhD programs. This will allow the influx from bachelor students in a PhD program and improve the visibility of the university to attract excellent (international) students.

List of PhD Candidates

Rather than a list of names and project, Figure 4 shows the number of PhDs graduated in any given year at the Research Groups existing in that year. (Following the guidelines, each PhD is listed only in the group of the first supervisor; a table including shared promotions with other departments would have shown slightly higher figures.) As can be seen, the average has been between 11 and 12 over the period 2003-2005, rising to slightly over 14 in the period 2006-2008 (though not evenly distributed over the years). A prognosis clearly shows that the average number of degrees will remain on this level or rise slightly further in the coming years.

Figure 4. Number of PhD theses. Empty cells indicate that the group did not exist in that year.

Group	2003	2004	2005	2006	2007	2008
ASNA	2	3	3	4	1	
DACS	2	2	1	2	1	3
DB	2	1	2	3	1	3
DIES	2	0	3	2	1	2
FMT	1	0	0	1	1	3
HMI	4	4	1	2	2	5
IS	1	0	0	0	1	1
PS						0
SE	0	0	1	1	1	2
Total	14	10	11	15	9	19

Success rates of PhD Graduates

The success rates are summarized in Tables 2.1 and 2.2 below, using the prescribed format.

Table 2.1 Standard PhD Candidates. The data in the shaded cells is not reliable, due to the fact that before 01-01-2004 the personnel data base did not register PhD candidates separately. Candidates who finished or quit before this date are therefore not included in the table.

Starting year	Enrollment #	Expected graduations #	Graduated after 4 years		Graduated after 5 years		Graduated after 6 years		Graduated after 7 years		Not yet finished		Discontinued	
			#	%	#	%	#	%	#	%	#	%	#	%
2004	26	19	13	50%	-	-	-	-	6	23%	7	27%		
2003	14	10	6	43%	2	14%	2	14%	-	-	4	29%		
2002	13	11	7	54%	3	23%	-	-	1	8%	2	15%		
2001	15	12	6	40%	5	33%	1	7%	-	-	1	7%	2	13%
2000	6	4	2	33%	1	17%	1	17%	-	-	-	-	2	33%
Total	74	56	34	46%	11	15%	4	5%	-	-	8	11%	17	23%

Roughly, about half of our standard PhD candidates graduate after 4 years. Again very roughly, another 25% graduates after 5 years or later, and the rest discontinues the project.

Table 2.2 External PhD Candidates (PNUT). For the interpretation of the shading, see the caption of Table 2.1.

Starting year	Enrollment #	Expected graduations #	Graduated after 4 years		Graduated after 5 years		Graduated after 6 years		Graduated after 7 years		Not yet finished		Discontinued	
			#	%	#	%	#	%	#	%	#	%	#	%
2004	3	3	-	-	-	-	-	-	3	100%	-	-		
2003	5	3	1	20%	1	20%	-	-	1	20%	2	40%		
2002	-	-	-	-	-	-	-	-	-	-	-	-		
2001	1	1	-	-	-	-	1	100%	-	-	-	-		
2000	1	1	-	-	1	100%	-	-	-	-	-	-		
Total	10	8	1	10%	2	20%	1	10%	-	-	4	40%	2	20%

The table of external PhD candidates shows that there were essentially too few to draw any conclusions.

In the reviewed period 2003-2008, the department had neither contract PhD candidates nor research staff conducting research for their PhD thesis.

Career destination of PhD Graduates

As the career destination is not officially recorded, the table below was composed from memory by the Heads of Group. Some issues of interpretation are:

- Most of the candidates grouped under "Trade and Industry" are actually employed at research laboratories or departments. A more fitting category, such as "technology transfer", is unfortunately missing from the prescribed list.
- For the academic staff abroad it was not always possible to decide whether they were tenured or not.
- The candidates for whom the destination could not be recalled are listed under "miscellaneous".

Table 3: Career destination PhD candidates after end of contract (graduation or termination)

	#	%
Tenured academic staff in the Netherlands	4	4%
Tenured academic staff abroad	20	18%
Non-tenured academic staff in the Netherlands	10	9%
Non-tenured academic staff abroad	16	15%
Trade and Industry	33	30%
Government	0	0%
Consultancy	14	13%
Miscellaneous	12	11%
Unemployed	1	1%
Total	110	

5. Resources, funding and facilities

The university policy is to make chairs accountable for their finances and to stimulate them to obtain external research funding. Establishing the UT research institutes has supported this policy, as these institutes are better positioned to obtain research funds in larger research programmes, which is generally not possible for individual chairs.

In the financial system used during the reporting period, most of the budget allocated to a Chair is determined by the research and teaching output of that Chair in the previous years. The main parameters are the number of successful PhD defenses, the volume of externally funded projects and the number of credits (ECTS) obtained by students with passing marks. Apart from this direct funding, a substantial amount of money is allocated to strategic programs of the research institutes such as the CTIT SROs.

Additional funding for the Computer Science Department was obtained from the 3TU Centre of Excellence for Dependable ICT systems (CeDICT), financing for five years the professorial position in Formal Methods and Tools, as well as several subsidiary positions.

The UT financial system has been very successful in stimulating the acquisition of external research funds. The system was, however, primarily based on output based financing, which is not always in line with the institutional research plans and maintaining proper attention for long-term fundamental research. In 2010 the financial system will therefore be modified. An important new component is that a significant part of the research funds will be based on a five year agreement between the Research Institute, Faculty and the Research Group regarding their joint long-term research plans and the prospective number of externally funded projects. This new system should provide more stability due to long term agreements about the finances and ensure a better balance between short-term and long-term objectives.

Each year before the Spring Management Meeting, the Heads of Group are asked to make integrated budget plans to be approved by the Management Team. The Research Groups generally have financial reserves as a result of income generated and expenditure made in the past, which can be used for additional temporary staff and investments.

Following a reorganization in 2006, the financial situation of the Faculty EEMCS is healthy, with currently a reserve of 34 MEuro. About 70% of this reserve is directly allocated to the research groups within EEMCS.

In the reporting period, the Computer Science Department had a technical support department that provided technical support staff to labs located in the Research Groups. When ICT support was centralized to the ICTS in 2007, lab support was moved to the Research Groups. Not all Research Groups have labs. Funding for computing equipment is either obtained from research projects or from funding directly allocated to the Research

Groups. During the reporting period, the library facilities have been centralized at the university.

In the context of NIRICT we will expand our lab facilities. In 2009 a new multidisciplinary 300 m² Smart eXPerience living lab will be established in the Computer Science building, which will link the labs of all CTIT-affiliated Research Groups (technical and non-technical), both within the university and with the 3TU Smart Environments labs of the Universities of Delft and Eindhoven.

Tables 4 and 5 indicate the yearly funding. Direct funding is 1st money flow (centrally funded from the university or through the CTIT). National (governmental) research funding is 2nd money flow (through government agencies such as NWO and STW). Research contracts with third parties are 3rd money flow.

From these tables some clear and significant trends can be observed. The total amount of funding has steadily gone up (with a larger jump in 2008) from 12,9 M€ in 2003 to 19,6 M€ in 2008: an increase of 50%. At the same time, the direct funding has remained reasonably stable. As a consequence, the *percentage* of direct funding has gone down from 70% in 2003 to 60% in 2008. Given that the direct funding includes income from teaching, this trend is actually quite impressive, showing the impact and timeliness of our research.

Table 4: Funding and expenditure at institutional level

Funding:	2003		2004		2005		2006		2007		2008	
	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Direct funding	8.875	70%	8.853	69%	9.141	63%	8.758	57%	9.784	59%	11.830	60%
Research funds	1.079	8%	1.162	9%	1.450	10%	2.308	15%	2.465	15%	1.893	10%
Contracts	2.775	22%	2.808	22%	3.826	27%	4.200	28%	4.308	26%	5.885	30%
Other												
Total	12.729		12.823		14.417		15.266		16.557		19.608	
Expenditure:	2003		2004		2005		2006		2007		2008	
	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Personnel costs	7.579	62%	7.894	60%	9.764	66%	10.286	70%	9.916	67%	12.758	67%
Other costs	4.554	38%	5.209	40%	5.046	34%	4.467	30%	4.849	33%	6.153	33%
Total	12.132		13.102		14.810		14.753		14.765		18.911	

With respect to the funding at group level, the same trends (an increase of total funding accompanied by a decreasing percentage of direct funding) can be observed for all Research Groups, with the exception of ASNA (which has, however, been discontinued in 2007). The divisions over the money flows, however, varies quite a bit. For instance, some groups (with topical research themes) are clearly more successful in attracting contractual funding.⁵ This is in particular true for IS, HMI, SE, and especially PS (started as a Research Group in 2007). To some degree, this is offset by a smaller degree of research funds; not so, however, for IS, which scores good on both fronts. Also note that FMT has scored very well in research funds.

⁵ Note that this includes European project funding.

Table 5: Funding per money flow and Research Group

Funding	Group	2003		2004		2005		2006		2007		2008	
		k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Direct funding	ASNA	1327	52%	1383	71%	1347	58%	1093	44%	1094	61%		
	DACS	1137	88%	800	77%	753	66%	907	61%	1051	63%	1231	73%
	DB	936	89%	953	83%	969	69%	993	75%	1226	73%	1247	76%
	DIES	1010	74%	1472	68%	1228	59%	1331	62%	1457	76%	1076	68%
	FMT	1069	71%	972	66%	1014	71%	846	54%	1000	58%	1436	64%
	HMI	1962	80%	1842	67%	1959	74%	2002	69%	2157	62%	2965	64%
	IS	728	93%	629	90%	1045	72%	863	67%	1053	66%	1497	49%
	PS											1088	46%
	SE	707	71%	801	81%	826	69%	723	64%	747	60%	1291	54%
Research funds	ASNA	30	1%	0	0%	0	0%	0	0%	0	0%		
	DACS	3	0%	39	4%	83	7%	167	11%	176	11%	134	8%
	DB	92	9%	95	8%	217	15%	195	15%	156	9%	194	12%
	DIES	140	10%	203	9%	242	12%	335	16%	223	12%	272	17%
	FMT	291	19%	347	23%	272	19%	707	45%	691	40%	522	23%
	HMI	39	2%	70	3%	125	5%	248	9%	255	7%	140	3%
	IS	0	0%	-10	-1%	187	13%	312	24%	456	28%	460	15%
	PS											34	1%
	SE	105	10%	151	15%	103	9%	87	8%	152	12%	137	6%
Contracts	ASNA	1238	48%	573	29%	968	42%	1367	56%	708	39%		
	DACS	157	12%	197	19%	309	27%	419	28%	443	27%	326	19%
	DB	29	3%	106	9%	214	15%	134	10%	302	18%	202	12%
	DIES	223	16%	484	22%	602	29%	490	23%	243	13%	224	14%
	FMT	151	10%	159	11%	140	10%	13	1%	23	1%	291	13%
	HMI	443	18%	824	30%	571	22%	640	22%	1068	31%	1516	33%
	IS	51	7%	81	12%	212	15%	107	8%	96	6%	1105	36%
	PS											1244	53%
	SE	190	19%	37	4%	274	23%	324	29%	342	28%	977	41%

6. Processes in research, internal and external control

As shown in Figure 2, our research is organized per Research Group as well as per CTIT SRO. This has led to a large number of cooperations among groups of the Department of Computer Science, as well as between those groups and other groups elsewhere in the UT.

Every two years the CTIT Director visits all groups participating in the institute. Such a visit consists of a scientific meeting (presentations and demonstrations) with the whole group and a private meeting with the Head of Group to discuss the performance of the group. In the latter the focus is mainly on acquiring externally funded projects. This is on top of the aforementioned yearly Spring management meeting of the Dean with each Head of Group, where performance and plans about teaching, research output, personnel management, and finance are discussed.

The SROs are evaluated every four years. The CTIT asks the SRO coordinators to self-assess their SRO. The CTIT scientific and business directors discuss with external stakeholders possible new directions. Based on the evaluations and possible new directions, the directors ask for advice from the Expertise Team. Based on this, the scientific director decides to terminate, redirect, or continue the SROs. This was done for example in 2006.

The research strategy of each Research Group is determined by the group itself based on research competence and interests within the group and opportunities that arise externally in the CTIT, NIRICT, national and international funding agencies. These processes have led to considerable cooperation among the nine Computer Science Research Groups as well as between these groups and other groups in the CTIT.

Communication of research results is done through the standard channels of scientific conferences and journals. In addition, in the Netherlands different research programmes offer platforms for exchange among Research Groups funded from this program. For example, all NWO-funded projects present themselves at the yearly conference SIREN (Scientific ICT-research event Netherlands) and CTIT organizes a yearly conference to showcase its research. Individual staff members of the different Research Groups have, moreover, organised a large number of international conferences and workshops at the University of Twente.

In the period under review, PhD candidates were evaluated after 12 months for a go/no go decision. Currently this system has evolved into one in which a formal performance evaluation takes place every 12 months, with informal reviews at 6 and 18 months. Our goal is to take measures to improve performance as early as possible, and to terminate a PhD contract if no sufficient performance level can be attained.

7. Academic reputation

The quality of the academic staff is illustrated by a number of prestigious prizes that have been awarded over the reporting period, and by a number of appointments of former staff at professorial level in institutions of high reputation. We only list the highlights:

2003

- Mariët Theune was awarded an NWO Meervoud grant entitled Angelica: A Natural-language Generator for Embodied, Lifelike Conversational Agents.
- Paul Grefen was appointed full professor at the TU Eindhoven
- Holger Hermanns was appointed full professor at Saarland University.

2004

- Ling Feng was awarded an NWO VIDI grant for the project ContextData: Towards Context-Aware Data Management for Ambient Intelligence.
- Joost-Pieter Katoen was appointed full professor at RWTH Aachen University

2005

- Ed Brinksma became scientific director of the Embedded Systems Institute (ESI)
- Peter Apers became chairman of the board of the Dutch Technology Foundation STW

2006

- Maya Daneva was awarded an NWO Meervoud grant entitled CARES: Collaborative alignment of cross-organizational ERP systems
- Roel Wieringa became scientific director of the School of Information and Knowledge Systems (SIKS)
- Machiel van der Bijl and Axel Belinfante were awarded the STW Valorization grant phase 1: SmarTest

2007

- Boudewijn Haverkort was elected Fellow of the IEEE "for contributions in performance and dependability evaluation of computer and communication systems".
- Aiko Pras became chair of IFIP WG 6.6 Management of Networks and Distributed Systems
- Sandro Etalle was appointed full professor at the TU Eindhoven

- Gurcan Gülesir and Lodewijk Bergmans were awarded the STW valorization grant phase 1 and 2: BloomWise
- Paul Havinga received the *ICT Regie* innovation Award 2007, Ambient Systems

2008

- Damiano Bolzoni, Sandro Etalle and Emmanuele Zambon were awarded the STW valorization grant phase 1 and 2: SecurityMatters
- Maria Lijding was awarded the STW valorization grant phase 2: Smartsigns
- Djoerd Hiemstra was awarded an NWO VIDI grant for the project Distributed Information Retrieval by means of Keyboard Auctions
- Maja Pantic received the European Research Council starting grant as one of the 2.5% best junior scientists in any research field in Europe in 2007
- Franciska de Jong became member of the governing board of the Netherlands Organization for Scientific Research (NWO)
- Ileana Buhan was awarded the European Biometrics Forum Industry award

8. Internal Evaluation

Quality control is done through a yearly report of all scientific research activities in a QAR (Quality Assessment Report). Statistics of publications and progress of projects and PhD candidates are reported, and the results of this report are discussed in the yearly spring management meeting between the EEMCS management team and the Heads of Groups.

We have described our personnel evaluation procedures in section 4 and our processes of research evaluation in section 6. In addition, three years after each research assessment we have a 3TU-wide mid-term review (MTR). The previous MTR took place in 2006 and covered the period 2003-2005. Based on this review we decided to emphasize quality over quantity of publications, and to start emphasizing software assets.

9. External validation

The volume of our second and third money flow ("research funds" and "contracts" in Tables 4 and 5), including highly competitive FP7 projects, is an indication of positive external evaluation both on quality and on relevance. These projects are externally evaluated. In addition, section 7 emphasizes valorization grants and appointments of department staff to high-level positions in other organizations, which is a token of external recognition too. Finally, through the CTIT and our participation in NIRICT, STW, NWO and the SIKS research school we are in a position to influence national research agendas. We view our involvement in national discussions about research policy as a token of appreciation of research quality in the department. A glance at the external validation sections in part B also shows that all our research groups have an extensive network of contacts with business and government organizations.

10. Overview of the results*Table 6*

Category		2003	2004	2005	2006	2007	2008
Academic publications	a. Refereed journals	23	35	50	40	44	38
	b. International conferences	162	194	303	251	261	295
	c. Book chapters	12	17	18	17	34	10
	d. Other academic publications	28	42	39	61	59	52
Total		225	288	410	369	398	395
Monographs		2					2
PhD-theses		14	10	11	15	9	19
Professional publications		10	14	21	12	21	3
Patents		1	3	2	8	4	1
Software		6	2	4	2	4	3

11. Analysis, perspectives, and expectations for the institute

Strengths

1. All groups produce top-level results that link basic research to relevant applications in society.
2. The CTIT has a proven capability to play a leading role in the national research agenda.
3. As indicated by the steep increase in external funding, all groups have a proven excellent capability to attract external funds, nationally and internationally.

Weaknesses

1. We do not communicate our research results to the general public sufficiently.

Opportunities

1. The university has taken measures (tenure track system, graduate school) by which we may attract more top talent at different levels.
2. National research policy is now putting topics on the agenda which we are well geared to research.
3. ICT can contribute to solving current problems in society and the economy.

Threats

1. Low acceptance ratio of important funding programs and the coordination overhead of very large projects is causing fragmentation of researcher's time.
2. For all groups, highly qualified staff at all levels is very difficult to find.
3. Public and private research funding in the Netherlands is becoming increasingly uncertain.
4. Funds need to be obtained in competition with other disciplines, but just as other technical sciences, computer science research scores less well on traditional performance indicators.

Analysis

We achieve our mission, but to maintain our high level of performance we need to counter the threats and actively engage with the opportunities listed above.

Adjusted goals

No change in goals.

Strategy

1. Professionalize our external communication about research results.
2. Focus on areas of (inter)national relevance, such as wireless and sensor networks, interactions & services, and dependability & security.
3. Be more proactive in scouting top talent.
4. Improve our support in requesting and managing large projects.

Part B: The Research Groups

Title of the Research Group:

Architecture and Services of Network Applications (ASNA)

Research themes: Architecture, Service Engineering, Service Infrastructure

NABS code: N07

Heads of Group: Prof. dr. eng. D. Konstantas (until 2004), Dr. ir. M.J. van Sinderen

End date of the Research Group: 2007

Formal affiliations outside the department and other formal co-operations: CTIT, ASCI research school

The ASNA group has been discontinued in 2007. Researchers and other personnel ("wp") listed in the following table, have moved to other groups as indicated below ("n.a." means that relocation is not applicable, since the person was no longer in the group or was not relocated to another group within the university):

Category	Name	New group
Tenured staff		
professor (hgl)	Konstantas, prof. dr. eng. D.	n.a.
	Vissers, prof. dr. ir. C.A.	n.a.
associate professor (uhd)	Ferreira Pires, dr. L.	SE
	Pras, dr. ir. A.	n.a.
	Sinderen, dr. ir. M.J. van	IS
assistant professor (ud)	Beijnum, dr. ir. B.J.F. van	BSS (EE department of EEMCS)
	Halteren, dr. A.T. van	n.a.
	Quartel, dr. ir. D.A.C.	n.a.
	Widya, dr. ir. I.A.	BSS (EE department of EEMCS)
postdoctoral fellow	Jones, dr. ir. V.M.	n.a.
Non-tenured staff		
professor (hgl)	Huizer, prof. dr. E.	n.a.
	Michiels, prof.ir. E.F.	n.a.
	Nieuwenhuis, prof. dr. ir. L.J.M.	ISCM (ISCM department of SMG)
assistant professor (ud)	Aroyo, dr. L.M.	n.a.
	Wegdam, dr. M.	IS
postdoctoral fellow	Gay, dr. V.C.J.	n.a.
	Jones, dr. ir. V.M.	BSS (EE department of EEMCS)
	Pereira Filho, dr. J.G.	n.a.
	Shishkov, dr. B.B.	n.a.
junior staff (aio, oio, moz-p)	Andrade Almeida, J.P.	n.a.
	Bonino da Silva Santos, MSc. L.O.	SE
	Boros, MSc. S.	n.a.
	Broens, dr. ir. T.H.F.	IS
	Daniele, MSc. L.	SE
	Diakov, N.K.	n.a.
	Dijkman, ir. R.M.	n.a.
	Dirgahayu, MSc. T.	IS
	Dockhorn Costa, P.	IS
	Fadlisyah, MSc. M.	n.a.
	Goncalves da Silva, MSc. E.	SE
	Guizzardi, dr. G.	n.a.
	Guizzardi-Silva Souza, R.	n.a.
	Harkema, drs. M.	n.a.
	Le, ir. M. van	n.a.
	Liu, MSc. H.	n.a.
	Mantovaneli Pessoa, MSc. R.	IS
	Meent, ir. R. van de	n.a.
	Mei, MSc. H.	BSS (EE department of EEMCS)
	Morales, J.M.	n.a.
	Parhonyi, R.	n.a.
	Pawar, MSc. P.	BSS (EE department of EEMCS)

Category	Name	New group
other junior staff (moz, twaio)	Sheikh, MSc. K.	n.a.
	Dokovski, N.T.	n.a.
	Koprinkov, G.T.	n.a.
	Wac, K.E.	n.a.

1. Mission statement

Network applications provide software services that support distributed users in their primary processes, such as healthcare, financial and production processes. Users, in this context, can be human users, business organizations but also other network applications. Network applications are implemented by building distributed software applications on top of communication networks. Network applications are heterogeneous, evolve dynamically, often comprise mobile application parts, and are resource constrained. Network applications increasingly also need to be context-aware, in order to automatically adapt service delivery to the unique and dynamic context properties (such as physical location and environmental conditions) of individual users.

The mission of the ASNA group was to develop methods, concepts and tools for the efficient and effective design of network applications, especially addressing interoperability issues that emerge as a consequence of heterogeneity, evolution, mobility, resource constraints, and context-awareness.

2. Leadership

The ASNA group was managed by a senior staff team (Van Sinderen, Konstantas (until 2004), Ferreira Pires, Van Halteren (until 2006)), which met every week. Van Sinderen took responsibility for HRM tasks and financial planning. Other tasks were allocated to members of the group. The permanent staff met twice a year to discuss and update the group's long-term vision on research and education. Project meetings and research seminars were used to facilitate interaction between individual group members and to disseminate research results within the group.

3. Strategy and policy

3.a. Design in brief

Network applications support the primary processes of users and are implemented by distributed software applications. This requires (sustained) interoperability of application parts, which is challenged in various ways:

Software applications are implemented with different languages using different technology platforms, while technology solutions and interoperability "standards" are continuously evolving.

Users (e.g. businesses) want short delays between the identification of a demand regarding network application support and the availability of this support through an implemented network application. Moreover, they want that legacy applications can be integrated and that future demands can be easily accommodated.

Users (e.g. consumers) prefer personalized support of a network application, i.e. the network application should take account of and adapt to the changing conditions and circumstances of each individual (mobile) user.

The mission of the ASNA group was to develop methods, concepts and tools for the efficient and effective design of network applications. To address the challenges mentioned above, we have organized our research in two related themes: service engineering, and service infrastructure.

Research on service engineering focused on service-oriented model-driven development. This research line was concerned with how individual services, service coordination and service composition can be modeled and how models can be used at design-time (to derive service

implementations from service specifications, according to a model-driven architecture) and at runtime (to publish, find, select, compose and bind services, according to a service-oriented architecture).

Research on service infrastructure focused on context-aware service infrastructures. This research line was concerned with how network applications can be built following a service-oriented architecture, how context information can be managed by collaborating context sources, and how context consumers use context information to take context-dependent decisions regarding application behavior.

3.b. Future development

Since the ASNA group has been discontinued in 2007, future development is not described.

4. Processes in research, internal and external collaboration

The ASNA group adopted an engineering approach to research, which means that we developed methods, concepts and tools for actual or perceived real-world problems, in collaboration or consultation with problem owners or solution providers. For this reason, most of our research was carried out in research projects with external (public, business and industry) partners.

The research themes of the group (service engineering, service infrastructure) are present in all of our projects. In each project at least one staff member was involved and usually one or more PhD candidates. Each PhD candidate was supervised by one or two staff members under the final responsibility of one of the full professors. The PhD candidate had weekly meetings with the supervisor(s) and monthly meetings with the full professor. The group had a weekly research seminar in which staff members and PhD candidates reported on research results and new ideas.

PhD candidates were encouraged in their first year to submit a paper to a doctoral consortium at an international conference. Furthermore, PhD candidates were recommended to follow training courses offered by the UT to strengthen their professional skills, and to attend relevant courses on research topics offered by one of the national research schools (especially ASCI, SIKS or IPA). PhD candidates were members of the ASCI research school.

Within the UT, the ASNA group participated in the CTIT, in particular in the SRO ASSIST on service science. As part of 3TU Federation, the group participated in the 3TU research institute NIRICT, where its research activities were part of the Strategic Research Agenda on computer networks. Staff members participated in international research networks, including steering committees, program committees, editorial boards, working groups and research projects.

5. Academic reputation

Prof. dr. ir. Chris A. Vissers

- Scientific Director of the Telematica Instituut

Prof. dr. ir. N.J.M. Nieuwenhuis

- Chairman of the innovation-driven research program Generic Communication (IOP-GenCom)
- General Director of the ExSer Center for Service Innovation

Prof. dr. eng. Dimitri Konstantas

- Chairman of the 1st INTEROP-ESA 2005 Conference, Geneva, Switzerland, 21-15 February 2005
- Chairman of the 9th International Conference on Object-Oriented Information Systems, Geneva, Switzerland, September 2003

- Expert evaluator for the Greek Ministry of Development General Secretariat or Research and Technology
- Expert evaluator for the Natural Sciences and Engineering Research Council of Canada (NSERC)
- Expert evaluator for the EU 6th FP
- Member of the MOCCA II, which is the Ericsson Think Tank on e-Health applications for wireless and mobile networks in emerging markets

Dr. ir. Marten van Sinderen

- Coordinator of CTIT's Strategic Research Orientation on service science (ASSIST)
- Editorial Board member of the Enterprise Information Systems (EIS) Journal
- Guest Editor of the EIS Special Issue on Challenges and Solutions on Enterprise Computing
- Steering Committee member of the IEEE Int'l EDOC Enterprise Computing Conference
- Program Committee and Monitor Committee member for the BSIK Freeband projects
- Expert evaluator for the Norwegian Research Council (VERDIKT program)
- Expert evaluator for the EU 5th FP (C-ARCTIC project)
- Chair of several conferences and workshops, including the 9th IEEE International EDOC Enterprise Computing Conference, Enschede, 17-18 March 2005

Dr. ir. Luís Ferreira Pires

- Co-chair of MDEIS Workshop, Miami, Florida, USA, 24-25 May 2005
- Co-chair of MDEIS Workshop, Paphos, Cyprus, 23-24 May 2006
- Co-Chair of the MDEIS Workshop, Funchal, Madeira - Portugal, 12-13 June 2007
- Co-chair of 3M4MDA Workshop, Bilbao, Spain, 11 July 2006
- Expert evaluator for the IWT ('Instituut voor de Aanmoediging van Innovatie voor Wetenschap en Technologie in Vlaanderen')

Dr. ir. Aiko Pras

- Guest Editor of the IEEE Communications Magazine on XML-based Management of Networks and Services
- Steering Committee member of the EUNICE Consortium
- Founding member of the IRTF Network Management Research Group (NMRG)
- Evaluator and reviewer for many EU 5th and 6th FP projects

6. Internal validation

Internal validation was accomplished by the 3TU Federation (midterm review), the faculty (evaluations of staff and PhD candidates), and CTIT (chair visits and evaluation of the SRO in which the group participated). On top of this, research results and ideas (e.g. grant and project proposals, papers to be submitted to major conferences) were discussed among the staff members and PhD candidates during our weekly research seminar. Important evaluations of PhD candidates were always done by at least two staff members. Feedback on activities of the group was discussed among the permanent staff twice a year and could result in an update of the group's long-term vision on research and education.

7. External validation

7.a. Societal relevance

The societal relevance of the group's research lay in supporting the primary processes of network application users. By developing better methods, concepts and tools for the design of network applications, these primary processes can become more efficient and effective. For example, we aimed at shortening development time and reducing maintenance cost of network application support for business processes through the use of service-oriented and model-driven design approaches. Also, we aimed at increasing the value perceived by consumers of services provided by network applications, by making these applications context-aware.

The group has focused on e-health as an important domain for network applications. The research considers, amongst others, prevention of health problems and automated support for home care through tele-monitoring and tele-treatment services. A prototype for a mobile health platform has been developed, validated and applied, together with various stakeholders in the healthcare chain. In addition, based on this platform, specific support has been developed for epileptic patients, chronic pain patients, spasticity patients and women with high risk pregnancies.

Software assets

- A language (ISDL) and framework (COSMO) have been developed for service design and analysis. Some associated tools are available at <http://isdl.ctit.utwente.nl/tools/>.
- The abovementioned prototype for a mobile health platform has been commercialized by a start-up company, MobiHealth. Information on products is available at www.mobihealth.com.

7.b. Industrial contacts

- National: Telematica Instituut (Enschede), TNO-ICT (Delft, Groningen, Enschede), Roessingh R&D (Enschede), Compuware (Amsterdam), BiZZdesign (Enschede), Lucent Technologies Bell Labs Twente (Enschede), Thales (Hengelo), Philips Research (Eindhoven), Ericsson (Rijen), Draeger (Best), GigSoft (Amsterdam), Orbis (Sittard), MST (Enschede), TMSI (Oldenzaal), Yucat (Driebergen), Sigmax (Enschede), Menzis (Enschede).
- International: France Telecom R&D (Issy les Moulineaux, France), Telenor (Fornebu, Norway), iO (Germany), Softeam (France), IKV++ Technologies AG (Berlin, Germany), Eurescom (Heidelberg, Germany), ICOM, Ericsson (Sweden; Germany), HCPB (Barcelona, Spain), LITO Polyclinics (Cyprus), Alcatel (France; Germany), Nokia (Finland), DoCoMo (Germany), Siemens (Germany; Austria), NEC (UK), Telecom Italia S.p.A. (Italy), TSystems (Germany), Microsoft (Germany), Telefonica (Spain), Thomson (France), VTT (Finland).

8. Researchers and other personnel ("wp")

ASNA permanent staff spent approximately 40% time on research, 40% on teaching and 20% on administrative and management tasks.

Table 1

Category	Name	2003	2004	2005	2006	2007	2008
Tenured staff							
professor (hgl)	Konstantas, prof. dr. eng. D.	0,09	0,03				
	Vissers, prof. dr. ir. C.A.	0,08	0,09	0,09	0,13		
associate professor (uhd)	Ferreira Pires, dr. L.	0,40	0,40	0,40	0,40	0,23	
	Pras, dr. ir. A.	0,80	0,26				
	Sinderen, dr. ir. M.J. van	0,80	0,40	0,40	0,40	0,23	
assistant professor (ud)	Beijnum, dr. ir. B.J.F. van	0,40	0,40	0,40	0,40	0,22	
	Halteren, A.T. van	0,40	0,40	0,40	0,34		
	Quartel, dr. ir. D.A.C.	0,40	0,40	0,40	0,40	0,26	
	Widya, dr. ir. I.A.	0,40	0,40	0,40	0,38	0,22	
postdoctoral fellows	Jones, dr. V.M.	1,00	1,00				
Total tenured staff		4,77	3,78	2,49	2,45	1,18	0,00
Non-tenured staff							
professor (hgl)	Huizer, prof. dr. E.	0,11					
	Michiels, prof. ir. E.F.	0,06					
	Nieuwenhuis, prof. dr. ir. L.J.M.	0,10	0,11	0,11	0,11	0,06	
associate professor (uhd)	Konstantas, dr. eng. D.			0,10	0,06		

Category	Name	2003	2004	2005	2006	2007	2008
assistant professor (ud)	Aroyo, dr. L.M.	0,21	0,21	0,03			
	Wegdam, dr. M.	0,02	0,11	0,11	0,11	0,06	
postdoctoral fellows	Gay, dr. V.C.J.	0,10					
	Jones, dr. V.M.			1,00	1,00	0,58	
	Pereira Filho, dr. J.G.	0,75					
	Shishkov, dr. B.B.			1,00	1,00	0,20	
other junior staff (moz, twaio)	Dokovski, N.T.	0,54					
	Koprinkov, G.T.	0,46					
	Wac, K.E.	0,25	0,08				
Total non-tenured staff		2,60	0,51	2,35	2,28	0,90	0,00
PhD Candidates							
junior staff (aio, oio, moz-p)	Andrade Almeida, J.P.	0,80	0,80	0,63			
	Bonino da Silva Santos, L.O.				0,40	0,46	
	Boros, MSc. S.	0,80					
	Broens, ir. T.H.F.		0,32	0,80	0,80	0,46	
	Daniele, L.M.					0,39	
	Diakov, MSc. N.K.	0,45					
	Dijkman, ir. R.M.	0,80	0,80	0,80	0,50		
	Dirgahayu, T.				0,73	0,80	
	Dockhorn Costa, P.	0,27	0,80	0,80	0,80	0,46	
	Dokovski, N.T.		0,26	0,12			
	Fadlisyah, M.			0,37	0,80	0,20	
	Goncalves da Silva, E.M.					0,39	
	Guizzard, G.	0,80	0,80	0,33			
	Guizzardi-Silva Souza, R.	0,80	0,71	0,66			
	Harkema, drs. M.	1,00	0,80	0,26			
	Le, ir. V.M.	1,00	0,80	0,53			
	Liu, H.			0,73	0,80	0,53	
	Mantovaneli Pessoa, R.					0,35	
	Meent, ir. R. van de	1,00	0,80	0,80			
	Mei, H.			0,40	0,80	0,46	
	Morales, MSc. J.M.	0,80					
	Parhonyi, R.	0,80	0,80	0,66			
	Pawar, P.			0,44	0,80	0,46	
Sheikh, K.			0,68	0,80	0,46		
Wegdam, M.	0,48						
Total PhD Candidates		9,80	7,69	9,01	7,23	5,42	0,00
Total Research Staff ASNA		17,17	11,98	13,85	11,96	7,50	0,00

9. Resources, funding and facilities

9.a. Laboratory infrastructure

The ASNA group was sufficiently equipped to perform the research described.

9.b. FTE-funding

The group targeted research funding (in Tables 2 and 3 labeled as "Contracts") from national programs (such as TS and BSIK) and European programs (such as FP5 and FP6) in order to reduce dependency from direct funding.

Table 2: Funding at group level

ASNA	2003	2004	2005	2006	2007	2008
Direct funding	52%	71%	58%	44%	61%	
Research funds	1%	0%	0%	0%	0%	
Contracts	48%	29%	42%	56%	39%	
Total	100%	100%	100%	100%	100%	

9.c. FTE-funding PhDs/postdocs

Table 3 displays the same trends as Table 2, though amplified due to the fact that we now focus only on funded (temporary) research positions. The amount of external (in particular, contractual) funding has been growing over the years, and at the end date of the group well exceeded the average of 73%.

Table 3: Funding of PhDs/postdocs

ASNA	2003	2004	2005	2006	2007	2008	Average
Direct funding	31%	29%	40%	18%	9%		25%
Research funds	8%	0%	0%	0%	0%		2%
Contracts	61%	71%	60%	82%	91%		73%
Other	0%	0%	0%	0%	0%		0%
Total	100%	100%	100%	100%	100%		100%

9.d. List of external funds

As can be seen from Table 4, ASNA has been quite successful in project acquisition, in particular from contractual funding. As remarked above, this has been an explicit strategy of the group.

Table 4

Name Project	Start	End	Sponsor
Agent Academy: A Data Mining Framework for Training Intelligent Agents	Nov-01	Apr-04	European Commission
CANDLE: Collaborative And Network Distributed Learning Environment	Jun-00	Jun-03	European Commission
E-NEXT: Network of Excellence Emerging Networking Experiments and Technologies	Jan-04	Jul-06	European Commission
HealthService 24: Continuous Mobile Services for Healthcare	Feb-05	Sep-06	European Commission
INTEROP: Interoperability Research for Networked Enterprises, Applications and Software	Jan-04	Dec-07	European Commission
MobiHealth: Innovative GPRS/UMTS mobile services for applications in healthcare	Apr-02	Dec-05	European Commission
MODA-TEL: Model Driven Architecture for Telecommunications Systems Development and Operations	Sep-02	Jan-05	European Commission
X-Motion: eMobile Testbed for Interoperability of Networks in eLogistics	Jul-02	Dec-03	European Commission
Casimir/RMSDDS: Reflective Middleware Support for Dynamic Data-Centric Systems	Jan-06	Jan-09	NWO
Management of DISH applications: Provider-based Accounting	Nov-99	Nov-05	NWO
EQUANET: End-to-end Quality-of-Service in Next Generation Networks	Dec-02	Mar-05	SENER
Freeband/A-MUSE: Architectural Modeling Utility for Service Enabling	Jan-04	Jan-09	SENER BSIK
Freeband/AWARENESS: context AWARE mobile NETworks and Services	Jan-04	Jan-09	SENER BSIK
AMIGO: Ambient Intelligence for the Networked Home Environment	Jan-04	Feb-08	Telematica Instituut
ArCo: Architectural Concepts for Service-oriented Design	Jan-03	Dec-05	Telematica Instituut
Freeband/WASP: Web Architectures for Services Provisioning	Aug-02	May-04	Telematica Instituut
M2C: Measuring, Modeling and Cost Allocation for Quality of Service	Jun-03	Dec-05	Telematica Instituut

Name Project	Start	End	Sponsor
Mobile & Wireless: Mobile Applications through Wireless Communications on the Train	Jan-04	Dec-05	Telematica Instituut
MobiLife: mobile applications and services supporting people's daily life	Jan-04	Dec-05	Telematica Instituut
MOSAIC: Mobile Worker Support Environments	Jan-04	Dec-05	Telematica Instituut

10. Overview of the results

10.a. Key publications

Table 5

Nr	Title
1	Sinderen, M.J. van , Halteren, A.T. van, Wegdam, M., Meeuwissen, H.B., Eertink, E.H. <i>Supporting context-aware mobile applications: an infrastructure approach</i> . IEEE communications magazine nr: 9, 44, (2006, September 1). (pp. 96-104) New York, NY, USA IEEE Communications Society ISSN: 0163-6804
2	Quartel, D.A.C. , Steen, M.W.A., Pokraev, S.V., Sinderen, M.J. van. <i>COSMO: a conceptual framework for service modelling and refinement</i> . Information systems frontiers nr: 2-3, 9, (2007, July 1). (pp. 225-244) Amsterdam Springer ISSN: 1387-3326
3	Andrade Almeida, J.P. , Dijkman, R.M., Ferreira Pires, L., Quartel, D.A.C., Sinderen, M.J. van. <i>Model-driven design, refinement and transformation of abstract interactions</i> . International journal of cooperative information systems nr: 4, 15, (2006, December 1). (pp. 599-632) Singapore World Scientific Publishing Co. ISSN: 0218-8430
4	Konstantas, D., van Halteren, A.T., Bults, R., Wac, K., Widya, I.A., Dokovski, N., Koprnikov, G., Jones, V. & Herzog, R. (2004) <i>Mobile Patient Monitoring: The Mobihealth System</i> . The Journal on Information Technology in Healthcare, 2(5): 365-373. ISSN 1479-649X
5	Guizzard, G. , Guarino, N., Sinderen, M.J. van. <i>An ontologically well-founded profile for UML conceptual models</i> . Proceedings of the 16th Intl. Conference on Advanced Information Systems Engineering, Lecture notes in computer science (nr: 3084), (2004, June 7 / 2004, June 11). Springer ISBN: 3-540-22151-4 / ISSN: 0302-9743 (Best paper award)

10.b. Numerical overview of the results in a fixed format of categories

Table 6

Category	2003	2004	2005	2006	2007	2008
Academic publications	a. Refereed journals	2	6	6	3	7
	b. International conferences	18	43	44	33	36
	c. Book chapters		3	2	7	
	d. Other academic publications	1		4	6	4
Total	21	52	56	49	47	
Monographs						
PhD-theses	2	3	3	4	1	
Professional publications		1	1		1	
Patents						
Software			1			

10.c. Full outcome list

2003

Journal articles

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- Veen, J.T. van der, Collis, B.A., Jones, V.M., *Network support for group-based learning: Is more better?* (2003). In: Interactive Learning Environments 11(2). pp. 127-146. Swets and Zeitlinger. ISSN:1049-4820.

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- Andrade Almeida, J.P. , Sinderen, M.J. van, Ferreira Pires, L., Quartel, D.A.C. *A systematic approach to platform-independent design based on the service concept*. Proceedings of the 7th IEEE international Conference on Enterprise Distributed Object Computing (2003, september 16 / 2003, september 19). (pp. 112-123) IEEE Computer Society ISBN: 0-7695-1994-6
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- Dockhorn Costa, P. , Pereira Filho, J.G., Sinderen, M.J. van *Architectural Requirements for Building Context-Aware Services Platforms*. Proceedings of the 9th Open European Summer School and IFIP Workshop on Next Generation Networks (EUNICE 2003) (2003, september 8 / 2003, september 10). (pp. 62-69)
- Eertink, H. , Kranenburg van, H., Hesselman, C.E.W. *Context-aware Content Distribution and Adaption*. Proceedings of the 6th International Symposium on Wireless Personal Multimedia Communications (2003). Yokosuka, Kanagawa, Japan

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11. SWOT-analysis

Since the ASNA group has been discontinued in 2007, a SWOT analysis is not provided.

Title of the Research Group:

Design and Analysis of Communication Systems (DACS)

Research themes: none

NABS code: N07

Head of Group: Prof. dr. ir. B. R. Haverkort

Starting date: January 1, 2003

Formal affiliations outside the department and other formal cooperations: CTIT, ASCI research school

The DACS group started with the appointment of professor Haverkort at the beginning of 2003. The period 2003-2005 can best be characterized as a period of change in which existing obligations were finished, and a new program was developed. The period 2006-2008 showed consolidation and a further focusing.

1. Mission statement

DACS focuses on the design and analysis of *dependable networked systems*. A (networked) system is called dependable, whenever reliance can justifiably be placed on the services it delivers. Tailored to communication systems, which can be wired, wireless, or embedded in other systems, this means that we aim:

to contribute to the design and implementation of dependable networked systems, as well as to methods and techniques to support the design and dimensioning of such systems, such that they are dependable, in all phases of their lifecycle.

We thereby interpret the term dependability as encompassing availability, reliability, performance (quality of service) and security.

2. Leadership

The DACS group is managed by the senior staff: Haverkort (Head of Group), Heijenck and Pras. To handle and discuss organizational, financial, and administrative issues, management meetings are organized typically once per month. The management team is also responsible for setting out the main lines of research (cf. Section 3). Next to that, the staff has a bi-monthly lunch meeting, in which plans, possibilities and problems with respect to research, teaching, and organizational affairs are discussed. The staff lunch has an informal nature; typically, in a single staff lunch, the focus is on a single topic only.

Information dissemination within the group goes along the line group leader—staff member—postdoctoral researcher & PhD candidate. Plenary organizational group meetings are held twice per year. A plenary colloquium is held every other week, in which primarily PhD candidates present their work. PhD candidates also report on their conference trips in this meeting (through 5-minute presentations). The colloquium is also used for information dissemination purposes. All staff members have an open door policy.

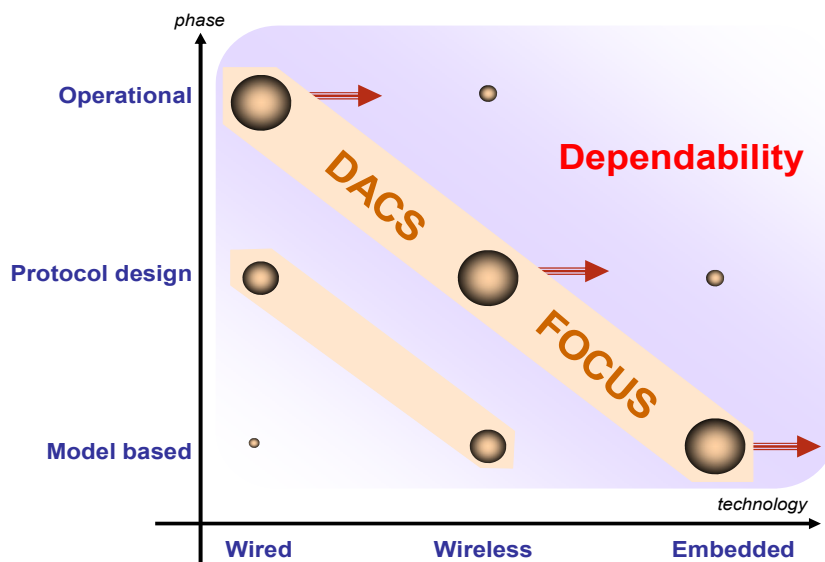
To improve the quality of leadership, all senior staff members followed in recent years one or more management courses.

3. Strategy and policy

3.a. Design in brief

Three phases in system design. We distinguish three phases in the design of dependable networked systems. In the first (exploratory) phase the emphasis lies on the development of system models and the model-based evaluation of key system characteristics. In the second, more concrete phase the emphasis lies on designing and/or standardizing systems architectures, protocols, and algorithms, as well as on implementing prototype systems. In the third, operational phase the systems have been implemented and the emphasis lies on

operationally managing them. As an example of these three phases, consider the Internet backbone. During 1965-1985, research concentrated on a variety of networking models (circuit-switching vs. packet-switching, various local area access mechanisms). In the period 1980-1995, research focus shifted toward designing, implementing and standardizing protocols (TCP/IP, Ethernet). Since the beginning of the 1990s, an ever more important challenge is to keep the Internet up and running, and solve problems related to (performance) management, security and scalability. A similar transition in focus can be seen for wireless communication system. The figure below illustrates, through a horizontal structuring, the above three phases in system design.



Three technologies for dependable networked systems. Research within DACS covers the whole spectrum of network technologies: from well-established technologies (like the wired Internet), via technologies that are under development (such as wireless networks) to emerging technologies (like embedded network systems).

In the case of well-established technologies, research concentrates on operational aspects, here, in particular, of the wired Internet. Specific topics include bandwidth allocation, accounting, self-management of lambda switches and protection against scans, denial-of-service attacks and phishing. Taking and interpreting measurements plays an important role in this research.

For technologies under development, research focuses on the design, evaluation, and prototype implementation of new protocols and algorithms for wireless and ad-hoc networks. Topics include algorithms for context- and power-aware routing in ad-hoc networks, and, lately, more and more on car-to-car communications and wireless sensor networks. These types of networking systems are exponents of embedded networking technologies as well.

The remaining research on embedded networking technologies focuses on system specification and evaluation techniques to describe such systems, and the resource constraints (performance, dependability, energy usage) they have to operate under. This includes the development of new stochastic model checking techniques and the application thereof to predict dependability and performance properties.

The figure above also shows these three technology domains (where a clear cut separation can, of course, never be made). When technologies mature over time, a shift in phase and type of activity is foreseen. Inherent to university research, DACS moves on the increasing side of the wave (to the right). Note that the presented structure is based on technical content, not an organizational sub-structuring of the group. There is strong collaboration between the various group members, and projects generally cover multiple issues.

3.b. Future development

The view toward the research within DACS as explained above has been developed over the last few years. Major changes in direction are not expected, although the three focal points will be further developed and emphasized in the years to come. More than in the past, we will ask the question how new activities fit in, before we take them up.

The research on operational aspects will be extended towards wireless networks. For that extension, the focus will be on WLAN, since it is, in contrast to GSM and UMTS, relatively easy to obtain measurements data for such networks. Furthermore, with the increasing use of 10Gbps technologies for the core Internet, scalability of measurement systems becomes problematic. Therefore the focus will be shifted to flow-based measurement and analysis techniques (Netflow, IPFIX, sampling).

At present, the area design of dependable wireless systems is shifting its focus towards vehicular networking. The focus is on using communication between vehicles to improve traffic efficiency, safety, and environmental impact. At the end of 2008, a new externally funded research project in this area has been started, and a number of proposals are being evaluated for funding.

The research area for embedded networking will focus more on truly embedded systems (and the evaluation of the performance and dependability of those systems), also in cooperation with ESI. We will have already started activities in the area of model-based design for in-car automotive systems, thereby adhering to architectural design languages and systems such as Autosar and East-ADL. Furthermore, we will focus on the design and evaluation (security, dependability, survivability) of embedded networking technology as part of vital infrastructures, such as industrial plants, water and energy networks.

Each of the three focal areas has as coordinator a full or associate professor: Pras for dependable operational network systems, Heijenk for (protocol) design of dependable wireless systems, and Haverkort for model-based issues in dependable embedded networked system design. Each of these area coordinators has a very clear presence in the respective international scientific community (e.g., as regular conference organizer, PC chair, editorial board member or area leader).

As of March 1, 2009, professor Haverkort has become director of the Embedded Systems institute in Eindhoven. He will continue to work for DACS, but only for 20%. The group leadership will be taken over by dr. Pras.

4. Processes in research, internal and external collaboration

PhD candidates typically meet once per week with their daily advisor. The daily advisor always is one of the tenured faculty, possibly supported by a postdoctoral researcher. When the full professor is not the daily advisor, meetings between the PhD candidate and full professor are less regular in the beginning years, but become much more intensive in the second half of the PhD period as well. It is expected that for a successful PhD candidate, 4-5 publications are produced and submitted to full-review international high-quality journals or conferences.

Since the three area coordinators within DACS are prominent and respected researchers in their respective world-wide communities, they have the possibility to involve their PhD candidates actively in all important scientific processes (e.g., in the review process for major conferences and journals, on which they serve on editorial boards) and to introduce them to other key players in the field (e.g., by arranging short visits, longer exchanges, or by bringing them in contact with fellow PhD candidates from other institutions). This provides the PhD candidates the possibility to acquire an "inside view" and to become active members of the international scientific community themselves. Active participation in conferences requires that PhD candidates submit quality papers to these conferences; this is strongly encouraged. In the beginning period, a PhD candidate is typically allowed to attend one or two (international) conferences without presenting own work, to get acquainted with the atmosphere and the way things work.

All tenured staff is involved in teaching, also the Head of Group (who lectures, among others, in the first year of the BSc degree program). PhD candidates and postdocs are actively supporting the educational processes, e.g., by guiding BSc and MSc students in individual assignments, by "running" exercise hours or in supervising literature search assignments.

The senior staff typically takes the lead in external project acquisition, sometimes supported by the more junior tenured staff and the postdocs.

DACS collaborates internally and externally at several levels:

- At *UT level*, the group is actively involved in the CTIT strategic research orientations (SROs) on dependable systems and networking (DSN), wireless and sensor networks (WiSe) and security (Istrice/Prosecco).
- At *3TU level*, DACS (Haverkort) has effectively led the efforts to set up the Centre for Dependable ICT Systems (CeDICT, the Centre of Excellence within NIRICT). In December 2008, CeDICT formed a Joint Research Unit (JRU) with the Embedded System Institute (ESI), to bring together all research in the Netherlands related to dependable embedded (network) systems. The fact that Haverkort has been appointed in 2009 as the new scientific director of ESI, is an important sign of reputation and recognition.
- Furthermore, at *national level* DACS is actively participating in the High Tech Automotive Systems (HTAS) innovation program, and DACS has been involved in the preparation of the FES-ICT proposal COMICT. DACS is also a member of the research school ASCI (Advanced School for Computing and Imaging).
- At *European level*, DACS is coordinating the research activities of the Emanics Network of Excellence on management of networks and complex services. DACS (Pras) is also chairing IFIP WG6.6 on management of networks and distributed systems. Further, DACS (Heijenck) is actively participating in the ERCIM eMobility working group on mobile technologies (eMobility workshop chair in 2008 and 2009).

5. Academic reputation

Prof. dr. ir. B.R. Haverkort

- Fellow of the IEEE, as of 2007
- Scientific director and chairman of the Embedded Systems Institute, as of March 2009.
- Chairman of the Board of Trustees of Stichting Breedned, as of January 1, 2009.
- General Chair, IEEE Conference on "Quantitative Evaluation of Systems 2004", Enschede, the Netherlands, 2004
- TPC chair, IEEE/IFIP Conference on "Dependable Systems and Networks 2005", Yokohama, Japan, 2005
- TPC chair, International Workshop on Parallel and Distributed Methods in Verification, 2006 (Bonn) and 2007 (Berlin)
- TPC member of 50+ conferences.
- Member, IFIP WG 6.3 "Performance of Communication Systems", since 1998
- Member, IFIP WG 7.4 "Computer Performance Modelling and Analysis", since 2005
- Leading role in the 3TU Centre of Excellence CeDICT, since 2006
- Board member, Dutch research school ASCI, since 2005
- Editorial board member, Performance Evaluation (Elsevier), since 2005
- Steering Committee member and chair, Int'l. Conference on Quantitative Evaluation of Systems; member 2003-2008; chair since 2008
- Steering Committee chair, Int'l. Workshop on Performability Modelling of Computer and Communication Systems, since 2000
- Steering Committee member, GI/ITG-Fachgruppe "Messung Modellierung und Bewertung von Rechen- und Kommunikationssysteme", since 2001
- PhD candidates A. Bell and L. Cloth, and MSc student A. Remke received the German GI/MMB prize for their best theses, in 2004, 2008 and 2005, respectively

Dr. ir. G.J. Heijenck

- Senior member IEEE, since 2006

- Member of ERCIM eMobility working group
- Editorial board member, Journal of Internet Engineering, since 2006
- Steering Committee member of IEEE Vehicular Networking Conference (formerly IEEE Workshop on Vehicle-to-vehicle communications, V2VCOM, and IEEE Workshop on Automotive Networking and Applications, AutoNet)
- General chair and organizer of the 7th Wired / Wireless Internet Communications Conference (WWIC), Enschede, the Netherlands, 2009
- TPC (co-)chair of 6th WWIC Conference, Tampere, Finland, 2008
- TPC (co-)chair of 2nd ERCIM eMobility Workshop, Tampere, Finland
- TPC (co-)chair and organizer of the ERCIM eMobility Workshop 2009
- PhD candidate R. Ait Yaiz won the KIVI/NIRIA Telecommunication prize, 2005
- Best paper award WWIC 2008, Tampere, Finland
- TPC member of approximately 25 international conferences
- Holds several patents, e.g. on CDMA scheduling, used in UMTS/HSDPA base-stations world-wide

Dr. ir. A. Pras

- Chair of IFIP WG 6.6: "Management of Networks and Distributed Systems", since 2007
- Founding member, IRTF Network Management Research Group (NMRG)
- Executive Committee / Research coordinator, European NoE on Management Solutions for Next Generation Networks (EMANICS)
- Series Editor, IEEE Communications Magazine: Network & Service Management, since 2006
- Associate Editor, International Journal of Network Management (Wiley), since 2007
- Editorial Advisory Board member, Journal of Network and Systems Management (Springer), since 2007
- Editorial Board member, IEEE Communications Surveys & Tutorials, since 2008
- Guest editor, IEEE Communications Magazine on XML-based Management of Networks and Services, 2004
- Guest editor, Journal of Network and Service management (JNSM) on P2P technologies in Network and Service Management, 2007
- Steering Committee member, IFIP/IEEE NOMS and IM Symposia (NISC), since 2007
- Steering Committee member, IFIP/IEEE Management of Networks and Services (Manweek) conference, since 2008
- Steering Committee member, IFIP International Conference on Autonomous Infrastructure, Management and Security (AIMS), since 2006-now
- Steering Committee member, European EUNICE Consortium, since 1999
- TPC chair, 9th IFIP/IEEE International Symposium on Integrated Network Management, Nice, France, 2005
- TPC chair, IEEE/IFIP Workshop on End-to-End Monitoring Techniques and Services, 2005 (Nice) and 2006 (Vancouver)
- TPC chair, 13th EUNICE Summer School, Enschede, the Netherlands, 2007
- Dissertation Digest chair, 11th IEEE/IFIP Network Operations and Management Symposium, Salvador de Bahia, Brazil, 2008
- PhD Workshop Chair, 2nd International Conference on Autonomous Infrastructure, Management and Security, Bremen, Germany, 2008
- Co-organizer, Joint EMANICS/IRTF-NMRG Workshop on Netflow/IPFIX Usage in Network Management, Munich, Germany, 2008
- TPC and OC member of nearly 50 international conferences
- Program Committee member of NWO Glance, Stare and iScience
- Evaluator and reviewer for many EU 5th, 6th and 7th FP projects
- Editorial group member of EU - Future Internet Assembly - MANA
- Invited presentation at the IETF plenary meeting, Prague, March 2007
- Invited one day tutorial on Network Management trends, NTNU, Trondheim, Norway, 2008
- Invited talk at farewell of Prof. H.G. Hegering, LMU/TUM/LRZ, Munich, Germany, 2008

Prof. dr. J.L. van den Berg

- KPN Diana Telecommunication prize, 2003
- TPC Chair of the 16th International Workshop on Quality of Service
- Steering Committee member of ITC (International Teletraffic Congress)
- Management Committee member COST Action IC0703 "Data Traffic Monitoring and Analysis"
- Member, COST 290 "Traffic and QoS in Wireless Multimedia Networks", 2006-2009
- Elevated to Senior Research Fellow within TNO, 2005
- Member, IFIP WG 6.3 "Performance of Communication Systems"
- Editorial board member, Telecommunication Systems Journal (Springer)

Dr. ir. G. Karagiannis

- Member IETF working group "Next Steps in Signaling"
- Steering committee member, International Workshop on Quality of Service (IWQoS)
- Co-author of many internet-drafts and the RFC 4080 "Next Steps in Signaling (NSIS): Framework", June 2005, 49 pages. <http://www.ietf.org/rfc/rfc4080.txt>
- Author of patents on "Seamless handoff in Mobile IP" and "DiffServ QoS management"
-

Dr. ir. P.-T. de Boer

- Steering committee member, Rare-Event Simulation workshop
- Guest-editor for a special issue of Annals of Operations Research (2003)

6. Internal evaluation

At the start of each PhD project, a training and supervision plan is developed that includes the courses to be followed by the PhD candidate, and the targets to be reached within the next 12 months. Every 6 months progress is monitored, and a decision is made with respect to continuation. In case progress is insufficient, appropriate actions are discussed with the personnel department and a decision may be taken to stop the PhD project.

Each year the work of postdocs and staff members is discussed with their supervisors. If necessary, a plan is made to guide further development of the employee; such a plan contains measurable milestones.

7. External validation

7.a. Societal relevance

DACS focuses primarily on the technical aspects of dependable communication systems. However, as such systems are omnipresent, there is a broad but indirect societal interest in our achievements. DACS takes its societal responsibility by also publishing in popular media and giving presentations for non-technical audiences. Examples include articles in *De Automatiseringsgids*, radio interviews, e.g., in "HoeZo?" on AM 747 (on embedded communication systems), on 3FM (on security issues for mobile phones) and RTV-Oost (on issues related to UMTS antennas), presentations for radio amateurs on software defined radio, lectures about internet and its history and UMTS technology for services and business clubs (Lions, Probus), as well as presentations in regional schools. A staff member (de Boer) of DACS also contributes to the organization of the annual Informatics Olympiad in the Netherlands.

7.b. Industrial contacts

There are several forms of industrial contacts:

1. *Joint projects*: Alcatel/Lucent Bell Labs, Centric TSolve, DoCoMo Eurolabs, Embedded Systems Institute, Ericsson Research, Ericsson Rijen, Fourtress, IBM, KPN, Mobilaria, Ordina, SURFnet, Small Advanced Mobility, Thales Communications, Telematica Institute, TNO-ICT, TNO-I&T (Automotive), WMC.

2. *Joint project proposals:* ABB, DevLab / Chess, Ericsson Ireland, ING-Direct, Infosim Gmbh, Interpay, Iskratel, MBI, MG-Soft, NEC Europe, NXP, Quarantainenet, Rabobank, Security Matters, Siemens AG, Sony Ericsson, Sun Microsystems, SURFnet, Telefonica ID, Telematica Institute, Telenor, Telfort/Tiscali, TNO-ICT, Unet, Waternet, Witteveen en Bos.
3. *Student exchanges:* 3T, British Telecom, DLR, DoCoMo Eurolabs, Ericsson Eurolab, Hives, Mobilaria, NEC Europe, NFI, SpeakUp, Telefonica ID, Telematica Institute, TNO-ICT, Versatel, Vodafone, WMC.
4. *Guest lecturers:* KPMG, Motorola, Samsung, Quarantainenet
5. *Cooperation within IETF/IRTF:* Alcatel, Roke Manor Research (UK), Cisco Systems (USA, France, Germany), Nortel (USA, Canada), Nokia (Finland), Sonus Networks (USA), AT&T (USA), Samsung (Korea), DoCoMo Euro-Labs (Germany), NEC (Germany), Ericsson Research (various countries), Hewlett-Packard (USA and UK).
6. Measurement-related projects with Cisco, Geant, Verizon, Waternet.

8. Researchers and other personnel ("wp")

Recruitment of PhD candidates and postdocs is based on different approaches, including web and mailing list advertisements. Personal contacts, at staff as well as PhD level, play an important role in finding suitable candidates. Selection of PhD candidates is often performed jointly with other groups, and previous supervisors are often contacted.

Among the PhD candidates and postdocs, more than 75% is of non-Dutch origin. We are very pleased to say that more than a large share of our postdocs and PhD candidates is female (but none of these are Dutch).

Since 2005, the tenured staff is encouraged to make plans for a 2/3-month sabbatical. As a result of this, Pras went on sabbatical in 2006 (INRIA, Nancy, France), whereas De Boer took a sabbatical early 2007 (IRISA, Rennes, France). Heijenk will take a sabbatical in the academic year 2009/2010. Within the context of the Emanics NoE, exchange programs are used for PhD mobility. Several visiting scientists stayed at DACS for periods ranging from 1 month to 1 year.

Table 1

Category	Name	2003	2004	2005	2006	2007	2008
Tenured staff							
professor (hgl)	Haverkort, prof. dr. ir. B.R.H.M.	0,40	0,40	0,40	0,40	0,40	0,40
associate professor (uhd)	Heemstra de Groot, dr. ir. S.M.	0,09	0,09	0,09	0,06		
	Heijenk, dr. ir. G.J.	0,23	0,40	0,40	0,40	0,40	0,40
	Nicola, dr. ir. V.F.	0,34					
	Pras, dr. ir. A.		0,14	0,40	0,40	0,40	0,40
assistant professor (ud)	Boer, dr. ir. P.T. de	0,40	0,40	0,40	0,40	0,40	0,40
	Karagiannis, dr. ir. G.	0,29	0,40	0,40	0,40	0,40	0,40
Total tenured staff		1,74	1,82	2,09	2,06	2,00	2,00
Non-tenured staff							
professor (hgl)	Berg, prof. dr. J.L. van den	0,05	0,10	0,10	0,11	0,11	0,11
	Bochove, prof. ir. A.C. van	0,10	0,10	0,10	0,11	0,11	0,11
postdoctoral fellows	Achir, dr. M.					0,10	
	Boudali, dr. H.						0,14
	Cloth, dr. L.				1,00	1,00	1,00
	Granville, dr. L.					0,14	0,33
	Heijenk, dr. ir. G.J.	0,09					
	Kuntz, dr. G.W.M.			0,08	1,00	1,00	0,66
	Meent, dr. ir. R. van de				0,21	0,20	
Remke, dr. A.K.I.						0,42	

Category	Name	2003	2004	2005	2006	2007	2008
	Sadre, dr. R.					0,59	1,00
	Yu, dr. Q.					0,92	0,22
other junior staff (moz, twaio)	Abendroth, D.	0,26	0,06				
	Edigarian, G.	0,73					
	Kamilova, MSc. M.	0,27					
Total non-tenured staff		1,50	0,26	0,28	2,43	4,17	3,99
PhD Candidates							
junior staff (aio, oio, moz-p)	Ait Yaiz, ir. R.	1,00	0,41				
	Bloem, MSc J.W.H.						0,17
	Cloth, dipl.-inf. L.	0,57	0,80	0,80			
	Dey, D.	0,33					
	Dimitrova, D.C.				0,34	0,80	0,80
	El Allali, ir. H.	1,00	1,00				
	Fioreze, T.			0,27	0,80	0,80	0,80
	Goering, P.T.H.	0,13	0,80	0,80	0,80	0,66	
	Jehangir, A.	0,40	0,80	0,80	0,80	0,83	
	Jongerden, drs. M.R.				0,73	0,80	0,80
	Kamilova, MSc. M.		0,13	0,80	0,53		
	Liu, F.		0,27	0,80	0,80	0,80	0,80
	Martinez Verdugo, J.M.	0,64	0,80	0,80	0,20		
	Moreira Moura, G.C.						0,27
	Remke, dipl.-inf. A.K.I.		0,30	0,80	0,80	0,80	0,46
	Salvador, MSc. M.R.	0,07					
	Sperotto, A.				0,13	0,80	0,80
Taniman, MSc. R.O.		0,67	0,80	0,80	0,80	0,53	
Yang, Y.				0,07	0,80	0,80	
Zaburnenko, T.S.	0,80	0,80	0,66	0,15			
Total PhD Candidates		4,94	6,78	7,33	6,95	7,89	6,23
Total Research Staff DACS		8,19	8,87	9,70	11,44	14,06	12,22

9. Resources, funding and facilities

9.a. Laboratory infrastructure

Besides the standard office equipment, we have a networking laboratory with a variety of routers (Cisco, Cabletron), switches (HP, IBM, D-link) and several compute servers (running Linux and Xen), as well as a variety of PCs with multiple network cards which can be connected in different configurations, as well as virtualization software and hardware for personal network experimentation. Within the NWO project VeriGEM we have used the ASCI distributed supercomputer (DAS) for large-scale model checking problems. We have a six (quad and eight core) compute servers. DACS is connected with two servers to the European Emanics labs, and our measurement equipment is installed at SURFnet, ICTS (the group running the UT campus-wide network) and Waternet. Within the context of EMANICS, DACS experiments with trace analysis (SNMP, NetFlow), Podcasting and RSS feeds. DACS provides to the community various (anonymized) traffic traces.

9.b. FTE-funding

After an initial period in which the group was repositioned, the group reached a stable situation with five permanent staff members. For the future, the target is to have three postdocs and 12 to 15 PhD candidates. An explicit strategy is followed to obtain funding from

multiple sources: internal (UT/CTIT), national (NWO, STW, SENTER Novem), international (EU) and direct company collaboration.

Table 2: Funding at group level

DACS	2003	2004	2005	2006	2007	2008
Direct funding	88%	77%	66%	61%	63%	73%
Research funds	0%	4%	7%	11%	11%	8%
Contracts	12%	19%	27%	28%	27%	19%
Total	100%	100%	100%	100%	100%	100%

9.c. FTE-funding PhDs/postdocs

The following table shows a healthy balance among the different sources of funding, which may serve as evidence of the strategy to obtain funding from multiple sources, explicated above.

Table 3: Funding of PhDs/postdocs

DACS	2003	2004	2005	2006	2007	2008	Average
Direct funding	48%	14%	9%	16%	28%	40%	26%
Research funds	18%	16%	23%	28%	21%	20%	21%
Contracts	35%	70%	69%	56%	51%	40%	53%
Other	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%

9.d. List of external funds

The following table shows that we have managed to acquire projects from a number of different funding agencies, according to the strategy formulated above.

Table 4

Name Project	Start	End	Sponsor
NSIS: Next Steps in Signaling	Jun-06	Jun-07	Ericsson
COST TMA: Traffic Measurements and Analysis	Mar-08	Mar-11	European Commission
Emanics: Management Solutions for Next Generation Networks	Jan-06	Dec-09	European Commission
E-NEXT: Network of Excellence Emerging Network Technologies	Jan-04	Jul-06	European Commission
Seacorn: Simulation of Enhanced UMTS Access and Core Networks	Mar-02	Mar-04	European Commission
Casimir: QoS for Metropolitan Ethernet Networks	Jan-06	Jan-09	NWO
EQUIP: Enabling Quality of Service in IP-Based Communication Networks	Aug-01	Jan-06	NWO
MC=MC: Model-Checking of Infinite-State Markov Chains	Aug-04	Aug-08	NWO
Model Checking Stochastic Systems using Rare Event Simulation	Aug-08	Aug-12	NWO
MOQS: Modeling and Analysis of QoS of Component-Based Designs	Sep-05	Dec-08	NWO
VeriGEM: A Verification Grid for Enhanced Model Checking	Dec-05	Dec-08	NWO
Voss: Validation of Stochastic Systems	Mar-01	Jan-04	NWO
Voss-2: Validation of Stochastic Systems II	Jan-05	Jan-08	NWO
Optische Netwerken	Sep-99	Sep-03	PTT-Research ITB
Bluetooth Networking	Apr-99	Dec-03	SENER BSIK
Freeband/Awareness: context AWARE mobile Networks and Services	Jan-04	Jan-09	SENER BSIK
Freeband/PNP2008: Development of a user centric ambient communication environment	Jan-04	Jan-09	SENER BSIK
Connect & Drive	Oct-08	Oct-10	SENER HTAS
FSAN: Full-service Access Network using Multimode Fibre	Mar-04	Mar-08	SENER IOP
PN@H: Quality of Service for Personal Networks at Home	Sep-03	Sep-07	SENER IOP

Name Project	Start	End	Sponsor
Q-Wing: Quality of Service in the Wireless Internet Next Generation	Jan-99	Dec-03	SENER IOP
Sequal: Service Optimization and Quality	Oct-08	Oct-12	SENER IOP
FLAMINGO: Flexible Multiwavelength Optical Local Access Network Supporting Multimedia Broadband Services	Mar-98	Mar-03	STW
Gigaport: Research on Networks	Jan-05	Dec-07	SURFNET
Fish and Chips	Jan-07	Jan-08	Telematica Instituut
E-Quality: Expertise Centre on Performance and Quality of Service in ICT	Dec-05	Dec-09	TNO-ICT

10. Overview of the results

10.a. Key publications

Table 5

Nr	Title
1	C. Baier, B.R. Haverkort, H. Hermans, J.-P. Katoen, <i>Model-Checking Algorithms for Continuous-Time Markov Chains</i> . IEEE Transactions on Software Engineering 29(6), 524-541, 2003, ISSN: 0098-5589. (191 citations in Google Scholar)
2	R. El Abdouni Khayari, R. Sadre, B.R. Haverkort, <i>Fitting world-wide web request traces with the EM-algorithm</i> . Performance Evaluation 52(2-3), 175-191, 2003, ISSN: 0166-5316. (51 citations in Google Scholar)
3	A. Pras, T. Drevers, R. van de Meent, D.A.C. Quartel, <i>Comparing the Performance of SNMP and Web Services-Based Management</i> , IEEE Transactions on Network and Service Management, 1(2), 72-82, 2004, ISSN: 1932-4537. (41 citations in Google Scholar)
4	P.T. de Boer, D.P. Kroese, S. Mannor, R.Y. Rubinstein, <i>A Tutorial on the Cross-Entropy Method</i> , Annals of Operations Research, 2005, pp. 19-67, ISSN: 0254-5330. (123 citations in Google Scholar)
5	Heijenck, G.J., <i>System and method for fair, channel-dependent scheduling for wireless systems</i> , 2006, Patent

10.b. Numerical overview of the results in a fixed format of categories

Table 6

Category	2003	2004	2005	2006	2007	2008	
Academic publications	a. Refereed journals	4	4	12	8	9	4
	b. International conferences	11	16	40	24	30	25
	c. Book chapters		1	2		1	
	d. Other academic publications	3	7	8	7	7	8
Total	18	28	62	39	47	37	
Monographs							
PhD-theses	2	2	1	2	1	3	
Professional publications		1	2		1		
Patents		1	2	2		1	
Software							

10.c Full outcome list

2003

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- Malhotra, R., *Quality of service modeling and analysis for carrier ethernet* (2008). 157 pp. Univ. of Twente. CTIT Ph.D.-thesis series No. 08-126. Thesis advisor(s): J.L.van den Berg, M.R.H.Mandjes. ISBN:978-90-365-2711-8.
- Remke, A.K.I., *Model Checking Structured Infinite Markov Chains* (2008). 154 pp. Univ. of Twente, Zutphen. CTIT Ph.D.-thesis series No. 08-118. Thesis advisor(s): B.R.H.M.Haverkort. Woermann Printing Service, Zutphen. ISBN:978-90-8570-304-4.
- Zaburnenko, T.S., *Efficient heuristics for simulating rare events in queuing networks* (2008). 172 pp. University of Twente. CTIT Ph.D.-thesis series No. 08-111. Thesis advisor(s): B.R.H.M.Haverkort, P.T.de Boer. Centre for Telematics and Information Technology, University of Twente. ISBN:978-90-365-2622-7.

Patents

- Karagiannis, G., Heijenk, G.J., El Malki, K., Soliman, H., *Seamless handoff in Mobile IP* (2008). Patent US 7353027 (Assigned).

11. SWOT-analysis

Strengths:

- DACS has a clear research vision and strategy, and is well focused
- Research within DACS covers all phases of the lifecycle of communication systems
- Output covers patents, IETF drafts/RFCs and well-cited conference and journal papers
- DACS researchers are leading their respective areas. Examples are: director of ESI, IEEE fellow, chair of IFIP WG6.6, editors of main journals and many steering committees, EU Future Internet Assembly

Weaknesses:

- Balance between conference and journal papers is too much on conference papers
- No spin-off companies

Opportunities:

- Cooperation within 3TU/CeDICT as well as the JRU with ESI allows us to become the leading group in dependable communication systems in the Netherlands
- Good presence in the emerging field of vehicular networks and strong research contacts within Europe makes DACS well positioned to obtain future funding
- Focus of EU FP7 on the "future Internet" provides possibilities for funding and further collaboration

Threats:

- New director position of Haverkort at ESI will allow him to be less present in Twente
- Within CTIT and the Netherlands, research on communication systems gets fragmented over multiple programs

Analysis

- Over the last 6 years, DACS has become a group with a strong focus, which is able to cover all phases of the lifecycle of communication systems.
- As opposed to the EU, research on communications systems within the Netherlands and the UT gets divided over multiple programs, which increases the risk to get fragmented.
- With the general trend of a decreasing number of (master) students, finding good quality PhD candidates at the start of projects becomes harder.

Adjusted goals

- No need to adjust vision and research goals.

Adjusted strategy

- For DACS, European research funding becomes more important.
- To avoid senior staff from being overloaded with management tasks, the younger staff (UDs) will get more involved in project acquisition.
- With the shortage of good PhD candidates, DACS will improve integration between MSc and PhD students, to increase the interest of MSc students in PhD research
- DACS would like to adjust its strategy and hire good PhD candidates once they are found, and not postpone a decision with respect to hiring until financing of new projects has started. DACS would like to invest in this and use its financial reserves
- DACS will focus more on journals

Title of the Research Group:

Databases (DB)

Research themes: none

NABS code: N07

Head of Group: Prof. dr. P.M.G. Apers

Starting date: none

Formal affiliations outside the department and other formal co-operations:

Research schools SIKS and IPA, CTIT.

1. Mission statement

Our mission is **to provide data management to create added value on top of autonomous data sources.**

Nowadays huge amounts of data are produced by both humans ("prosumers") and devices connected to the Internet. This has led to information overload and a decrease in the trust of data (lack of quality: inaccuracy, ambiguity, and even inconsistency), as well as an increase of privacy threats. At the same time applications need data of high quality, and a way to deal with privacy sensitivity. Our approach is to extend database systems with data management functionality that filters and computes relevant information out of the data, reduces the unreliability of the data, and protects the privacy.

2. Leadership

The senior staff of the group consists of Peter Apers, Willem Jonker, and up to September 2006 also Ling Feng. For personal reasons Ling Feng had to leave to China in 2006, where she now works as a full professor at the Tsinghua University in Beijing. We still have a strong cooperation with her. Peter Apers, as full professor, has final responsibility for research and teaching activities and strategy. Willem Jonker, as part-time professor from Philips, is responsible for security-related activities in the group and provides an intensive cooperation with the largest ICT R&D lab (Philips Research) in the Netherlands. Together with the assistant professors Maarten Fokkinga, Djoerd Hiemstra, Maurice van Keulen, and Andreas Wombacher, the supervision of the PhD-candidates is done. The staff has an excellent national and international network, both in academia and industry. The strength of the group is its ability to reach its goals despite the fact that the full professors are only part-time available.

The permanent staff meets every two weeks to discuss group-related issues, such as progress of projects and PhD candidates. In addition, opportunities for new projects are discussed. The whole group meets every month to listen to presentations of PhD candidates and discuss their research. In the meantime, the daily advisors and PhD candidates meet frequently to discuss the progress; besides face-to-face meetings and brainstorming, here and at locations of our partners, we also exploit ICT communication media (email, VOIP, video conferences, and wiki's). We also have regular meetings with our Master students working on their theses. In addition we provide ad hoc presentation sessions for staff members and PhD candidates before giving a presentation at a conference or an interview for a grant.

Every year the permanent staff plus the postdocs of the group meet to discuss the future of the group in terms of research and teaching focus. To improve the supervision of PhD candidates, related experiences are exchanged. Furthermore, regular team-building events are organized for the whole group. Most PhD candidates are given the opportunity to spend three months abroad at a relevant academic or industrial lab.

The management style can be described as challenging and supportive to give each researcher the opportunity to reach his or her highest possible level.

3. Strategy and policy

3.a. Design in brief

The core competence of the group is data management. On top of that, individual members of the group have expertise in database technology, information retrieval, security, XML, and streaming data. This combined expertise makes it possible to work on our mission. To address the issue of information overload, we work on *Search on semi-structured data* where database query processing and information retrieval meet. To deal with a lack of trust we work on *Enriching uncertain data*, and finally to deal with privacy threats we work on *Security and Privacy*.

- *Search on semi-structured data*

With the rise in application of XML technologies, the need arises for management of large collections of XML documents. Our research on querying and searching of semi-structured data aims to extend relational technology for processing XML data. This allows leveraging decades of research and experience with relational databases and is expected to aid in industrial acceptance of the proposed techniques. When document collections reach, for instance, enterprise scale, even selective queries produce more results than a user can comprehend in reasonable time. Ranking aims to put the most promising results on top. Our research on ranking focuses on three scenarios: 1) document retrieval, 2) element retrieval and 3) entity retrieval. Entity retrieval tries to rank real world entities such as persons and locations. The group primarily addressed XML query optimization and search and ranking. The results are:

Construction of one of the fastest XML database management system called MonetDB/XQuery (65000 downloads since its open source release in 2005)	A model to incorporate the context and user preferences in answering queries in order to better satisfy a user's information need (PhD Van Bunningen)
Development of structured information retrieval approaches for XML data and integration of research results in open source software releases of MonetDB/XQuery in June 2007	Scalability in querying huge volumes of complexly structured data, by means of a way to transform item-at-a-time processing into bulk processing (PhD Van Ruth)
Development of so-called score region algebra, a logical abstraction layer for searching in XML databases using content and structure queries (PhD Mihajlovic)	Development of entity retrieval techniques and the integration of these techniques in XQuery database management systems (PhD Rode)
The publishing of the book <i>Multimedia Retrieval</i> , Springer 2007 (eds Blanken, Blok, Feng, all from our group, and Arjen de Vries from CWI), together with authors from our faculty, TNO, Telematica Instituut, UVA, LIACS, Philips Research, and CWI.	

- *Enriching uncertain data*

Uncertain data can be found in many flavors. Data integration matches schemas and data of different sources, possibly leading to ambiguities and conflicts. Processing multi-media data introduces uncertainty, e.g. by the quality of feature extractors. The same applies for acquired sensor data, e.g. the location of a person acquired by a localization system. The processing, querying, and retrieval of extracted metadata must acknowledge uncertainty in the data. We investigate how to increase certainty by relating uncertain data with additional context/ application/ community knowledge, in particular pertaining to context aware systems, location based services, and multimedia retrieval. The results are:

A novel technique for data integration that can deal with ambiguities and conflicts thus significantly reducing effort on entity resolution and data cleaning (PhD De Keijzer)	The establishment of the annual International VLDB workshop on Management of Uncertain Data (MUD), which started as a local Twente Data Management workshop in 2006 and continued as international VLDB workshop in 2007 and 2008
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A scalable clustering technique for web-scale schema matching (PhD Smiljanic)	Scalability (with respect to the number of locations, the number of sensors, and the time interval) in probabilistic processing of sensor data (forthcoming PhD thesis Evers)
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- *Security and Privacy*

Work has been done in the following areas: search in encrypted data, access control and privacy protection. Regarding search in encrypted data, we investigated the problem how personal, sensitive data can be securely stored on a (third party, attractive but) untrustworthy server. Solutions have been developed by means of encryption of the data in such a way that it can still be searched. A generic model for analyzing the efficiency and effectiveness of solutions is being developed. Regarding access control, we investigated how secret keys, stored by authorized users and used for cryptographic enforcement of access control mechanisms, can be distributed and managed. Regarding privacy protection, our idea is to subject data to progressive degradation while preserving the intended usability of the data. Progressive degradation is a refinement of limited retention (an "all-or-nothing" approach). The results are:

The firm establishment of the annual International VLDB workshop on Secure Data Management, which started in 2004 and celebrated its 5th anniversary in 2008.	Three approaches for a client to query a database such that the server neither learns the query nor the stored data (PhD Brinkman)
The publishing of the book <i>Security, Privacy and Trust in Modern Data Management</i> , Springer 2007 (eds Jonker, together with Milan Petkovic from Philips).	A method of, and device for, querying of protected structured data. Patent PHNL040611 US (Pending).

3.b. Future development

The overall score of the last evaluation was "very good"; the only point that required attention was "leadership". This had to do with the fact that the Head of Group was a member of the Executive Board of the university for some time. Peter Apers is now back in the group, although he is also scientific director of CTIT.

During the midterm review more attention was asked for seeing software as an asset. This resulted in making part of our software prototypes available via open source and to continue developing open source software tools in new projects. Also, research on uncertain data has been expanded.

Since the previous evaluation, the focus of the group has shifted more towards the management of data that is not necessarily stored in databases. This means that a shift from pure database technology and data modeling towards creating added value out of data, independent of whether it is stored in databases, and including the security and privacy aspect of data. First, expertise on Information Retrieval was added to the group, strengthening the retrieval focus. Furthermore, the retrieval focus was lifted to creating added value for ambient intelligence. Looking at the lack of quality of data and the new sources that produce data (sensor networks) we introduced new topics to deal with uncertainty of data and streaming data. During the whole period, the activity on security and privacy has grown.

- Search on semi-structured data

Future work on search is developed along three lines:

1. *Large-scale distributed search.* Search systems experience serious problems in keeping up with the growth of the web. Data centers consume a huge amount of energy. We plan to develop distributed internet search functionality in such a way that communities of users and/or federations of small search systems provide search services in a collaborative way. The challenge is how to distribute queries over many small autonomous search systems and process them locally.

2. *Social search for communities.* In recent years, solutions have been developed to personalize general purpose search applications for individuals. However, internet applications, such as Flickr, Delicious, and Facebook target communities searching for people and other imperfectly tagged entities. We plan to specifically investigate social search for children. Children's ability to use the Internet is severely hampered by the lack of appropriate search tools that return information suitable and relevant for children.
 3. *Spatial search.* Geo-data processing for applications such as mentioned below in "Enriching uncertain data", is moving towards web services-based workflows that exchange data in well-defined XML standards. Spatial database support, however, is currently limited to inflexible relational database technology. We plan to advance spatial data infrastructure by extending XML database technology with scalable spatial support and methods for orchestration and choreography of web services-based (neo-)geographic workflows.
- *Enriching uncertain data*
Being aware of uncertainty that arises in combining and processing of data, "enriching uncertain data" aims to increase the certainty by relating the data with additional knowledge from the context, application, and community. Dealing with uncertainty is challenging in particular when the data volumes are huge. These data volumes are created, e.g., by large communities or by automatic acquisition of streaming sensor data. In particular, we will investigate data integration, entity matching/identification/resolution, streaming data processing specification, evolution and provenance, and data quality improvement with user & system feedback.

The above mentioned challenges are investigated in different application domains. We plan to combine handling uncertain data with spatio-temporal and web data as e.g. used in GIS applications and web portals. Another application domain is sensor data in the environmental engineering domain: processing of streaming data requires a notion of data provenance which is capable of aligning automatic data quality assessments. Finally, an ambient intelligence application domain is investigated addressing indoor localization. In this scenario, we plan to improve predictive data quality models by interrelating sensor readings and other context information.
 - *Security and Privacy*
Regarding security, we aim to address secure handling of healthcare data, and investigate amongst others key management and distribution in medical applications. Work will be done in close collaboration with Philips Research. The challenges here are how to secure (multimedia) data by cryptographic techniques and how to manage (e-health) applications of such techniques. Regarding privacy, we intend to complete the work of the last years on elaborating and implementing our ideas for making data degradation practically useful and feasible.

4. Processes in research, internal and external collaboration

Given the focus of the group, external funding for specific projects is acquired to implement our goals. Some projects are submitted by individuals, others are submitted by a consortium of researchers or a mix of researchers and people from industry. In all cases, the PhD candidates have to work in teams.

Our research group has over the years been successful in acquiring externally funded projects (NWO, Bsik), resulting in highly visible research results (high quality conferences and journals). Within the faculty, there is cooperation with HMI and DIES, and a growing cooperation with Pervasive Systems (especially sensor networks).

In the CTIT, the group participates mainly in the Strategic Research Orientations:

- NICE (Natural Interaction in Computer-mediated Environments) allows the group to perform interdisciplinary research and cooperation with other subareas of Computer Science. Our group cooperates in several projects with HMI on the topics of search on semistructured data and enriching uncertainty data.
- ISTRICE (Integrated Security and Privacy in a Networked World): the SRO ISTRICE was formed by the CTIT in order to bundle various research activities. The security and privacy research of our group contributes substantially to the area of Information Security.
- ASSIST (Applied Science of Services for Information Society Technologies -- for our work on streaming data): the work in the group on the processing of streaming sensor data in a distributed system infrastructure as well as the evolution and documentation of this evolution (data provenance) is useful in the context of the ASSIST SRO. A joint project with research groups DB, IS and SE has been granted by the ASSIST SRO on service mediation and evolution.
- WiSe (Wireless and Sensor Systems): the work in the our group about handling and processing uncertain data and increasing data quality by sensor data enrichment is useful in the context of the WISE SRO. A grant for setting up and configuring a sensor infrastructure has been awarded by the ASSIST and WISE SRO.

The above participations enable the group to work in a multidisciplinary setting and to contribute to challenging topics.

Members of our group are member of the national research School for Information and Knowledge Systems (SIKS) and the Institute for Programming research and Algorithmics (IPA). PhD candidates follow the SIKS educational program. Nationally there is a long lasting, strong cooperation with the database group at CWI. At the international level, there is contact with quite a few universities and academic institutes. With a couple, we have contacts that are more formal: Technical University of Munich, University of Konstanz, INRIA, Stanford University, Microsoft and Yahoo.

The research of the group is validated by working with researchers from different sub-disciplines of computer science and sometimes from other disciplines, both at a national and international level, and by working with R&D labs of industry.

5. Academic reputation

Prof. dr. Peter M.G. Apers

- Scientific director of CTIT
- Chairman of the board of the Technology foundation STW
- Member of advisory board of ICTRegie
- Member of the Endowment of the VLDB (publication chair)
- Member of the steering committee of the EDBT
- Editor of Distributed and Parallel Databases, Kluwer
- Editor of Data and Knowledge Engineering, Elsevier
- Scientific director of NIRICT
- PC member of major database conferences: VLDB, SIGMOD, ICDE

Prof. dr. Willem Jonker

- Vice president Philips Research
- Sector-head Lifestyle Experience Solutions, Philips Research
- Chairman Sentinels
- Chairman IIP Veilig Verbonden
- Co-editor *Security, Privacy and Trust in Modern Data Management*, Springer Verlag Berlin, SBN 978-3-540-69860-9
- Organizer *Secure Database Management*, VLDB workshops 2004, 2005, 2006, 2007, 2008
- Various PC memberships

Prof. dr. Ling Feng

- NWO Vidi Vernieuwingsimpuls award (NWO).
- Distinguished International Research Fellow at Curtin University's Centre for Extended Enterprises and Business Intelligence, Australia.
- Asian-Pacific editor of International Journal of Informatica.
- Associate editor of International Journal of Data Warehousing and Mining.
- Guest co-editor of International Journal of Computer Science, System & Engineering on "Trends in XML Technology for the Global Information Infrastructure". Vol.18, No.5, September 2003.
- Editorial member of International Journal of Neuroscience Methods.
- Editorial member of International Journal of Data Analysis Techniques and Strategies.

Book editorships

- Henk Blanken, Arjen P. de Vries, Henk Ernst Blok, and Ling Feng (Eds.). Multimedia Retrieval: Data-Centric Systems and Applications. Springer-Verlag Berlin Heidelberg. ISBN 978-3-540-72894-8, 2007.
- Ling Feng, Guoren Wang, Cheng Zeng, Ruhua Huang (Eds.): Web Information Systems - WISE 2006 Workshops, WISE 2006 International Workshops, Proceedings Springer, 2006.
- Qing Li, Guoren Wang, and Ling Feng (Eds.). Web-Aged Information Management, Lecture Notes in Computer Science, Springer, ISBN 3-540-22418-1, 2004.

(Co-) organizer and PC memberships

- Tutorial chair and publicity co-chair of the 6th Intl. Conf. on Web-based Learning, 2007;
- Workshop chair of the 7th Intl. Conf. on Web Information Systems Engineering, 2006;
- Publication chair of the 5th Intl. Conf. on Web-based Learning, 2006;
- Chair of the 1st IFIP WG 2.12 & WG 12.4 Intl. Workshop on Web Semantics, 2005;
- Publication chair of the 5th Intl. Conf. on Web-Age Information Management, 2004;
- PC member of EUROSSC, ICDM, DEXA

For personal reasons Ling Feng had to leave to China in 2006, where she now works as a full professor at the Tsinghua University in Beijing. We still have a strong cooperation with her.

Dr. ir. Djoerd Hiemstra

International activities:

- 2007 – present: Information Director of ACM SIGIR.
- 2005 – present: Scientific advisory committee of SIKS: the Dutch Research School on Information and Knowledge Systems.
- 2004 – 2007: Program officer of NWO Open Competition Computer Science (BeoordelingsCommissie Informatica, BCI) 2004-2007
- 2008 – present: Editorial Board of Information Retrieval Journal, Springer, 2008.
- Co-organizer of the ACM Conference on Research and Development in Information Retrieval, SIGIR 2007.
- Co-organizer of the SIKS/Yahoo Seminar on Searching and Ranking, SSR 2008.
- Co-organizer of the Dutch-Belgian Information Retrieval Workshops, DIR 2005
- Co-organizer of the Twente Data Management Workshop, TDM 2004.
- PC member of SIGIR, CIKM, WWW and others.

Grants and prizes:

- Distributed Information Retrieval by means of Keyboard Auctions (NWO-Vidi-grant) funded by the Netherlands Organization for Scientific Research (2 PhD candidates)
- Radical Decentralization of Search, research grant by Yahoo Research, Barcelona (\$ 25,000)
- Best student paper award at the European Conference on Information Retrieval (ECIR) 2007 with Pavel Serdyukov.

Dr. ir. Maurice van Keulen

- Co-editor of ICT-Zakboek, 3e druk, PBNA Polyzakboekjes, Reed Elsevier, Published in 2007
- Co-organizer of 2008 Dagstuhl Seminar 08421 on Uncertainty Management in Information Systems 2008
- Co-organizer of VLDB workshop on Management of Uncertain Data (MUD 2008)

- Co-organizer of VLDB workshop on Management of Uncertain Data (MUD 2007)
- Co-organizer of 2006 Dagstuhl Seminar on XQuery Implementation Paradigms
- Co-organizer of Twente Data Management workshop on Uncertainty in Databases (TDM 2006)
- Co-organizer Dutch-Belgian DataBase Day (DBDBD 2005)
- Co-organizer of EDBT Summerschool 2004
- Co-organizer MultimediaN/AmbientDB workshops 2003, 2004, 2005, 2007
- Observer of IFIP Working Group 2.6 on Data Semantics
- Member of EUSFLAT Working Group SCDMIR on Soft Computing in Database Management and Information Retrieval
- Member of EDBT Association
- PC member of ICDE, VLDB, EDBT, SUM and others

Dr. Andreas Wombacher

Participation in OCs

- Workshop chair IEEE Conference on Commerce and Enterprise Computing (CEC) 2009
- Services Education Methodology Summit Chair to IEEE International Conference on Web Services (ICWS) 2009
- Publicity chair Int. conf. on Services Computing (SCC) 2008
- Demo chair of Intl Conference on Business Process Management (BPM) 2008
- Steering Committee Inaugural IEEE International Digital Ecosystems and Technologies Conference IEEE-DEST 2007
- Publicity Chair of Infoscale 2007
- Track Chair at IEEE International Digital Ecosystems and Technologies Conference IEEE-DEST 2007
- Panel Chair at International Conference on Collaborative Computing: Networking, Applications and Worksharing (CollaborateComp) 2006
- Tutorial chair joint conferences Int. Conf. on Web Services (ICWS) & Int. conf. on Services Computing (SCC) 2006
- Chair of Workshop on Dynamic Process Management (DPM) 2006
- Publicity chair at Int. Conf. on Data Engineering (ICDE) 2006
- PC-Vice chair at IEEE Conf. on Electronic Commerce 2006
- Chair of Int. Workshop on Security and Trust in Decentralized/Distributed Data Structures (STD3S) 2006
- Steering committee Semantic Web Service Challenge 2006
- Organizer Web Service Challenge 2005 and 2006
- Workshop chair at IEEE Conf. on Electronic Commerce 2005
- Chair at workshop on Service oriented Solutions for Cooperative Organizations (SoS4CO) 2005 and 2006
- Tutorial chair at Int. Conf. on e-Technology, e-Commerce and e- Service (EEE) 2005
- International liaison chair at IEEE Int. Conf. on e-Business Engineering (ICEBE) 2005
- Editorial board at Int. Journal on Web Service Research (JWSR)
- Editorial board at Int. Journal of Business Process Integration and Management (IJBPIIM)
- Review board on Transactions on Knowledge and Data Engineering since 2006
- PC member of ICWS, BPM, EDOC and others

6. Internal evaluation

Most of the evaluation processes are organized by the 3TU (midterm review), the faculty (evaluations of staff and PhD candidates), and CTIT (chair visits). On top of that, grant proposals, articles to be submitted to major conferences, and important presentations are discussed among the members of the permanent staff. Important evaluations of PhD candidates are always done by at least two staff members.

Feedback on activities of the group are discussed among the permanent staff may result in an adjustment of the focus or of the group's strategy.

7. External validation

7a. Societal relevance

Information overload via WWW is becoming a serious societal problem. More and more data becomes available on the web, making it more difficult to find relevant information. Search engines like Google are doing a good job; however, keyword search is a rather limited way of formulating queries. Also, due to several reasons, the quality of the data is decreasing. This is a severe threat for the Internet and its open structure. By dealing with uncertainty techniques, we try to address this problem. Part of the research is conducted within the Pathfinder consortium that together develops and supports the open source XML database system MonetDB/XQuery with the open source Pathfinder/Tijah XML search sub-system.

In addition, the fact that almost all data can somehow be accessed by unauthorized persons is a security threat. Protecting data, not only commercial data, is becoming more and more important. On top of that there is a tradeoff between collecting as much data as possible to support ambient intelligence and preserving the privacy of individuals.

In all three areas, we have close cooperation with industrial partners.

Software assets

The tools mentioned above are made available to the public under the following URLs:

- MonetDB/XQuery: <http://www.monetdb-xquery.org>
- PF/Tijah: <http://dbappl.cs.utwente.nl/pftijah>
- Pathfinder: <http://www.pathfinder-xquery.org>
- Open source development platform: <http://sourceforge.net/projects/monetdb>

7b. Industrial contacts

National:

- Philips Research: Security and privacy in e-health, multimedia search, ambient intelligence, and grid access methods and applications
- Nederlands Forensisch Instituut (NFI), FINAN, X-Hive, Procedia: XML databases
- MAG research, eMaxx, Topicus, e-System Solutions: (Probabilistic) data integration
- V2: multimedia search and ambient intelligence
- LogicaCMG, Arcadis: Spatial databases and GIS
- WCC: Text matching evaluation
- Souki.com: Information extraction
- Gladior, WODC: Data mining

International:

- Microsoft Research Cambridge (UK): Language models for information retrieval
- Yahoo Research: Radical decentralization of search

8. Researchers and other personnel ("wp")

The personnel policy is focused on quality. Permanent staff and PhD candidates are selected after an international search. More than half of the members of the our group are from abroad.

For the PhD candidates we have an initial interview by phone. After they are selected they have to give a presentation for the group. They stay for at least one day to give the members of the group the opportunity to talk to them. When they are hired they have to take courses provide by the research school SIKS. They get a personal supervisor. Frequently they have to report on their research in meetings where all PhD candidates are present. During their PhD period, excellent candidates get the opportunity to stay at another university abroad or an international R&D lab for several months.

For permanent staff, the procedure is more or less the same. For them the focus is more on developing their own research area, getting externally funded projects, being the supervisor of PhD candidates. NWO has personal grants at three levels: VENI, VIDI, and VICI. The group puts a strong emphasis on obtaining such a grant. Until now, two VIDI-proposals were granted. Furthermore, permanent staff has the opportunity to spend some time abroad and to follow a course on Academic Leadership. Almost all staff members make use of that.

Table 1

Category	Name	2003	2004	2005	2006	2007	2008
Tenured staff							
professor (hgl)	Apers, prof. dr. P.M.G.	0,20	0,20	0,20	0,20	0,20	0,20
associate professor (uhd)	Blanken, dr. H.M.	0,27	0,16				
	Feng, L.	0,40	0,40	0,40	0,30		
assistant professor (ud)	Fokkinga, dr. M.M.	0,40	0,40	0,40	0,36	0,36	0,36
	Hiemstra, dr. ir. D.	0,40	0,40	0,40	0,40	0,40	0,40
	Keulen, dr. ir. M. van	0,34	0,40	0,40	0,40	0,40	0,40
	Wombacher, dr. A.					0,14	0,40
Total tenured staff		1,97	1,92	1,76	1,46	1,30	1,56
Non-tenured staff							
professor (hgl)	Jonker, prof. dr. W.	0,11	0,11	0,11	0,11	0,11	0,11
associate professor (uhd)	Blanken, dr. H.M.			0,08	0,08	0,01	
assistant professor (ud)	Choenni, dr. ir. R.S.	0,10		0,11	0,11	0,11	0,08
postdoctoral fellows	Anciaux, dr. N.L.G.			0,84	0,24		
	Blok, dr. ir. H.E.	1,00	1,00	1,00	0,58		
other junior staff (moz, twaio)	Singh, A.						0,14
	Vonk, ir. J.	0,33					
Total non-tenured staff		1,54	1,11	2,14	1,12	0,23	0,33
PhD Candidates							
junior staff (aio, oio, moz-p)	Abdel Kader, R.				0,40	0,80	0,80
	Aly, R.B.N.				0,40	0,80	0,80
	Boldareva, L.	0,80	0,80	0,23			
	Bunningen, A.H. van		0,60	0,80	0,80	0,80	0,20
	Derks, ir. W.L.A.	0,80	0,80	0,39			
	Evers, ir. S.			0,67	0,80	0,80	0,80
	Groote, ir. E. de				0,49	0,31	
	Heerde, H.J.W. van				0,68	0,80	0,80
	Ibraimi, L.						0,80
	Keijzer, A. de	0,49	0,77	0,80	0,80	0,80	0,20
	Klinger, S.			0,47			
	Li, R.					0,77	0,80
	Meratnia, N.	0,80	0,80	0,13			
	Mihajlovic, V.	1,00	1,00	1,00	0,70		
	Petkovic, M.	0,17					
	Rode, H.		0,60	0,80	0,80	0,80	0,20
	Ruth, drs. J. van	0,80	0,80	0,80			
	Saffarian, M.						0,40
	Serdyukov, P.			0,58	0,80	0,80	0,80
	Smiljanic, M.	1,00	1,00	1,00			
Tigelaar, ir. A.S.						0,20	
Zych, A.		0,13	0,80	0,80	0,33		
Total PhD Candidates		5,86	7,30	8,47	7,47	7,81	6,80
Total Research Staff DB		9,37	10,33	12,37	10,05	9,34	8,69

9. Resources, funding and facilities

9.a. Laboratory infrastructure

Besides the standard desktop or laptop systems, we have a lab room with a varying number of on average 10 PCs (Linux and Windows). For demonstration purposes we have a Dell 64 bit Xeon server running all demonstration and teaching software produced by the group from a publicly accessible Apache web server. For large scale database and IR experiments we have 1 AMD and 2 Intel 64 bit PCs with several terabytes of disk space and 4G internal memory. As of the start of 2009, we have a cluster of 16 Dell R200 3Ghz Xeon systems with 8G memory and 1TB disk per node for distributed information retrieval research.

For our sensor network research we have 3 powerful Dell servers managing sensor data from a network of Ubisense, Bluetooth and Ambient system sensors together with a couple of video cameras.

9.b. Funding at group level

Table 2 shows a slowly increasing level of non-direct funding for the group, evenly divided over research funds and contractual funding. It is the aim of the DB group to further increase the acquisition of externally funded projects.

Table 2: Funding at group level

DB	2003	2004	2005	2006	2007	2008
Direct funding	89%	83%	69%	75%	73%	76%
Research funds	9%	8%	15%	15%	9%	12%
Contracts	3%	9%	15%	10%	18%	12%
Total	100%	100%	100%	100%	100%	100%

9.c. FTE-funding PhDs/postdocs

The volume of external funding for PhD candidates and postdocs has increased substantially (see Table 3). All external funding is obtained in competition; NWO being the most competitive research funding, both in the Open Competition of Exact Sciences and the VernieuwingsImpuls. In the NWO VernieuwingsImpuls two group members, Ling Feng and Djoerd Hiemstra, obtained the very prestigious VIDI-grant. In the Bsik-funding the group was very successful in participating in the MultimediaN project. Currently, the group focuses on the next round of Bsik-funding by participating in COMICT and on FP7. Already one FP7 project has been accepted: PuppyIR.

Table 3: Funding of PhDs/postdocs

DB	2003	2004	2005	2006	2007	2008	Average
Direct funding	57%	45%	30%	20%	18%	18%	31%
Research funds	29%	24%	44%	47%	46%	56%	41%
Contracts	14%	31%	26%	33%	36%	26%	28%
Other	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%

9.d. List of external funds

The list of projects clearly shows the equal division over the categories of research funds and contractual funding. The two prestigious NWO-VIDI projects speak for the high potential of the group. Also note that more than half of the projects listed were acquired during the second half of the assessment period, and are still running at this time. This provides a good basis on which to further increase the level of non-direct funding for the group.

Table 4

Name Project	Start	End	Sponsor
AMIS: Advanced Multimedia Indexing and Searching	Jul-97	May-03	NWO
CIRQUID: Complex Information Retrieval Queries in a DBMS	Oct-02	Jan-07	NWO
Effort: effective focused retrieval techniques	Jan-07	Jan-11	NWO
OPAQUE: Optimization of Pathfinder Queries	Jun-05	Jul-10	NWO
CADMAI: Towards Context-Aware Data Management for Ambient Intelligence	Mar-05	Mar-10	NWO VIDI
Distributed Information Retrieval By Means Of Keyword Auctions	Oct-08	Oct-13	NWO VIDI
DRM Technology for electronic health record systems	Jul-06	Jul-10	Philips Electronics
Secure Meta Data: Secure Content Management In Ambient Environments	Feb-03	Feb-07	Philips Electronics
Secure Patient	Jan-08	Dec-11	Philips Electronics
BRICKS/PDC1: Security, Identification and Authentication	Jan-04	Jan-10	SENER BSIK
MultimediaN/N3: Multimedia databases	Jan-04	Jan-10	SENER BSIK
MultimediaN/N5: Semantic access	Jan-04	Jan-10	SENER BSIK
GRAAL: Guidelines Regarding Architecture ALignment	Sep-02	Dec-05	Telematica Instituut

10. Overview of the results

10.a. Key publications

Table 5

Nr	Title
1	Li, Q., Feng, L., Wong, A.K.Y. <i>From Intra-transaction to Generalized Inter-transaction: Landscaping Multidimensional Contexts in Association Rule Mining</i> . Information sciences nr: 3--4, 172, (2005). (pp. 361-395) ISSN: 0020-0255
2	Grust, T., Keulen, M. van, Teubner, J. <i>Accelerating XPath Evaluation in Any RDBMS</i> . ACM transactions on database systems nr: 1, 29, (2004). (pp. 91-131) ISSN: 0362-5915. <i>This is the extended version of: Grust, T., Keulen, M. van, Teubner, J. Staircase Join: Teach a Relational DBMS to Watch its (Axis) Steps. Proceedings of the 29th International Conference on Very Large Databases (2003). (pp. 524-535) Berlin, Germany Morgan Kaufmann Publishers ISBN: 0-12-722442-4</i>
3	Boncz, P., Grust, T., Keulen, M. van, Manegold, S., Rittinger, J., Teubner, J. <i>MonetDB/XQuery: a fast XQuery processor powered by a relational engine</i> . Proceedings of the 2006 ACM SIGMOD international conference on Management of data (nr: 2), (2006, June 1). (pp. 479-490) New York, NY, USA ACM Press ISBN: 1-59593-434-0
4.	Hiemstra, D., Robertson, S.E., Zaragoza, H. <i>Parsimonious Language Models for Information Retrieval</i> . Proceedings of the 27th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval (2004). (pp. 178-185) ISBN: 1-58113-881-4
5.	Brinkman, R., Feng, L., Doumen, J.M., Hartel, P.H., Jonker, W. <i>Efficient Tree Search in Encrypted Data</i> . Information systems security nr: 3, 13, (2004). (pp. 14-21) ISSN: 1065-898X

10.b. Numerical overview of the results in a fixed format of categories

Table 6

Category		2003	2004	2005	2006	2007	2008
Academic publications	a. Refereed journals	5	7	6	1		
	b. International conferences	24	16	33	23	21	29
	c. Book chapters	6		4	1	10	1
	d. Other academic publications	5	5	3	6	9	7
Total		40	28	46	31	40	37
Monographs		1					
PhD-theses		2	1	2	3	1	3
Professional publications			3	3		6	
Patents			1		1	1	
Software				1		1	

10.c. Full outcome list**2003****Journal articles**

- Feng, L. , Dillon, T. *Using Fuzzy Linguistic Representations to Provide Explanatory Semantics for Data Warehouses*. IEEE transactions on knowledge and data engineering nr: 1, 15, (2003). (pp. 86-102) ISSN: 1041-4347
- Jonker, W. *XML and secure data management in an ambient world*. SPECIAL ISSUE: Trends in XML Technology for the Global Information Infrastructure International journal of computer systems science and engineering nr: 5, 18, (2003). (pp. 311-317) ISSN: 0267-6192
- Lu, Hongjun , Yu, J.X., Feng, L., Li, Z. *Fully Dynamic Partitioning: Handling Data Skew in Parallel Data Cube Computation*. Distributed and parallel databases nr: 2, 13, (2003). (pp. 181-202) ISSN: 0926-8782
- Tung, A.K.H. , Lu, Hongjun, Han, J., Feng, L. *Efficient Mining of Inter-Transaction Association Rules*. IEEE transactions on knowledge and data engineering nr: 1, 15, (2003). (pp. 43-56) ISSN: 1041-4347
- Westerveld, T.H.W. , Vries, A.J. de, Ballegooij, A. van, Jong, F.M.G. de, Hiemstra, D. *A Probabilistic Multimedia Retrieval Model and its Evaluation*. Eurasip journal on applied signal processing 2, (2003). (pp. 186-198) ISSN: 1110-8657

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- Hiemstra, D. , et al, *Challenges in Information Retrieval and Language Modeling*. Sigir Forum / A Publication of the Special Interest Group on Information Retrieval 37 (nr: 1), (2003). 17 pp. New York ACM Press
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11. SWOT-analysis

Strengths

- Ability to attract external funding, high level of funding from NWO (a.o. 2 Vidi projects)
- Capitalize on research results by producing (open source) software
- Being able to address retrieval problems from a combined database and Information Retrieval perspective

Weaknesses

- Insufficient outreach of our research results
- Added-value of many industrial collaborations is insufficient

Opportunities

- Multimedia, internet, and streaming applications are hot topics
- More research funding becomes available for human-centric research

Threats

- Funding for database research is diminishing

Analysis

- Focus is on data management topics (not only pure database research) eases funding
- Publishing needs more attention, more focus on top quality publications.
- Stronger coupling between own goals and external funding

Adjusted goals

- Streaming data and uncertainty of data are new research goals

Adjusted strategy

- More focus on top quality publications
- Investing more in a structural relationships with selected partners

Title of the Research Group:

Distributed and Embedded Security (DIES)⁶

Research themes: none

NABS code: N07

Head of Group: Prof. dr. P.H. Hartel

Starting date: none

Formal affiliations outside the department and other formal co-operations: IPA research school, CTIT, 3TU.NIRICT.

1. Mission statement

Research area:

Distributed and embedded systems, especially when they are resource constrained, dynamically evolving, unattended, and interacting with a physical environment with the ultimate purpose of serving people (Smart Systems), provide significant security challenges. Examples of the specific systems for which we provide the security include body sensor networks, process automation networks, and health information systems.

Mission:

To foster systematic reasoning about the fundamental security properties of distributed and embedded systems.

We are interested in security properties because threats and faults are huge practical problems, whereas the solutions require sophisticated theory, advanced tools and extensive experimentation.

2. Leadership

The group is managed by senior staff (profs. Hartel and Etalle), with frequent informal consultation of other staff. Formal group meetings with all academic staff and postdocs involved in lecturing take place 3 to 4 times a year. The group has a weekly seminar, and an up-to-date web site. In the past eight years, DIES has been successful in acquiring external research funding, getting papers accepted in high quality conferences and journals, applying for patents, and guiding a significant number of PhD candidates towards the doctorate. We believe that this success is due to extensive cooperation within the group and with other groups in the faculty, CTIT and in NIRICT. Hartel is the leader of the CTIT SRO Istrice and Etalle is the leader of the University Spearhead Program Prosecco; this constitutes the largest multidisciplinary security research group in the Netherlands. The synergy created by these two activities contributes to the achievements of the group, both locally, nationally and internationally. Hartel and Etalle also lead the NIRICT SRA security. At the national level, Hartel has created the STW/Sentinels funding program for Security research in the Netherlands (with prof. Jacobs from RU), and the ICT Regie Innovation Platform "Veilig Verbonden" (with prof. Jonker from Philips and Dr de Jager from TNO).

3. Strategy and policy

3.a. Design in brief

Currently, our research focuses on three classic system properties (the CIA): *confidentiality* (absence of unauthorized disclosure of information), *integrity* (absence of improper system and data alterations), and *availability* (readiness for correct service). Confidentiality is a security property, and availability and integrity are both security and dependability properties. We are increasingly interested in an aggregate property, *accountability*, which expresses that participants in a transaction are held responsible for their actions, being required to justify and explain their behavior. Accountability is a security property.

⁶ Formerly Distributed and Embedded Systems (DIES)

The interplay between resource constraints, dynamics, unattended operation and the four properties listed above provides a rich area of research. The challenges we face include:

1. To *experiment* with security designs for distributed and embedded systems in order to increase our knowledge and understanding.
2. To take *modeling* secure systems and their environment from art to science. For example, it is relatively easy to make a different model for each different property of a system, or for a different purpose (analysis, optimization, simulation). It is hard to keep those models consistent.
3. To develop *methods and tools* supporting a holistic view of systems. For example, many properties are delicate: only one bottleneck may be sufficient to spoil the availability, and one leak is sufficient to spoil the confidentiality of a system.
4. To develop *protocols and algorithms* to improve the properties listed above of systems under stringent conditions such as resource constraints, dynamics, and unattended operation.

DIES is the hub of the multidisciplinary security research in Twente, which gives it a unique position amongst the security groups in the Netherlands.

Historical note:

Following the recommendation of the previous research assessment committee, DIES has completely focused its research on security; we have even changed the name of the group from Distributed and Embedded Systems to Distributed and Embedded Security to reflect the new focus. This process has been made possible by hiring new staff with expertise in security and in particular cryptography (Nikova), as well as the retirement of staff (Vervoort, Schoute and Jansen) and the move of DIES staff to the Control Engineering group (Mader) and the Pervasive Systems group (Mullender and Scholten). Please refer to the reports of those groups for further information about our colleagues. In 2007 Etalle was appointed as a full professor in Eindhoven (0.8) and in Twente (0.2). The refocusing process started in 2007, just after the mid term review, was formalized by the name change on Jan 1st 2008, and is due to be completed by the end of 2009. At present (spring 2009) we are in the process of hiring another assistant/associate professor to complete the academic staff.

The recent research results that we are most proud of are:

- DIES lecturer dr. Nikova is a member of the team of COSIC, KULeuven, which has submitted the hash function LANE to the 2008 NIST competition for new hash function standard - SHA3.
- The world's most comprehensive suite of integrated anomaly-based network intrusion detection tools [Thesis Bolzoni 2009].
- A prize winning protocol that allows two parties who have never met to set up a secure communication channel without a trusted third party [Thesis Buhan 2008].
- A range of methods to support searching in encrypted data [Thesis Brinkman 2007].
- Several extensions of the Dolev Yao model with tool support to verify security protocols in the presence of more versatile attackers [Thesis Corin 2006].
- A detailed understanding of the mechanisms available to attack and to defend all common MAC protocols used in WSN [Thesis Law 2005].

3.b. Future development

Most of our research takes place in externally funded projects with partners from industry and government, who provide us with many interesting practical problems. We use these problems as a source of inspiration for our more theoretical research and at the same time we work on concrete solutions of industrially and socially relevant problems. We are currently working on security *design* methods, security *tools*, security *protocols*, and cryptographic *algorithms* to solve problems in the following application areas:

- Healthcare. There is an increasing demand for IT support in healthcare to improve the efficiency of the health care system. We work on cryptographically enforced distributed

access control *protocols* and privacy preserving *protocols* for outsourcing health records. This is joint work with the DB group.

- Body Sensor Networks. Care and well being applications can benefit significantly from dependable and secure sensors that are inexpensive and easy to deploy. We work on light weight cryptographic *algorithms* and user friendly key management *protocols* for severely resource constrained Body Sensor Networks nodes. This is joint work with the BSS group.
- SCADA. Supervisory Control and Data Acquisition networks are heavily used in process automation. The legacy equipment of many such networks is being replaced by standard equipment (Ethernet, PCs) with standard protocols (TCP/IP), standard operating systems (Windows) and also standard vulnerabilities. We are investigating how successful Internet based techniques such as our own Intrusion Detection *tools* can be adapted to SCADA. This is joint work with the DACS group.
- Risk management. 100% IT security is not realizable, and if it were realizable it would be too expensive to be adopted. Risk management is the art of striking the right balance between security and costs associated with it. Managers will not invest in security unless they are convinced that the risks of not investing outweigh the cost of the security investments. Therefore, the success of security technology depends largely on how much influence it has on the risk balance enterprises are confronted with. To understand this aspect of security and to improve the scientific level of risk management decisions, we are working on a set of *tools* to analyze security risks in corporate environments. This is joint work with the IS group.
- Crime Science. Most systems are criminogenic by design, because security is added as an afterthought. The Internet is one of the most prominent examples of this approach. We are working with colleagues from many disciplines across the university to establish the new discipline of Crime Science in Twente. Our own aim is to *design* ICT systems that provide as little opportunity and temptation for criminal behaviour as possible. This is joint work with the SAS group and groups from the faculties of Behavioural Sciences, Management and Governance, and Engineering Technology.

4. Processes in research, internal and external collaboration

All PhD candidates are supervised by one or two academics often with assistance from one or more of the postdocs. All papers written by PhD candidates are read and extensively discussed with at least one of the two professors of the group. Each PhD candidate is expected to publish at least 5 papers in journals or good conferences to form the basis of the PhD thesis. Several of our past PhD candidates have exceeded this requirement by a large margin. In the assessment period 2003-2008, ten DIES PhD candidates have defended their thesis, and four more are expected to complete in 2009 (i.e., on average 2 per year over a period of 7 years).

Internal collaboration:

- All our projects are joint projects with other groups in the faculty and the university
- All members of academic staff are active in teaching and research. PhD candidates are not often involved in teaching because there are unfortunately too few bachelor and master students with an interest in security.
- Our office space is home not only to DIES staff, postdocs and PhD candidates but also to the PhD candidates and postdocs from the IS and DB groups who work on security. This improves the cooperation between groups in a significant manner, as for example witnessed by joint publications and grant applications.
- DIES has the best coffee machine of the entire building, and a well appointed coffee room that is popular not only amongst members of the group but many others as well. This stimulates interaction and is conducive to good research.

External collaboration:

- DIES is an international group (75% foreign nationals), which makes for a lively and stimulating atmosphere in the group. We advertise our vacancies widely, to attract the best candidates. On average we receive 200 applications a year from all over the world, of which we hire about 2-3 people.
- DIES PhD candidates are member of the IPA research school, and the National SPAN network of PhD candidates in security. This brings the PhD candidates into contact with their peers in the Netherlands. As part of the standard training we send our PhD candidates to relevant international summer schools.
- Staff and PhD candidates are encouraged to work for a longer period of time at other universities and research labs. For example Brinkman, and Zych spent a year each at Philips research in Eindhoven, Corin and Khatib visited UC Santa Cruz, California for several months, Sundramoorthy worked at the US National Institute of Standards and Technology for the summer, and Etalle worked for a year at the University of Trento, Italy.

5. Academic reputation*Awards*

- Damiano Bolzoni, Sandro Etalle & Emmanuele Zambon, STW valorization grant phase 1 & 2, 2008
- Ileana Buhan, European Biometrics Forum Industry award, 2008

Prof. dr. Pieter Hartel

- Deputy Dean of the faculty of Electrical Engineering, Mathematics and Computer science (Jun 2006 - Aug 2008).
- Head of the Computer Science Department (Jun 2005 - Aug 2008).
- Founding member of IFIP working group 8.8 on smart cards (Secretary Sep. 1998 - Jan. 2000 and Chair Jan. 2000 - Dec. 2004).
- Member of the board of CaberNet, a European Network of Excellence in Distributed and Dependable Computing Systems, Jan 2001 - Mar 2004.
- Member of the steering committee of RESET, a European Road map for smart cards, Sep 2002 - May 2003.
- Secretary of the Dutch ICT Innovation Platform Security and Privacy Veilig Verbonden from Nov. 2006 – present.
- Member of the program committee of SENTINELS, a funding program for security research in the Netherlands under auspices of STW, NWO and EZ, since Jan 2004 – present.
- Co-chair (with Bart Jacobs of RU) of the preparation committee of SENTINELS, a funding program for security research in the Netherlands under auspices of STW, NWO and EZ, May 2001 - Dec 2003.
- Invited talk Int. Workshop Construction and Analysis of Safe, Secure and Interoperable Smart cards (CASSIS), March 10-14, 2004, Marseille, France.
- Keynote 6th Int. Workshop on Issues in the Theory of Security (WITS) Mar. 25–26 2006, Vienna, Austria.
- Invited talk joint EU/NSF/DHS seminar on "Cyber security and Trust" 26-27 Apr. 2007, Champaign, USA.

Prof. dr. Sandro Etalle

- Program chair together with Steve Marsh of the 2007 IFIP Conference on Trust Management (also Joint Itrust-PST International Conference) Canada.
- Program chair together with Mirek Truszczynski of ICLP 2006, 22nd International Conference on Logic Programming, part of the Federated Logic Conference (FLoC'06). Seattle, Washington.
- Program chair of Lopstr 2004, International Symposium On Logic-Based Program Synthesis and Transformation. Verona, Italy.

- Founding member and vice president of the IFIP working group 11.11 on Trust Management. Since 2006.
- Member of the program committee of SENTINELS, a funding program for security research in the Netherlands under auspices of STW, NWO and EZ, since Oct 2008.
- Member of the Scientific Committee of the International School on Foundations of Security Analysis and Design, since 2007.
- Member of the ERCIM working group on security and Trust Management. Since 2005.
- Member of the Executive Committee of the International Association for Logic Programming. 2003 – 2008.
- Member of the steering committee of LOPSTR "International Symposium On Logic-Based Program Synthesis and Transformation". 2004 – 2009.
- Member of the IFIP WG 1.7 "Theoretical Foundations of Security Analysis and Design". 2003.
- Lecturer at the International Summer School on Foundations of Security Analysis and Design (FOSAD). Bertinoro, Italy, September 2006.
- Invited speaker at the kick-off meeting of the ERCIM working group on security and trust management.

Dr. Svetla Nikova

- Chair of the organizing committee and member of the program committee of the NATO Advanced Research Workshop "Enhancing Cryptographic Primitives with Techniques from Error Correcting Codes", Veliko Tarnovo, Bulgaria, 2008.

6. Internal validation

Each year, the Head of Group has a formal performance appraisal meeting with each member of staff, postdoc, and PhD candidate. Supervisors are normally present at the appraisal meetings with the PhD candidates and the postdocs. The progress of PhD candidates is monitored, and in case of expected or observed slow progress carefully documented. Unfortunately, over the years, the contract of about 25% of the PhD candidates had to be terminated prematurely because of lack of performance, or lack of motivation, or illness.

Upon graduation, we encourage our PhD candidates to seek a postdoc position elsewhere, because we believe it to be in their best interest to learn new things in a new environment. This policy has a disadvantage for the group in the sense that expertise regularly disappears in this way.

7. External validation

7.a. Societal relevance

We target our work at a variety of applications, ranging from smart guns, via smart healthcare to smart homes. The smartness in each case refers to a specific property of the application that improves the functionalities beyond what is possible today. In our smart home (PhD Thesis Sundramoorthy) we facilitate near-zero configuration. This allows users to bring in new appliances that integrate with the installed home automation system, seamlessly and securely. A smart gun (PhD thesis Buhan) is smart because it will recognize the rightful owner. This means that if a gun is lost, stolen or wrestled out of the hands of the owner, it will simply refuse to fire. Our surroundings are smart (PhD thesis Law) when they anticipate on, and contribute to the activities of the people in these surroundings. For example, when sensors in a building can detect changes in environmental conditions such as temperature, and humidity to which the system can react adequately.

We have developed tools that can help companies both in the analysis of risks (VRIEND project) and the detection of intrusions (IPID project). A spin off company "Security Matters" has been created in 2008 to market our anomaly based network intrusion detection tools (IPID project).

Software assets

The Twente Security Lab <http://www.tsl.utwente.nl/> maintains the security tools, networks, and data sets that are available for public use. Other tools that have been created as part of our research are available on a commercial basis from <http://www.securitymatters.eu>.

7.b. Industrial contacts

- Companies and organizations participating in our current research projects either as member of the STW user committee or as partner in an EU project are: Akzo Nobel Chemicals, Arnhem; Atos Origin Nederland, Utrecht; Belastingdienst, Apeldoorn; BiZZdesign Company, Enschede; Cap Gemini, Utrecht; Carl Walther, Ulm, Germany; Corus Staal, IJmuiden; DevLab, Eindhoven; DSM Corporate ICT, Sittard; Equens, Utrecht; ESI, Eindhoven; FN, Herstal, Belgium; Fox-IT, Delft; Getronics PinkRocade, Lelystad; Heckler & Koch, Oberndorf, Germany; IBM Research Zurich, Switzerland; Irdeto, Eindhoven; KLPD, Apeldoorn; Nokia Research, Espoo, Finland; NXP Research, Eindhoven; Philips Research, Eindhoven; Rabo Bank, Utrecht; Roessingh R&D, Enschede; Telindus, Utrecht; TI-WMC, Enschede; TNO FEL, Den Haag; TNO ICT, Delft; TNO Industrie & Techniek, Delft; TSST, Enschede.
- Companies where our Master students take their final year project include: British Telecom, Martlesham Heath, UK; Cap Gemini, Utrecht; TNO ICT, Groningen.

8. Researchers and other personnel ("wp")

Table 1

Category	Name	2003	2004	2005	2006	2007	2008
Tenured staff							
professor (hgl)	Etalle, prof. dr. S.						0,06
	Hartel, prof. dr. P.H.	0,40	0,40	0,40	0,40	0,40	0,40
associate professor (uhd)	Etalle, dr. S.		0,38	0,40	0,40	0,34	0,06
	Jansen, ir. P.G.	0,40	0,40	0,40	0,36	0,36	0,33
	Schoute, dr. A.L.	0,40	0,32	0,32	0,23	0,06	
assistant professor (ud)	Etalle, dr. S.	0,38					
	Mader, dr. A.H.	0,09	0,34	0,34	0,34	0,34	0,26
	Nikova, dr. S.I.						0,09
	Scholten, ir. J.	0,40	0,40	0,40	0,40	0,34	
	Vervoort, ir. W.A.	0,20	0,20	0,18			
Total tenured staff		2,26	2,44	2,44	2,13	1,84	1,20
Non-tenured staff							
professor (hgl)	Michiels, prof. ir. E.F.	0,05	0,11	0,04			
	Mullender, prof. dr. S.J.	0,11	0,11	0,11	0,11	0,11	
assistant professor (ud)	Doumen, dr. J.M.			0,15	0,50	0,50	0,35
postdoctoral fellows	Cederquist, dr. J.G.		0,25	1,00	0,75		
	Corin, dr. R.J.				0,14	0,21	0,03
	Dijk, dr. ir. H.W. van			0,80	1,00	0,70	0,64
	Doumen, dr. J.M.	0,30	1,00	0,70			
	Gong, dr. Z.						0,06
	Hartog, dr. J.I. den		0,75	1,00	1,00	1,00	0,13
	Lijding, dr. M.E.M.	0,84	0,42	0,50	0,50	0,42	
	Mader, dr. A.H.	0,63					
	Pieters, dr. ir. W.						0,17
	Tang, dr. Q.					0,13	1,00
Zwaag, dr. ir. B.J. van der			0,50	0,50	0,50		

Category	Name	2003	2004	2005	2006	2007	2008
other junior staff (moz, twaio)	Rosien, ir. M.A.J.	0,46					
Total non-tenured staff		2,39	2,64	4,80	4,50	3,57	2,38
PhD Candidates							
junior staff (aio, oio, moz-p)	Akkiraju, S.				0,67	0,39	
	Bolzoni, D.			0,40	0,80	0,80	0,80
	Brinkman, ir. R.	0,70	0,80	0,80	0,80	0,10	
	Buhan, I.R.		0,13	0,80	0,80	0,80	0,66
	Chong, C.N.	0,80	0,80	0,20			
	Corin, R.J.	0,80	0,80	0,80	0,34		
	Czenko, M.R.		0,13	0,80	0,80	0,80	0,66
	Dimkov, T.					0,10	0,80
	Durmaz, O.			0,73	0,80	0,80	
	Hanssen, ir. F.T.Y.	1,00	0,66	0,84	0,33		
	Kavaldjiev, N.K.	0,80	0,80	0,80	0,36		
	Kaya, O.S.		0,20	0,49			
	Khatib, M.G.		0,03	0,40	0,40	0,40	0,40
	Law, Y.W.	0,80	0,80	0,75			
	Lenzini, G.	0,20	0,80				
	Lijding, M.E.M.	0,16					
	Marin Perianu, R.S.		0,13	0,80	0,80	0,80	
	Moniava, ir. G.						0,18
	Morali, A.					0,54	0,80
	Saptawijaya, A.		0,07	0,66			
Sedghi, S.					0,34	0,80	
Staicu, I.		0,39					
Sundramoorthy, V.	0,80	0,80	0,80	0,35			
Tran, H.M.			0,80	0,40			
Total PhD Candidates		6,06	7,34	10,87	7,88	5,87	5,10
Total Research Staff DIES		10,72	12,42	18,11	14,51	11,31	8,72

9. Resources, funding and facilities

9.a. Laboratory infrastructure

We are building the "Twente IT Security Lab" with the objectives to (1) Strengthen the cooperation among the security researchers in Twente; (2) Provide a safe environment for security-related experiments for both staff members and students; (3) Exchange best practices and strengthen the relationships with other (inter)national security labs; (4) Serve as a training facility for university staff and students.

9.b. FTE-funding

Table 2 shows a more or less stable division of funding over the three categories. External funding accounts for about one third of our funding.

Table 2: Funding at group level

DIES	2003	2004	2005	2006	2007	2008
Direct funding	74%	68%	59%	62%	76%	68%
Research funds	10%	9%	12%	16%	12%	17%
Contracts	16%	22%	29%	23%	13%	14%
Total	100%	100%	100%	100%	100%	100%

9.c. FTE-funding PhDs/postdocs

Table 3 shows the same trends as Table 2, amplified due to the fact that here we focus on temporary, project-related staff.

Table 3: Funding of PhDs/postdocs

DIES	2003	2004	2005	2006	2007	2008	Average
Direct funding	4%	12%	18%	5%	9%	16%	11%
Research funds	46%	29%	39%	39%	41%	54%	42%
Contracts	50%	58%	43%	56%	50%	29%	48%
Other	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%

9.d. List of external funds

Table 4 shows the list of externally funded projects of the DIES group over the assessment period. A significant number of projects have been acquired in very competitive funding rounds, such as the NWO and STW Open Competition.

Table 4

Name project	Start	End	Sponsor
AMETIST: Advanced Methods for Timed Systems	Apr-02	Jul-05	European Commission
AMSD: Accompanying Measure on System Dependability	Jun-02	Jun-03	European Commission
ARTIST-2: Network of Excellence on Embedded Systems Design	Oct-04	Oct-08	European Commission
CaberNet: Network of Excellence in Distributed and Dependable Computing Systems	Jan-96	Jan-04	European Commission
EYES: Energy-Efficient Sensor Networks	Mar-02	Mar-05	European Commission
Inspired: Integrated Secure Platform for Interactive Personal Devices	Dec-03	Dec-06	European Commission
ProTeM: Probe-based Terabit Memory	Oct-06	Oct-10	European Commission
RESET: Roadmap for European research on Smartcard related Technologies	Sep-02	May-03	European Commission
TEAHA: The European Application Home Alliance	Jan-04	Apr-07	European Commission
@HA: @ Home Anywhere	Nov-01	Jul-06	NWO Open Competition
Account: Accountability in Electronic Commerce Protocols	Oct-04	Oct-06	NWO Open Competition
AMIS: Advanced Multimedia Indexing and Searching	Jul-97	May-03	NWO Open Competition
Gecko: Communication and Scheduling in Reconfigurable Multimedia	Jun-02	Jan-07	NWO Open Competition
MOCA: Modeling Control Aspects of Embedded Systems	May-05	Sep-09	NWO Open Competition
MoMS: Methods of Modelling Embedded Systems	Jan-03	Jan-07	NWO Open Competition
Secure Meta Data: Secure Content Management In Ambient Environments	Feb-03	Feb-07	Philips Electronics
SPCMHD: Secure Patient-Centric Management of Health Data	Nov-07	Nov-11	Philips Electronics
BRICKS/PDC1: Security, Identification and Authentication	Jan-04	Oct-10	SENER BSIK
ESI/POSEIDON: System Evolvability and Reliability of Systems	Jun-07	Jun-11	SENER BSIK
Freeband/I-share: Sharing resources in virtual communities for storage, communications, and processing of multimedia data	Jan-04	Jan-09	SENER BSIK
Smart Surroundings	Apr-04	Nov-08	SENER BSIK
ALwEN: Ambient Living With Embedded Networks	Jan-08	Jan-11	SENER IOP
PAW: Privacy in an Ambient World	Oct-03	Sep-08	SENER IOP
A4: Adaptive non-volatile storAge systems for Adaptive Applications	Oct-04	Apr-11	STW Open Competition
Chameleon: Reconfigurable computing in hand-held multimedia computers	Dec-99	Dec-04	STW Open Competition

Name project	Start	End	Sponsor
Secure Grip	Nov-04	Dec-08	STW Open Competition
Feather-light distributed systems	Sep-04	Sep-08	STW Progress
IPID: Integrated Policy-based Intrusion Detection	Jul-05	Jul-09	STW Sentinels
PEARL: Privacy Enhanced security Architecture for RFID Labels	Aug-07	Aug-11	STW Sentinels
PINPASJC: Program Inferred Power Analysis in Software -- JavaCard	Jan-05	Dec-08	STW Sentinels
SEDAN: Searchable Data Encryption	Aug-07	Aug-11	STW Sentinels
VISPER: The VIRTUAL Security PERimeter for digital, physical, and organisational security	Jan-07	Jan-12	STW Sentinels
VRIEND: Value-Based Security Risk Mitigation in Enterprise Networks that are Decentralized	May-07	May-11	STW Sentinels
My Way: personalized Guidance And Messaging	Aug-07	Feb-08	STW Valorization
Security Matters	Feb-08	Dec-08	STW Valorization
LicenseScript: A language and framework for calculating licenses on information over constrained domains	Oct-02	Dec-04	Telematica Instituut
MESEC: Mobile Enabled Secure Exchange of Content	Apr-04	Apr-05	Telematica Instituut

10. Overview of the results

10.a. Key publications

Table 5

Nr	Title
1	Hartel, P.H. and Abelmann, L. and Khatib, M.G. (2008) Towards Tamper-Evident Storage on Patterned Media. In: 6th USENIX Conf. on File and Storage Technologies (FAST), Feb. 26-29, 2008, San Jose, California. pp. 283-296. USENIX Association. ISBN 978-1-931971-56-0
2	Bolzoni, D. and Etalle, S. (2008) Boosting Web Intrusion Detection Systems by Inferring Positive Signatures. In: Confederated International Conferences On the Move to Meaningful Internet Systems (OTM), November 9-14, 2008, Monterrey, Mexico. pp. 938-955. Lecture Notes in Computer Science 5332. Springer. ISBN 978-3-540-88872-7
3	Buhan, I.R. and Doumen, J.M. and Hartel, P.H. and Veldhuis, R.N.J. (2007) Fuzzy extractors for continuous distributions. In: Proceedings of the 2nd ACM Symposium on Information, Computer and Communications Security (ASIACCS), 20-22 March 2007, Singapore. pp. 353-355. ACM press. ISBN 1-59593-574-6
4	Corin, R.J. and Saptawijaya, A. and Etalle, S. (2006) <i>A Logic for Constraint-based Security Protocol Analysis</i> . In: IEEE Symposium on Security and Privacy (S&P), 21-25 May 2006, Oakland, US. pp. 155-168. IEEE Computer Society Press. ISBN 0-7695-2574-1
5	Law, Y.W. and Doumen, J.M. and Hartel, P.H. (2006) <i>Survey and Benchmark of Block Ciphers for Wireless Sensor Networks</i> . ACM Transactions on Sensor Networks, 2(1):65-93. ISSN 1550-4859

10.b. Numerical overview of the results in a fixed format of categories

Table 6

Category		2003	2004	2005	2006	2007	2008
Academic publications	a. Refereed journals		4	4	2	4	2
	b. International conferences	23	25	28	25	29	21
	c. Book chapters		2			2	
	d. Other academic publications	3	4	1	3	8	2
Total		26	35	33	30	43	25
Monographs							
PhD-theses		2		3	2	1	2
Professional publications		3		2	3	2	
Patents		1	1		5	3	
Software		1				1	

10.c. Full outcome list**2003****Conference proceedings**

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11. SWOT-analysis

Strengths

1. Leading the only multidisciplinary security research activity in the Netherlands.
2. All projects are in cooperation with industry; there is an excellent relationship with many important companies in the Netherlands and beyond.
3. Proven ability to publish high quality papers, PhD theses, and many patents.

Weaknesses

1. The team has been too small for too long.

Opportunities

1. The new European public Private Partnership in Trust in cyberspace in which the IIP Veilig Verbonden plays a key role will create further funding and cooperation opportunities.
2. A new interdisciplinary cooperation around the theme "Crime Science" should lead to new and interesting research, teaching, and funding opportunities.

Threats

1. Too few Master students.

Analysis

1. Our research portfolio has become considerably more focused by targeting security, but the focus could still be improved because security is a broad topic.
2. The team is incomplete and as such does currently not yet have the critical mass required.

Adjusted goals

1. No adjustments needed.

Adjusted Strategy

1. Teach the security related courses to promote security for Bachelor & Master students with the ultimate aim of increasing the number of local PhD students.
2. Buildup the European public Private Partnership in Trust in cyberspace
3. Develop the "Crime Science Twente" program.
4. Foster cooperation with Universities in South East Asia.

Title of the Research Group:

Formal Methods and Tools (FMT)

Research themes: none

NABS code: N07

Heads of Group: prof. dr. H. Brinksma (until July 2005), dr. ir. A. Rensink (July 2005 until Sept. 2007), prof. dr. J.C. van de Pol (from Sept. 2007)

Starting date: none

Formal affiliations: IPA research school, CTIT, 3TU.CeDICT, 3TU.LaQuSo

1. Mission statement

To develop mathematical theories, methods, algorithms and high-performance tools for the design of software-intensive embedded systems, facilitating the modeling, analysis and prediction of their functional and quantitative aspects.

Research area:

Our mission builds on extensive experience in concurrency theory, in particular process algebra and model checking, for the modeling and analysis of distributed reactive systems. Our focus areas are: modeling and analysis of quantitative aspects for embedded and hybrid systems; application to complex object-oriented models and software (UML, Java); and high-performance analysis tools. Also, automated model-based testing has played an important role in the evaluation period.

2. Leadership

Halfway the assessment period (2005), prof. Ed Brinksma accepted the position of scientific director of the Embedded Systems Institute in Eindhoven for 0.8 fte. Daily leadership of the FMT group was taken over by dr. Arend Rensink, who then joined the group (coming from the Software Engineering group). Since September 2007, prof. Jaco van de Pol has been appointed as full professor, and is the current leader of FMT.

The structure of the FMT group is flat and the mode of interaction is informal. Staff members have been relatively autonomous and free in their choice of research topic and approach, in their activities to pursue national and international collaborations, and to attract funding. This loose structure, which relies heavily on the quality of the individual researchers, has been very successful, as can be seen from the number of research projects awarded during the assessment period, as well as from the fact that two of the senior researchers, dr. Holger Hermanns and dr. Joost-Pieter Katoen, obtained professorial positions outside the university (in Saarbrücken and Aachen, respectively) in the course of 2003 and 2004. Also, this sense of freedom is essential in attracting new talent. During the evaluation period, Dr. Mariëlle Stoelinga and Dr. Marieke Huisman have joined the staff in tenure track positions, besides the current Head of Group Van de Pol.

The current leadership focuses on defining a small number of unifying strategic goals that put the different research topics in a common perspective, while increasing the outreach of the research and encouraging fruitful interaction between research topics. These strategic goals are explained in Sect. 3b.

International leadership: the FMT group has a strong international reputation and has shown leadership in the following research areas in the far and recent past: modeling languages (standardization LOTOS), automated model-based testing and testing theory, quantitative modeling and analysis, graph transformation, and distributed model checking. Several group members have key positions in the steering committees and as program chairs of the important conferences and workshops in the field.

3. Strategy and policy

The research in FMT pursues a balanced interaction between fundamental, tool-oriented, and application-oriented aspects. *Fundamental research* provides a sound theoretical and algorithmic foundation, *tool-oriented* research enables scientific experiment, provides visibility, and scales theoretical results up to application requirements, and *application-oriented research* is needed to validate both the theory and the tools; it provides valuable feedback and inspiration for fundamental research, and fulfills our societal mission. In section 3a we list the research topics in theory-tools-applications during the evaluation period. Section 3b introduces the long-term strategic goals of the group.

3.a. Design in brief

Fundamental research

This research is focused on the extension and integration of modeling methods and analysis algorithms. The main challenge is to extend successful compositional approaches to the modeling and analysis of reactive systems to more expressive and powerful techniques. Particular areas of attention are: continuous behavior (real-time and hybrid systems); probabilistic and stochastic behavior (soft-real time systems, high-level performance and dependability analysis); concurrent behavior (process algebra, graph transformation, partial-order semantics, shared memory); and software modeling (formalization of object-oriented paradigms, software dynamics). We investigate new symbolic, parallel and distributed algorithms to move the frontiers and push the scale at which these extensions can be analyzed today.

Tool-oriented research

Building tools is an important step bridging pure theoretical research and practical applications. First of all, we build *proof-of-concept tools*, to demonstrate the feasibility of theory and algorithms, and conduct experiments and measurements. However, our ambition is to develop also *academic tools*, which result from the accumulation of common group efforts, have a longer lifespan, better support, incremental development, and actual users outside the group of developers.

The current tool-oriented research is organized around the following themes: model checking (mc on grid/multi-core, real-time mc, software mc); testing (model-based test generation and selection, coverage analysis); and quantitative analysis (integrated verification and performance analysis tools, hybrid analysis tools). Ongoing tool efforts that can be classified as *academic tools* are: MoDeST/MRMC (probabilistic/stochastic model checking), GROOVE (OO software/design model checking), MoonWalker (C#-software model checking), TorX (test generation, coverage and online testing) and LTSMIN (symbolic and parallel/distributed model checking).

Application projects

The ongoing application of formal methods and tools to industrial applications is part of the research program of the group. The Head of Group is a firm believer in and practitioner of the industry-as-laboratory principle, for instance via the Embedded Systems Institute. The group's strategy is to expand its contacts with SMEs via its spin-off company Axini, founded by former PhD candidate Machiel van der Bijl, focusing on automated model-based testing, and with industrial partners via internships.

An early, very successful application was the verification of the control algorithms for the flood control barrier built in the late nineties near Rotterdam harbor, with the Dutch firm CMG. This led to a very successful line of research in testing and model checking, which put Twente at the cutting edge of research today. On December 1st 2006, the University of Twente awarded an honorary doctorate to Dr. Gerard Holzmann of NASA/JPL Pasadena, California in recognition of his work on model checking. For more examples see Section 7a (societal relevance).

Recent application projects include Tangram on *automated model-based testing* (with ESI and ASML), the *validation of the European Railway Interlocking safety standard* (FP7 project

INESS with a.o. UIC, ProRail, DB, etc), *worst and average case performance analysis of packet switches* for ASML (in FP7 project Quasimodo with a.o. ESI, Hydac, Chess, Terma), the *analysis of biological cell behavior* (FP6-NEST project with a.o. INRIA, U Brno, VU), and *certified UML model transformations for MDA* (ARTEMIS project CHARTER).

All these projects led to interesting theoretical challenges, for instance on integration, compositionality, and extendibility of formalisms; usability and scalability of algorithms; and quantitative evaluation of test coverage, performance, reliability, etc.

3.b. Future development

Below we describe unifying long-term strategic goals that put the different research topics in a common perspective, while increasing the outreach of the research and encouraging fruitful interaction between research topics in these focus areas.

Goal 1: Analysis of object-oriented software designs, code, and runtime systems
(Huisman, Van de Pol, Rensink, Ruys, Weber)

This research line bridges the modeling gap, by applying model checking and theorem proving directly to the artifacts of software engineers (e.g. UML design models and Java or C# code) and by applying test generation, online testing and run-time monitoring.

Scientific challenges are; the formalization of static and dynamic aspects of object-orientation (e.g. by graph rewriting), development of appropriate logics for object-orientation and multi-threading (e.g. permission-based separation logic) with appropriate automatic verification techniques, automated model extraction (e.g. by static analysis and abstract interpretation) and scaling to larger systems (by breaking down the verification problem using compositional verification techniques, and by using multi-core model checking, cf. Goal 3). An interesting approach is verification at the assembly or bytecode level.

Through cooperation with the Software Engineering group, this strategy will expand the outreach of analysis methods to the Model Driven Engineering trend in industry. In testing, we collaborate with the spin-off company Axini.

Goal 2: Quantitative analysis of embedded/wireless systems
(Katoen, Langerak, Van de Pol, Stoelinga)

“Ubiquitous computing” is one of the fastest growing application areas in computer science. Due to its embedded and wireless nature, it faces all kinds of resource restrictions. This young discipline is led by the drive to build. Due to the dynamic nature of the applications, providing a fundamental approach for designing under quantitative constraints and predicting the behavior on the basis of models poses a real challenge. Through cooperation with ESI, and the groups *CAES* and *PS*, we seek to expand the outreach of quantitative analysis techniques.

Scientific challenges are: to combine various quantitative aspects in convenient compositional notations and semantic models, and to explore and push the fundamental boundaries of what is algorithmically possible and feasible to compute. We team up with the *DACS* and *DIES* groups on performance, dependability and security analysis, also in the context of 3TU.CeDICT.

Quantitative methods have a bearing on the advancement of formal testing theory as well (see Goal 1). Our test research will focus on improved *test selection techniques* for non-deterministic and probabilistic systems with data; i.e., among the infinite number of potential tests, how to select a feasible subset that has the highest chance of uncovering the most important errors. This requires probabilistic and stochastic methods for defining, measuring, optimizing and predicting *quantitative test coverage criteria*.

Goal 3: Development of high-performance model checking algorithms and tools
(Van de Pol, Rensink, Ruys, Weber)

In the end, formal analysis can only be fruitful if it scales to a fundamentally larger scale than currently possible. This becomes evident soon, when applying model checking to software (Goal 1) or wireless embedded systems (Goal 2). We seek a solution in clever algorithms and implementation techniques (symbolic algorithms, automatic abstraction, compression) and parallel and distributed model checking algorithms running on multi-core and Grid hardware.

Scientific challenges are: the development of new algorithms (e.g. DFS is not efficiently parallelizable), the development of a tool architecture to combine different successful techniques, and the development of language independent model checking libraries. We have made a first step with our tool LTSMIN, which combines symbolic and distributed model checking for the process algebra mCRL and for Promela.

4. Processes in research, internal and external collaboration

As described above (Section 2) the leadership style has been to stimulate that individual researchers take responsibility for research themes. This means that there are smaller groups within the Research Group that meet regularly around a common theme, such as: distributed model checking; probabilistic, stochastic and hybrid modeling; testing; and graph transformation. The current subgroups (along the lines of the goals in Section 3b) consist of at least two staff members and some postdocs and PhDs. The subgroups are not disjoint, and are mutually beneficial. This significantly improved the coherence of the group during the last few years. Besides this, there is a weekly meeting for all tenured and non-tenured staff, devoted to a scientific presentation by one of the group members or guest researchers. This is *the* group-defining event. Recently, a bi-weekly formal methods reading group has started as well.

PhD candidates interact primarily with their direct supervisors and the other members of their sub-group. In addition, during the weekly lunch presentation, besides the regular 1-hour presentations, every 6 weeks there is a session where everybody presents briefly his/her current activities in 5 minutes, with opportunity for the others to react.

The organization of the group is facilitated by a one-hour bi-weekly meeting with the permanent staff. At this meeting, current issues are discussed and actions are decided and assigned. There is a general delegation of regular organizational and administrative tasks, regarding research, teaching, finance, housing and equipment, among the permanent staff. All other issues are taken up by the Head of Group and delegated on an ad hoc basis where necessary. There is also a plenary "administrative meeting" every 2 months, brainstorm days on our research and education strategies with the permanent staff at least once per year, and a social event for the whole of FMT every 1-2 years.

Within every sub-theme there is a strong cooperation with other research groups, both within the faculty and (inter)nationally. There are for instance shared PhD candidates or master projects, locally with the DACS, DIES and SE groups of Computer Science, and with the MSCT group of Applied Mathematics. We also have collaboration nationally with the Radboud University (Vaandrager), the CWI and the University of Eindhoven (Baeten, Groote, Rooda), VU Amsterdam (Bal, Fokkink) and internationally with groups in Aachen (Katoen); Aalborg (Larsen); Marburg (Taentzer); Dresden (Baier); Cordoba (D'Argenio), INRIA Rhône-Alpes (Garavel); KTH, Sweden (Gurov, Dam); Paderborn (Engels, Wehrheim); Pasadena, California (Holzmann); Saarbrücken (Hermanns); Santa Cruz, California (De Alfaro); Brno (Brim) - to name but a few.

Nationally, there is much emphasis on networks. FMT is coordinating the Twente activities in both the 3TU.CeDICT (*Center of Excellence on Dependable ICT*), as well as the 3TU.LaQuSo (*Laboratory for Software Quality*). Currently, FMT coordinates the CTIT strategic research orientation DSN (*Dependable Systems and Networks*). Finally, FMT participates in the Joint Research Unit 3TU-ESI, the *Embedded Systems Institute*. FMT participates in EU projects with ESI (Quasimodo) and LaQuSo (INESS). As a consequence, FMT is also well presented in the current round of the national FES proposal.

5. Academic reputation

Prizes and awards

- Van der Bijl, Belinfante: winners STW-workshop "Orientation on entrepreneurship" (2006)
- Van der Bijl, Belinfante: STW Valorisation grant phase 1, "Smartest, clever testing of software"
- Arend Rensink, for his work on the graph transformation tool Groove: Best Tool Demonstration award, AGTIVE 2003.
- Pepijn Crouzen, master student to Mariëlle Stoelinga: ENIAC MSc prize (2007)
- Viet-Yen Nguyen, master student to Theo Ruys, on incremental hashing in model checking:
EEMCS MSc prize 2008, ENIAC MSc prize '08, M&I Informatie MSc prize '08;
- Mariëlle Stoelinga: Prof. De Winter Prize 2008 for J. ACM publication in 2007
- Iovka Boneva, Markos Kurban and Arend Rensink: EATCS Best Theoretical Paper Award, ICGT 2008
- Michael Weber: EASST Best Paper Award, FMICS 2006
- Marieke Huisman: EASST Best Paper Award at ETAPS/FASE 2004.
- Mariëlle Stoelinga: ICALP Best paper Award (2003)

Prof. dr. H. Brinksma: (full time until july 2005, 0.2fte until dec 2008)

- Scientific Director ESI (2005-2008)
- Member Gebiedsbestuur Exacte Wetenschappen NWO (2005-2006)
- Editorial Board Member of:
 - IEEE Transactions on Software Engineering (2003);
 - Software Tools for Technology Transfer (2003-now);
- Steering committee member of:
 - TACAS (Tools and Algorithms for the Construction and Analysis of Systems, 2003-now);
 - FORTE (Formal Description Techniques for Networked and Distributed Systems) (2003);
- Strategic Management Board, ARTIST 2 IST Network of Excellence on Embedded Systems (2004-now)
- President Research Advisory Committee for Computer Science (BCI) of the Netherlands Organisation for Scientific Research (2003-2004)

Prof. dr. H. Hermanns (part-time until Oct. 2006)

- Full professor Saarbrücken University (2003)
- Steering Committee member of
 - QEST (Quantitative Evaluation of SysTems, 2004-now)
 - ETAPS (European Joint Conference on Theory and Practice of Software, 2004-2005)
- Co-editor of
 - CAV 2007 (Computer Aided Verification)
 - CONCUR 2006 (Concurrency Theory)
 - TACAS 2006 (Tools and Algorithms for the Construction and Analysis of Systems)
 - FIT 2005 (Foundations of Interface Technologies)

Dr. M. Huisman (from Aug. 2008)

- Tenure track position U Twente (2008)
- Principal investigator NWO proposal SLALOM (applied Oct 2008; just granted)
- Coordinator:
 - task forces for the definition of the Bytecode Modeling Language (BML)
 - Site-coordinator for the French national research project Geccoo (2003 - 2006)
 - Coordinator of collaborative project with KTH, Sweden (2005)
- Guest editor for special issues:
 - JLAP (Journal of Logic and Algebraic Programming), 2004
 - JOT (Journal of Object Technology), to appear 2009
- PC Chair/co-organizer:
 - FTfJP 2008 (Formal Techniques for Java-like Programs) (@ECOOP)

- VAMP 2007 (Verification and Analysis of Multi-threaded Java-like Programs) (@CONCUR)
- Bytecode 2007 (@ETAPS),
- Cassis 2004 and 2005 (Construction and Analysis of Safe, Secure and Interoperable Smart devices)
- Member of jury Isabelle Attali best technical paper award at e-Smart 2005 and 2006

Prof. dr. ir. J.-P. Katoen (full time until june 2005; 0.2 fte since then)

- Full professor RWTH Aachen (2004).
- Member editorial board of Journal of Software, Academy Publishers (2006-now).
- Steering committee member of:
 - PROBMIV (Process Algebra and Performance Modelling, since 1999);
 - ETAPS (2002, 2003, 2005-now);
 - QEST (Quantitative Evaluation of SysTems, 2005-now)
- Guest editor of:
 - IEEE Transactions on Software Engineering (2006);
 - Software Tools for Technology Transfer (2006);
 - ACM SIGMETRICS Performance Evaluation Review (2005);
 - Journal of Software Tools and Technology Transfer (Springer, 2004);
 - Journal of Logic and Algebraic Programming (Elsevier, 2003);
 - Theoretical Computer Science (Elsevier, 2002).
- Editor/Organizer/PC chair of:
 - GI/Dagstuhl seminar on Model-based testing (2002);
 - GI/Dagstuhl seminar on Validation of Stochastic Systems (2004);
 - QEST 2004 (Quantitative Evaluation of SysTems);
 - Workshop on 25 years process algebra (2005);
 - WAL 2007 (Workshop on Automata and Logics);
 - Dagstuhl Seminar on Quantitative Aspects of Embedded Systems (2007);
 - Lorentz Center Seminar on Validation of Stochastic Systems (2007)
- Memberships:
 - IFIP Working Group 1.8 (Concurrency Theory) (2007-now)
 - Review College Engineering and Physical Research Council (2006-now)
 - Evaluation Committee NWO VENI Projects (2007-now)
- Selection invited talks/keynotes:
 - IEEE Conf. on Decision and Control (2008), GLOBAN Summer School (2008), IFIP/IEEE TASE (2008), FORMATS (2007), ARTIST MOTIVES Summer School (2007), German Verification Day (2006), FMCO (2005), AVOCS (2005), PASM (2004), TACAS10 (2004)

Prof. dr. J.C. van de Pol (from Sept 2007)

- Full professor *Formal Methods & Tools*, University of Twente (2007)
- Secretary NVTI ('05-'09; now chairman)
- Vice-chairman ERCIM working group FMICS ('02-now)
- Guest editor of:
 - Journal of Software Tools and Technology Transfer (2004, 2005)
- Editor/Chair of:
 - IC on Integrated Formal Methods (IFM 2005)
 - IW on Parallel and Distributed Methods in verifiCation (PDMC 2005, 2006, 2009)
- Organizer of national events:
 - Dutch Testing Day (2000)
 - SAFE-NL security workshop (2002)
 - Dutch Proof Tools Day (2003)
 - Symposium on Embedded Software Quality (2005)
 - Symposium in honor of Prof. J.W. Klop (2005)
 - Dutch Computer Science Theory Days (NVTI 2005-2009)
- Project coordinator FP6 project EC-MOAN (NEST-STREP)

Dr. ir. A. Rensink (full period)

Board member of

- EAPLS (European Association of Programming Languages and Systems, 2006-now)

Steering Committee member of

- ECMDA-FA (European Conference on Model-Driven Architecture: Foundations and Applications, 2005-now)
- Guest editor of
 - TAOSD (Transactions on Aspect-Oriented Software Development, 2006)
 - STTT (Journal on Software Tools for Technology Transfer, 2008)
- PC chair/editor/organizer of
 - GraBaTs (Graph-Based Tools workshop, 2008 and 2009)
 - ECMDA-FA (European Conference on Model-Driven Architecture: Foundations and Applications, 2006 and 2009)
 - AGTIVE Tool Contest (Applications of Graph Transformation with Industrial Relevance, 2007)
 - GT-VC (Graph Transformation for Verification and Concurrency, 2005–2007)
 - MDAFA (MDA: Foundations and Applications, 2003)
 - FMOODS 2002 (Formal Methods for Object-Oriented Distributed Systems)
 - Workshops chair of ECMDA-FA 2005 and 2007
- Invited presentations at
 - ESSCASS Summer School 2008
 - Fujaba Days 2007
 - LAC 2007 (Landelijk Achitectuurcongres)
 - ICGT 2006 (International Conference on Graph Transformation)
 - Segravis Summer School 2006
 - Trustsoft Summer School 2006
 - NVTI 2006 (Nederlandse Vereniging voor Theoretische Informatica)

Dr. M.I.A. Stoelinga (since May 2004)

- Organizer of
 - FIT (co-editor; workshop on Foundations on Interface Technologies, 2005).
 - Nederlandse Testdag (2005)
 - IPA Lentedagen over Software Testen (2006)
 - Dutch Workshop on Formal Testing Techniques (2005, 2007, 2009)
- Invited talks at
 - FIT 2008 (Workshop on Foundations on Interface Technologies).
 - AADL standardization committee, 2008
 - NVTI 2008 (Nederlandse Vereniging voor Theoretische Informatica)
 - GDV 2005 (Games in Design and Verification, Edinburgh)
 - Annual meeting of European Research Training Network Bordeaux, 2004.

6. Internal Evaluation

The standard evaluation procedures of the faculty are in place, like yearly assessments of all staff, evaluations of PhD candidates, and development plans with evaluation for tenure track positions.

Actually, internal evaluation of the research in the group is based on objective indications from external evaluation. We make sure to submit to high-profile conferences with low acceptance rates, like CAV (*Computer Aided Verification*), LICS (*Logic in Computer Science*), TACAS (*Tools and Algorithms for the Construction and Analysis of Systems*), etc; and high-profile journals in our field, like J ACM (*Journal of the Association of Computing Machinery*), TCS (*Theoretical Computer Science*), STTT (*Software Tools for Technology Transfer*), JLC (*Journal of Logic and Computation*), IC (*Information and Computation*), etc. New ideas are encouraged to be shaped as proposals in competitive funding schemes (STW, NWO VC, Vidi/vici, EU). This gives the primary, objective information to evaluate the success of individual researchers. This takes place formally in "year-assessments" per individual group member, and (when necessary) via intermediate evaluations.

Equally important is the informal evaluation and continuous discussion of research topics. This happens in the weekly lunch meetings, and by reading each other's papers (in particular by supervisors; we stimulate cross reading of papers by PhD candidates). The recently started bi-weekly Formal Methods Reading Group allows putting our own research in international perspective. Finally, we organize strategic meetings with permanent staff on both research and education 2-4 times per year. (For education other evaluation mechanisms are in place as well).

7. External validation

7.a. Societal relevance

The availability of methods to produce and assess correct and reliable software systems is of great relevance for modern society. The ever-increasing dependency on software system functionality and performance in all facets of modern society makes their correct, secure and reliable operation a critical factor. Formal methods and tools contribute to the development of dependable systems by developing methods and tools for their systematic design and analysis. The transfer of knowledge from the research within the group to industry is effected through the development of proof-of-concept and academic tooling and joint application projects; see above.

An early example of the impact of FMT was the thrilling application of formal methods to the storm surge barrier in the Nieuwe Waterweg (see section 3a). In the assessment period, the former FMT Head of Group Ed Brinksma became director of ESI, mediator of academic and industrial research, giving shape to private-public cooperation for high-tech industry (NXP, ASML, OCE). Our work on model based testing enabled ASML to automate large parts of their integration & testing process. More recent examples are projects on Model Driven Design (with SE); the current FP7 project INESS to standardize, harmonize, and verify safety requirements for the European Railway Interlockings (with LaQuSo, UIC, and ProRail); and Quasimodo (FP7), with applications in controller/scheduler synthesis, testing and code generation (with Chess, Hydac, Terma Space as industrial partner).

Another, recently emerging, application is the use of modeling and analysis in science. Van de Pol is project leader of EC-MOAN (FP6) with biologists in Grenoble and Amsterdam. There are connections with Henri Bal (PDMC, Dagstuhl, VL-e, E-science, participation in the FES proposal). Finally, there is collaboration via a master project with HMI and BMI on this theme.

Software assets

The Research Group maintains the following tools for public usage:

- TorX, for automatic model-driven test generation and application
<http://fmt.cs.utwente.nl/tools/torx/>
- LTSMIN, for symbolic and parallel/distributed model checking
<http://fmt.cs.utwente.nl/tools/ltsmin/>
- GROOVE, for graph transformation-based state space exploration and model checking
<http://sf.net/projects/groove>
- MoDeST/MRMC, for probabilistic/stochastic model checking
<http://www.mrmc-tool.org/trac/>
- MoonWalker, for C#-software model checking)
<http://wwwhome.cs.utwente.nl/~ruys/moonwalker/>

7.b. Industrial contacts

We list industries with which we have had joint projects with MSc or PhD candidates or postdocs.

- ASML Eindhoven: automated testing and schedulability analysis for high-tech machines
- Axini: our spin-off company on automated test generation and test execution
- Bosch-Siemens: action refinement in model-driven testing
- Chess, Haarlem: hybrid system control for the Chessway in Quasimodo
- Klasse Objecten, Soest: model driven architecture

- Logica CMG, Nieuwegein: test generation and application of formal methods
- National Aerospace Laboratory NLR: application of formal methods to aerospace
- Neopost, Drachten: controller synthesis for mailroom automation such as envelope filling machines
- NXP, Eindhoven: design and analysis of (multi-core) hardware designs
- Ordina: action refinement in model-driven testing
- OCE, Venlo: model-driven design of copier machines
- Philips Medical Systems, Eindhoven: safety analysis of medical equipment.
- ProRail, Utrecht: safety analysis of Railway Interlocking systems.

8. Researchers and other personnel ("wp")

Table 1

Category	Name	2003	2004	2005	2006	2007	2008
Tenured staff							
professor (hgl)	Brinksma, prof. dr. H.	0,40	0,40	0,20			
	Pol, prof. dr. J.C. van de					0,14	0,40
associate professor (uhd)	Hermanns, prof. dr.-ing. H.	0,10	0,09	0,09	0,06		
	Katoen, prof. dr. ir. J.P.	0,40	0,40	0,22	0,09	0,09	0,09
	Rensink, dr. ir. A.			0,20	0,40	0,40	0,40
assistant professor (ud)	Langerak, dr. ir. R.	0,40	0,40	0,40	0,40	0,40	0,40
	Ruijs, dr. ir. T.C.	0,40	0,40	0,40	0,35	0,17	0,34
	Stoelinga, dr. M.I.A.						0,40
other junior staff (moz, twaio)	Belinfante, ir. A.F.E.	0,06	0,80	0,80	0,80	0,80	0,80
Total tenured staff		1,77	2,49	2,30	2,10	1,99	2,82
Non-tenured staff							
professor (hgl)	Brinksma, prof. dr. H.			0,05	0,11	0,11	0,11
	Larsen, prof. K.G.	0,10	0,11	0,11	0,11	0,11	0,02
assistant professor (ud)	Huisman, dr. M.						0,18
	Stoelinga, dr. M.I.A.		0,21	0,50	0,50	0,50	
postdoctoral fellows	Andova, dr. S.	1,00	0,58				
	Argenio, dr. P.R. d'			0,42	0,17		
	Blom, dr. S.C.C.					0,17	1,00
	Boneva, dr. I.B.				0,42	1,00	0,75
	Boudali, dr. H.			0,17	1,00	1,00	0,83
	Bujorianu, L.M.			0,17	1,00	1,00	0,76
	Daws, dr. C.F.	1,00	0,91		0,38	0,37	
	Jansen, dr. D.N.			1,00	1,00		
	Ketema, dr. J.						0,25
	Krilavicius, dr. T.				0,33		
	Sathyanathan, dr. P.W.			0,50	0,01		
	Usenko, dr. Y.S.	1,00	0,66				
	Weber, dr. M.					0,33	1,00
Zimakova, dr. M.V.						0,33	
other junior staff (moz, twaio)	Klaren, ir. J.	0,80	0,74				
Total non-tenured staff		3,90	3,21	2,92	5,03	4,59	5,23
PhD Candidates							
junior staff (aio, oio, moz-p)	Bijl, ir. H.M. van der			0,50	0,53		
	Bohnenkamp, H.C.	1,00	1,00	0,66			
	Brandan Briones, L.	0,64	0,80	0,80	0,80	0,16	
	Distefano, D.S.	0,46					
	Han, T.			0,13	0,80	0,80	0,80
	Kakumani, R.	0,18	0,40	0,22			

Category	Name	2003	2004	2005	2006	2007	2008
	Kastenberg, ir. H.			0,40	0,80	0,80	0,46
	Kleppe, drs. A.G.				0,84	0,84	
	Kordy, P.T.			0,12	0,40	0,40	0,80
	Krilavicius, T.	0,80	0,80	0,80	0,13		
	Kuijper, drs. W.			0,27	0,80	0,80	0,80
	Kurban, M.E.	0,63	0,80	0,80	0,80	0,16	
	Maneesh Khattri, M.		0,33	0,14			
	Neuhausser, M.			0,13	0,80	0,80	0,80
	Timmer, M.						0,27
	Turetayev, D.	0,80	0,60				
	Zambon, E.						0,33
	Zapreev, I.		0,64	0,80	0,80	0,80	0,16
Total PhD Candidates		4,51	5,37	5,77	7,50	5,56	4,42
Total Research Staff FMT		10,18	11,06	10,99	14,63	12,14	12,47

9. Resources, funding and facilities

9.a. Laboratory infrastructure

As described in Section 3, the research carried out in the group counts two activities that need laboratory support to some degree: tools development and application-directed projects. The latter are typically carried out in close cooperation with the industrial partner in question, and the necessary laboratory infrastructure is borrowed from them. For industry-as-laboratory experiments, our strategy is to fall back on ESI and 3TU.LaQuSo (Eindhoven).

Tool development, on the other hand, involves group-internal software development. Especially for the category of *academic* tools (see section 3), there are two aspects that potentially need support: the physical system necessary for the development, including the development platform of choice, and the development process.

With regard to the former (the platform): for most projects, average off-the-shelf PCs, possibly with memory extensions, suffice as a physical system. For our efforts on distributed model checking we took the lead in purchasing and building a 14-node cluster of 8-multicore PCs connected by high-bandwidth network and including a few high-memory and high-storage servers. This cluster is now maintained by the ICT group.

With respect to the latter (the process): the FMT group has taken the lead within the faculty in initiating a shared software repository with facilities for versioning, reporting and collaboration. In the coming years, we will continue devoting effort to this important part of the infrastructure. Our strategy within 3TU.LaQuSo will be to support a tool environment in order to make academic tools interoperable and more viable. We first focus on modeling/analysis tools in DACS, DIES, FMT and SE. We are actively searching for a highly-skilled technician for this purpose. This is in line with a recommendation in the last midterm review.

9.b. FTE-funding

The following table shows that before 2005, around 30% of funding came from external sources (research funds and contracts); from 2006 onwards, this percentage rose to approximately 40%. The larger share of the external funding came from research funds.

Table 2: Funding at group level

FMT	2003	2004	2005	2006	2007	2008
Direct funding	71%	66%	71%	54%	58%	64%
Research funds	19%	23%	19%	45%	40%	23%
Contracts	10%	11%	10%	1%	1%	13%
Total	100%	100%	100%	100%	100%	100%

9.c. FTE-funding PhDs/postdocs

Table 3 shows the same overall picture and trends as Table 2, though amplified as this table only shows personnel hired on 3- and 4-year (mostly externally funded) projects. Especially the percentage of research funding has been high throughout the assessment period; however, in 2008 we have again started to attract contract funding as well.

Table 3: Funding of PhDs/postdocs

FMT	2003	2004	2005	2006	2007	2008	Average
Direct funding	19%	5%	21%	14%	0%	7%	11%
Research funds	67%	70%	69%	86%	97%	78%	78%
Contracts	13%	24%	10%	0%	3%	16%	11%
Other	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%

9.d. List of external funds

The list of projects clearly confirms the group's strength in acquiring research funding, already noted above.

Table 4

Name project	Start	End	Sponsor
AMETIST: Advanced Methods for Timed Systems	Apr-02	Jul-05	European Commission
ARTIST: Advanced Real-Time Systems	Apr-02	Apr-06	European Commission
ARTIST-2: Network of Excellence on Embedded Systems Design	Sep-04	Sep-08	European Commission
EC-MOAN: Studying emergent cell behaviour by modeling and analysis	Feb-07	Mar-10	European Commission
HYCON: Hybrid Control -- Taming Heterogeneity and Complexity of Networked Embedded Systems	Sep-04	Sep-08	European Commission
INESS: Integrated European Signalling System	Oct-08	Oct-11	European Commission
ADHOC: Analysis and Design of Hybrid Systems using Optimal Control	Jul-03	Oct-07	NWO
AiSHA: Abstraction in Stochastic and Hybrid process Algebra	Nov-05	Nov-08	NWO
CASH: Compositional Analysis and Specification of Hybrid Systems	Sep-01	Jan-06	NWO
DARTS: Design and Analysis of Robust Timed Systems	Sep-05	Sep-09	NWO
GRAIL: Graphs for The Abstract Interpretation Of Languages	Aug-08	Aug-12	NWO
GRASLAND: Graphs for Software Language Definitions	Jan-06	Sep-09	NWO
GROOVE: Graphs for Object-Oriented Verification	Aug-04	Oct-08	NWO
IMPASSE: Implementing McMillan Prefixes against State Space Explosion	Mar-03	Mar-07	NWO
MC=MC: Model-Checking of Infinite-State Markov Chains	Mar-04	Mar-08	NWO
MOCA: Modeling Control Aspects of Embedded Systems	May-05	Sep-09	NWO
MOQS: Modeling and Analysis of QoS of Component-Based Designs	Nov-05	Feb-09	NWO
QUPEs: Verifying Quantitative Properties of Embedded Software	Nov-05	Nov-09	NWO
SPACE: Specification-based PerformAbility ChEcking	Oct-00	Oct-03	NWO

Name project	Start	End	Sponsor
STRESS: Systematic Testing of Real-time Software Systems	Mar-03	Jan-08	NWO
VeriGEM: A Verification Grid For Enhanced Model Checking	Sep-07	Nov-08	NWO
Voss: Validation of Stochastic Systems	Mar-01	Mar-04	NWO
Voss-2: Validation of Stochastic Systems II	Jan-05	Jan-08	NWO
Verification of performance and dependability	Oct-01	Oct-06	NWO/Vernieuwingsimpuls
ESI/TANGRAM: Test Approach based on iNtegrated product Generation and product Realization applied to ASML Machines	Mar-03	Dec-05	SENER
ATOMYSTE: Atom splitting in embedded Systems testing	Jul-05	Apr-06	STW
Côte de Résys: Conformance Testing for Reactive Systems	Mar-00	Feb-03	STW
HaaST: Verification of Hard and Softly Timed Systems	Aug-99	Dec-03	STW
Smarttest: slimmer testen van software	Mar-07	Jan-09	STW

10. Overview of the results

10.a. Key publications

Papers (1) and (3) show that FMT is clearly leading (witnessed by #citations in Google Scholar) in some fields: quantitative analysis (173), and graph transformation (90). Paper (3) appeared in the most prestigious journal in Computer Science. The work in paper (4) won 3 MSc prizes. Paper (5) is the most recent result in FMT's new direction on distributed and multi-core model checking.

Table 5

Nr	Title
1	Baier, C., Haverkort, B.R., <u>Hermanns, H.</u> , and <u>Katoen, J.P.</u> , <i>Model-checking algorithms for continuous-time Markov chains</i> . IEEE Transactions on Software Engineering, 29(6):524–541, 2003, ISSN 0098-5589
2	<u>Rensink, A.</u> <i>The GROOVE Simulator: A Tool for State Space Generation</i> . Proc. of Applications of Graph Transformations with Industrial Relevance (AGTIVE). LNCS 3062:479-485. Springer Verlag, 2004, ISSN 0302-9743
3	Cheung, L. and <u>Stoelinga, M.I.A.</u> and Vaandrager, F.W. <i>A testing scenario for probabilistic processes</i> . Journal of the Association for Computing Machinery, 54(6)29:1-45, 2007, ISSN 0004-5411
4	<u>Nguyen, V.Y.</u> and <u>Ruys, T.C.</u> , <i>Incremental Hashing for SPIN</i> . In: Model Checking Software, Proc. of SPIN Workshop. LNCS 5156:232-249, Springer Verlag, 2008, ISBN 978-3-540-85113-4
5	van de Pol, J.C., and Weber, M. <i>A Multi-Core Solver for Parity Games</i> . Proc. of Parallel and Distributed Methods in verification, PDMC08. Electronic Notes in Theoretical Computer Science 220 (2):19-34, 2008, ISSN 1571-0661

10.b. Numerical overview of the results in a fixed format of categories

Table 6

Category		2003	2004	2005	2006	2007	2008
Academic publications	a. Refereed journals	4	2	9	2	6	5
	b. International conferences	15	18	25	25	27	39
	c. Book chapters		3	4	2		2
	d. Other academic publications	1	6	2	11	7	5
Total		20	29	40	40	40	51
Monographs							1
PhD-theses		1			1	1	3
Professional publications		2					
Patents							
Software		1	2	1	1	1	2

10.c. Full outcome list

2003

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- Buchholz, P., Katoen, J.P., Kemper, P., Tepper, C., *Model-checking large structured Markov chains* (2003). In: Journal of Logic and Algebraic Programming 56(1-2). pp. 69-97. ISSN: 1567-8326.
- Hermanns, H., Katoen, J.P., Meyer-Kayser, J., Siegle, M., *A tool for model-checking Markov chains* (2003). In: Int. Journal on Software Tools for Technology Transfer 4(2). pp. 153-172. Springer Verlag, London. ISSN: 1433-2779.
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- Cloth, L. , Haverkort, B.R.H.M., Hermanns, H., Katoen, J.P., Baier, C. *Model Checking path CSL*. PMCCS-6: The sixth international workshop on performability modeling of computer and communication systems (2003, september 6 / 2003, september 7). (pp. 19-22) Urbana-Champaign CRHC
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LTSMIN: Symbolic and parallel/distributed model checking, Stefan Blom, Michael Weber, Jaco van de Pol. URL: <http://fmt.cs.utwente.nl/tools/ltsmin/>

11. SWOT-analysis

Strengths

- Research quality and output, and international reputation are high
- International scientific network and industrial contacts, indicated by EU+NL projects
- Successful mix of theory/tools/application oriented research
- Competences cover the broad spectrum of formal methods

Weaknesses

- Currently too few PhD students relative to other staff
- No direct contracts with industry (3rd money-flow)
- The previous period had a number of changes in leadership

Opportunities

- Booming context for embedded systems and wireless networks
- Network for multi-disciplinary cooperation on dependability (CTIT, CeDICT, ESI, LaQuSo) can enforce the outreach of quantitative analysis.
- Availability of (international) education programmes (graduate school; Erasmus)

Threats

- Finding good junior personnel is hard, especially PhD employees
- Too low funding ratio, especially compared to efforts in proposal writing
- Perceived low applicability of methodological research in industry

Analysis

Scientifically, FMT is doing very well as demonstrated by the high number of papers and the quality of the venues and journals. The group has taken the lead in active and promising research areas: testing, quantitative analysis, graph transformation, and (recently) high-performance model checking.

The permanent staff constitutes a high critical mass and is very talented. The group members are well presented in organizing committees. Comparatively, the number of postdocs and especially PhD employees is on the low side. One or two extra technicians are needed to assist in software tool development. The number of master students that do their research inside FMT is low.

The network with international academic partners and industry is well maintained and effective. So far, contact with industry has hardly led to directly paid contracts, despite a spin-off company. This should be addressed by a sharper focus on application domains, and by multi-disciplinary collaboration with more application-oriented research groups.

Adapted goals: no change

Adapted strategy:

- Focus on software (design) verification; quantitative analysis; multi-core model checking
- Strengthening visibility of theoretical CS in education
- Internationalization of education with Brno and Aalborg
- Better exploitation of local collaboration in application domains
- Selection of particular industrial application area(s)

Title of the Research Group:

Human Media Interaction (HMI)

Research themes: none

NABS code: N07

Head of Group: Prof. dr. ir. A. Nijholt

Starting date: none

Formal affiliations outside the department and other formal co-operations: NWO, Philips Electronics Netherlands, Imperial College London

1. Mission statement

Human Media Interaction is a broad research field dealing with capturing, analysis, fusion, interpretation, transformation, generation, and fission of multimodal data. Syntactic, semantic and pragmatic analysis of multimodal input and multimedia data can take place in a static (off-line) or dynamic (online) context. In the former case, the emphasis is on providing intelligent access (retrieval) to stored multimedia content, where "intelligent" refers to the possibility to manipulate stored multimedia in order to provide cross-modal multimedia presentations. In the latter case, we have multimodal interaction with reactive and pro-active smart environments and devices. Mixed reality and virtual humans are among the related research topics that are addressed. In this context, our mission is:

To support (multimodal) interactions with and within smart environments and to support the use of and the interaction with multimedia information.

2. Leadership

The group is managed by the Head of Group (Nijholt) with frequent formal and informal consultation of other staff. In order to help managing the many externally funded projects, HMI has appointed a part-time project manager.

In the past the group has made some changes in its research orientations. Presently it is a large and internationally recognized Human Computer Interaction and Multimedia research group with a reputation of original and advanced research. As such there are many invitations to join in establishing European and Dutch research projects, Networks of Excellence and COST actions. These invitations extend to invited talks and lectures at Summer Schools. The group aims at doing research in a multidisciplinary context and is in particular interested to cross existing borders of traditional research areas and research communities. The group has been actively engaged in defining innovative and multidisciplinary research programs on both a national level (NWO CATCH, Brains and Cognition, IIP Create) and a European level through chairing programs, being active in the project definition or as member of EU task forces. The group has established a Masters degree program (also labeled Human Media Interaction) that allows HMI researchers to teach their research topics and approaches to students. HMI is in the core of the CTIT SRO NICE (Natural Interaction in Computer-mediated Environments). HMI is actively looking for possibilities to create new positions for female researchers and to fill (PhD) vacancies with female researchers.

3. Strategy and policy

3.a. Design in brief

HMI research is the core partner in the CTIT SRO NICE (Natural Interaction in Computer-mediated Environments). This SRO provides the context for project acquisition and research. The research covered by the SRO NICE, and thus HMI, aims to improve the ease of use of new technologies in computer-mediated environments in order to turn smart surroundings into habitable environments.

The more global context of the HMI research can be best explained as follows. As stated in the FP7 program, an important goal for ICT research is "to bring technology closer to

people". This can mean hiding the complexity of the technology, revealing the functionality only when it is assumed to be needed and making technology easy to use, available at all time, affordable and adaptable to the users' context and preferences.

Closely related is the Ambient Intelligence vision as defined in the statement of the theme of the 2nd European symposium on ambient intelligence (Eindhoven, 2004): "Ambient Intelligence represents a vision of the future where we shall be surrounded by electronic environments, sensitive and responsive to people. Ambient intelligence technologies are expected to combine concepts of ubiquitous computing and intelligent systems putting humans in the centre of technological developments."

The European Union has always had a strong interest in promoting the use of ICT for creativity and personal development. The creative industries have also become an important domain in ICT research in the Netherlands, witness several initiatives (NWO, NOAG-ict, Dutch Entertainment Computing Consortium, GATE). The interest in entertainment, art, (new) media, design, games and cultural heritage is another reason why technology has to care about the user experience.

All of these are means to enhance the ways in which people can interact with technology.

Given the above context, the Computer Mediated Environments considered in HMI range from ambient intelligent environments to worlds created in virtual reality. Whereas in the ambient vision the computer disappears into the background and the interaction with technology is envisaged to become completely "unmediated", in virtual reality the medium superimposes on the real natural environment. From Virtual to Ambient Environment there is thus a complete scala of interaction strategies and techniques to be studied.

The research questions in NICE have been gathered around four research topics: multi-media, human interaction, synthetic environments and games. These are also the research topics on which HMI will continue to concentrate.

Multi-Media

According to the NOAG-ict on the "Data-explosion" research theme, the last step in controlling the data-explosion should be directed at the interaction with the users; mid-term research should make it possible for information retrieval and information visualization to use the relation between data management and data mining to improve the access to data and provide users with better navigation tools. Personalized presentations and summaries could improve the digital experiences of many users.

- Indexing and semantic access;
- Context-aware retrieval;
- Context-aware presentation;
- Question-Answering: multimedia queries;
- Information fission and multi-media presentations;
- Personalization.

For these research topics there is cooperation with the other research groups in the SRO NICE.

3.b. Future development

Human Interaction

An important aim for research that looks into "natural" modes of interaction has always been to design intelligent systems that can analyze and interpret the communication channels that humans naturally use. Speech and natural language understanding is therefore also on the NICE research agenda. However, there are many other modes and channels through which humans communicate with each other and interact with their environment. The challenge for the next generation systems that look into processing human interaction will need to go

beyond the borders of traditional computational linguistics research and deal with (1) other modes of communication such as nonverbal displays, and (2) other dimensions of content beside propositional information but including propositional attitudes (certainty-doubt), liking, and emotion. There are various situations for which answers to major research questions are beneficial: for understanding user actions in ambient environments, for the collection and retrieval of human communication situations (meeting memories, personal digital memories), for computer supported communication and for traditional human computer interaction, where the mental state of the user can be inferred from his or her actions.

Synthetic environments and Games

Synthetic environments and games have not yet received sufficient attention yet. Nevertheless, virtual environments have been created and research, in particular related to properties and effects of the behavior of virtual humans in such environments, has been performed. Therefore, in the near future our aim is to put more effort in research and development on entertainment games, games that adapt to the mental and affective state of the user and games that allow controlled brain activity input from the user. In particular we investigated bodily interaction, interaction that allows input from physiological processes, input from gestures, body postures, speech and facial expressions, and, more recently, input from measured brain activity. In our research in the direction of brain-computer interfacing (BCI), our working assumption will be that BCI is a subset of CHI. Measuring and monitoring brain activity makes it possible to evaluate a particular interface (including its interaction modalities) and possibly redesign it, and to adapt the interface to the affective state of a particular user. Direct control of the interface using brain-controlled input, together with other input modalities, is a research direction we are exploring.

In summary the future research directions of HMI will be focused towards "the ABC of HMI"; Affective Computing, Behavioral Computing and Cognitive Computing. In these area's HMI takes sometimes a scientific and sometimes an engineering stand.

4. Processes in research, internal and external collaboration

All PhD candidates are supervised by an academic staff member. All papers written by PhD candidates are read and extensively discussed with staff members of the group. Each PhD candidate is expected to co-author two or three scientific publications every year. PhD candidates that have been appointed in national and international research projects generally have no problem to fulfill this expectation.

There is much cooperation between staff members since they often work on the same (externally funded) projects. This means that there are often joint visits to national and international project meetings and workshops and that most of our research papers have several staff members as authors. HMI is very active in organizing scientific and teaching events. Students of the Masters Human Media Interaction are stimulated to actively participate in these events and they are asked to present their student research. PhD candidates help in advising HMI Master students and, when possible, research of Master students is in the domain of interest of PhD candidates. Publications co-authored by Master students are no exception.

Staff members successfully cooperate in project acquisition. HMI has been widely acknowledged for its added value in multi-disciplinary research in networks of excellence and European projects. Research results in these projects and networks have led to many multidisciplinary and joint publications.

5. Academic reputation

Dr. D.K.J. Heylen

- Guest Editor of Theoretical Computer Science (1).
- Chair of several workshops at several AI and NLP conferences: AISB and AAMAS.
- Reviewer for Dutch and Swiss research funding councils.

- Member of the NWO Vernieuwingsimpuls committees (VIDI).
- Reviewer for FP7 projects.
- Member of the project management board of EU projects Semaine and SERA.
- CTIT SRO NICE coordinator.
- Member IIP Create advisory board.
- Member of the Supervisory board of the Media technology program at the Hogeschool Utrecht.

Prof. dr. F.M.G. de Jong

- Member Governing Board Netherlands Organization for Scientific Research (Algemeen Bestuur NWO; since 2008).
- Chair of Preparatory Commission for NWO theme Creative Industry (2008)
- Expert/panelist/reviewer EU FP6/FP7.
- Coordinator of Puppy-IR, an EU FP7 project to be launched in Spring 2009.
- Member Board Dutch-Flemish Institute for Lexicology (INL; since 2007).
- Member Steering committee CLEF (Cross-Language Evaluation Forum; since 2001).
- Member Management Committee of the EU project MESH (2006-2009).
- Initiator of a series of ACM SIGIR workshops on searching conversational speech (since 2007).
- Member Board Dutch Research Council for the Humanities (Gebiedsbestuur NWO Geesteswetenschappen; 2004-2008).
- Member Board Taal- en Spraaktechnologie (Dutch-Flemish Taalunie; 2004-2008).
- Chair Board NWO-program IMIX (Interactive Multimodal Information Extraction; 2002-2008).
- Member Committee Investerings NWO Geesteswetenschappen (2002-2004).
- Member EU/NSF working group Spoken Word Archives.
- On invitation of NIST (National Institute of Standards and Technology, USA, www.nist.gov), HMI's speech recognition technology has been used to generate transcriptions for the Dutch data (700 hours) in the test collection of TRECVID, an international video retrieval benchmark. The transcriptions have been made available to the participants of TRECVID (80 groups in 2008).

Prof. dr. ir. A. Nijholt

- Guest-editor of the journals Theoretical Computer Science (2), Artificial Intelligence for Society (2), and IEEE Transactions on Systems, Man, & Cybernetics.
- Member editorial board of the journal Grammars (until 2004). Member Editorial Board International Journal of Autonomous and Adaptive Communications Systems (IJAACS), Associate Editor of International Journal of Creative Interfaces and Computer Graphics (IJCICG).
- Scientific advisor Philips Electronics Netherlands
- In the period 2003-2008 initiator and co-chair of four ACM-CHI workshops, program co-chair of IFIP International Conference on Entertainment Computing 2004, program chair of Social Intelligence 2004 and 2007, initiator and co-chair of workshops and special sessions on entertainment computing, facial expressions, and brain-computer interfacing.
- Invited speaker on recommender systems, ambient intelligence, affective computing and multimodal interaction at various conferences and meetings.
- Reviewer for Dutch, Swiss, Czech, Finland, Belgian and Austrian research funding councils.
- Invited participant of EU FP7 preparatory meetings. EU FP7 FET reviewer. Member of the Future Media and 3D Internet Task Force of the EU (FM3DI-TF).
- Member Advisory Board IIP Create, the ICT-Innovation Platform Creative Industry of the ICT-Regie Organization, the Netherlands.
- Member GATE (Game research for Training and Entertainment) Steering Committee, AGS, Utrecht.
- Founding member of MMI Platform Nederland.

- Board NWO VIEW (Visual Interactive Effective Worlds) committee and founding member of DECC (Dutch Entertainment Computing Community). Member of NWO 'Open Competition' review board. Member of IFIP WG 14 committees.
- Member of the review committee of the International Graduate School in Information and Communication Technology of Trento (Italy). Until 2007 member of the advisory committee of the JFS PhD research school in Eindhoven and the Masters program Media and Knowledge Engineering of the Technical University of Delft.
- Member of the Board of the EU AMI (Augmented Multi-party Interaction) Consortium. Member of the managing committee of EU COST2102.
- Received in 2005 the title of distinguished visitor of the city of Santiago de Cuba for his efforts to promote computational linguistics research in Cuba.

Prof. dr. ir. M. Pantic

- Received in 2008 the European Research Council Starting Grant as one of 2.5% best junior scientists in any research field in Europe in 2007.
- Guest-editor of the following journals: Image and Vision Computing Journal (2), Int'l Journal of Image and Video Processing, and IEEE Transactions on Systems, Man, & Cybernetics.
- Associate Editor of the following journals: IEEE Transactions on Systems, Man, & Cybernetics, Image and Vision Computing Journal, and Computer Journal.
- In the period 2003-2008 initiator and co-chair of the IEEE Int'l Workshop on Computer Vision and Pattern Recognition for Human communicative Behaviour analysis (CVPR4HB) (2), initiator and co-chair of Int'l Workshop on Artificial Intelligence for Human Computing, initiator and co-chair of special sessions on automatic facial expression analysis, affective computing, human naturalistic behavior analysis, social signals processing and socially-aware computing, and implicit human-centered tagging.
- General Chair of the IEEE Int'l Conference on Automatic Face and Gesture Recognition 2008 (FG'08), General Chair of the Belgium-Netherlands Conference on Artificial Intelligence 2008 (BNAIC'08), General Chair of the IEEE Int'l Conference on Affective Computing and Intelligent Interaction 2009 (ACII'09), Special Sessions Chair and co-organizer of the IEEE Int'l Conference Systems, Man and Cybernetics 2004 (SMC'04).
- Key Note speaker at the Int'l Conference on Artificial Intelligence Applications and Innovations (AIAI'06), Annual Symposium of the German Association for Pattern Recognition (DAGM'08), Int'l Conf. Articulated Motion and Deformable Objects (AMDO'08), and Int'l Workshop on Machine Learning and Multimodal Interaction (MLMI'08).
- Invited speaker on automatic facial expression analysis, human-centered computing, and automatic human behavior analysis at various seminar series and meetings.
- NWO VENI Panel Member 2007-2009, Scottish Funding Council – Panel Member 2008
- Reviewer for Scottish, Dutch, Swiss, and USA (NSF) research funding councils.
- Member of the Management Board of the EU Humaine Association 2007-2009, EU Semaine (emotionally-colored HCI) Consortium 2008-2011, EU SSPNet (social signals processing NoE) Consortium 2009-2013.
- Scientific Director of the EU FP7 SSPNet NoE 2009-2013

6. Internal evaluation

Each year the work of post-docs and staff members is discussed with their supervisors. If necessary, a plan is made to guide further development of the employee; such plans contain measurable milestones and sometimes courses are suggested.

At the start of each PhD project, a training and supervision plan is developed that includes the courses to be followed by the PhD candidate, and the targets to be reached within the next 12 months. Every 6 months progress is monitored, and a decision is made with respect to continuation. In case progress is insufficient, appropriate actions are discussed with the personnel department and a decision may be taken to stop the PhD project. With one or two

exceptions during the review period, HMI PhD candidates have been able to finish their research with a PhD thesis in about four years.

7. External validation

7.a. Societal relevance

Our work is targeted at a variety of applications, ranging from providing access to the daily broadcast-news (8-uur Journaal) and cultural heritage archives from the Second World War to user support in smart homes and smart meeting environments and entertainment applications. In our smart environment research we aim at supporting meeting participants during a business meeting and allowing off-line access to captured meeting activities. Technology transfer is an important aim of our research. Together with our European research partners, we have initiated and participated in technology transfer events in Brussels and Amsterdam. Our research on multimodal interaction has been visible in various entertainment applications that have been shown at several public events in and outside Europe. Close relations with several small local companies, sometimes run by our ex-students, help to transfer our research results and approaches to these companies.

In recent years we have demonstrated our research at research meetings, but also at meetings for a more general audience, for example, ICT Delta, CeBIT (Hannover), Wainhouse Research European Forum in Berlin, and at several Community of Interest meetings of the EU projects AMI, AMIDA and MESH. HMI research results and activities have drawn attention from Dutch radio and television, but also from (international) newspapers and magazines, such as the New York Times, Dutch, Austrian, and Italian newspapers and youth magazines writing about scientific issues. This list of interviews and citations during the review period contains more than thirty entries.

Software assets and showcases

The Research Group maintains the following tools, datasets and showcases for public usage:

- *Nite-NIXT*, Tool for creation, analysis, and browsing of annotated multimodal, text, or spoken language corpora, and represents both timing and rich linguistic structure. See <http://nite.sourceforge.net/>
- *Shout*, speech recognition software, which can be used for automatic annotation of video content. See <http://sourceforge.net/projects/shout-toolkit/>
- Audiovisual datasets (Buchenwald, speeches Queen Wilhelmina, Interviews and lectures of Willem Frederik Hermans).
- Twente Nieuws Corpus. See <http://hmi.ewi.utwente.nl/twnc>
- Mocop corpus. See <http://hmi.ewi.utwente.nl/mocapdb>
- Development of showcases, see <http://hmi.ewi.utwente.nl/showcases>

7.b. Industrial contacts

HMI collaborates with small, medium-sized & large companies/organizations in the areas of

- Multimedia (NOS, NOB, Beeld en Geluid, TNO ICT, Medialab, Carp Technologies, TeleCats, ParaBots)
- Experience processing (Philips)
- Image processing, graphics & virtual reality (re-Lion, VicarVision, Kunst&vanLeerdam))
- Games & simulation (T-Xchange, Green Dino, Thales/DECIS Lab)
- Usability testing (Noldus, IBM, TNO Human Factors)
- Interaction & presentation technology (Oce Research, Telematica Instituut, Philips, Forward Thinking, Q-go Nederland)
- Smart environments (Home Automation Europe, TalkingHome, Spiderfone, VisualNexus)
- Publishing companies (PCM, Van Dale Lexicografie)
- Search Technology (Teezir, Telecats, Q-go Nederland)
- Stichting Notas (group of SMEs with focus on applications of language engineering)

- Libraries/archives (Koninklijke Bibliotheek, dbnl, Gemeentearchief Rotterdam, Veteraneninstituut)

There have been personal memberships of industrial bodies: (Franciska de Jong): (1) advisory board Van Dale Lexicografie (chair), (2) advisor/reviewer Senter, (3) supervisory board Q-go Nederland BV; (Theo Huibers): (1) Non-executive board CITO-group, (2) Advisor CA-ICT, (3) Chairman Accenture Innovation Award.

8. Researchers and other personnel ("wp")

Table 1

Category	Name	2003	2004	2005	2006	2007	2008
Tenured staff							
professor (hgl)	Jong, prof. dr. F.M.G. de	0,24	0,25	0,26	0,25	0,25	0,25
	Nijholt, prof. dr. ir. A.	0,40	0,40	0,40	0,40	0,40	0,40
associate professor (uhd)	Zwiers, dr. J.	0,40	0,40	0,40	0,40	0,40	0,40
assistant professor (ud)	Akker, dr. ir. H.J.A. op den	0,40	0,40	0,40	0,40	0,40	0,40
	Asveld, dr. ir. P.R.J.	0,40	0,40	0,40	0,36	0,40	0,10
	Dijk, dr. E.M.A.G. van	0,40	0,40	0,40	0,40	0,40	0,40
	Heylen, dr. D.K.J.	0,40	0,40	0,40	0,40	0,40	0,40
	Kuper, dr. ir. J.	0,40	0,40	0,40	0,40	0,40	
	Poel, dr. M.	0,40	0,40	0,40	0,40	0,40	0,40
	Theune, dr. M.	0,28	0,34	0,34	0,34	0,34	0,34
	Vet, dr. P.E. van der	0,40	0,40	0,40	0,36	0,40	0,40
postdoctoral fellows	Ordelman, dr. R.J.F.						0,86
Total tenured staff		4,12	4,18	4,19	4,10	4,18	4,34
Non-tenured staff							
professor (hgl)	Huibers, prof. dr. T.W.C.	0,10	0,11	0,11	0,11	0,11	0,11
	Pantic, prof. dr. ir. M.				0,02	0,11	0,11
	Roosendaal, Prof. dr. H.E.	0,08					
	Vosselman, prof. dr. ir. M.G.				0,11	0,11	
associate professor (uhd)	Ruttkey, dr. Z.M.		0,11	0,21	0,21	0,38	0,42
postdoctoral fellows	Bui Huu Trung, dr. B.H.T.						0,17
	Heeren, dr. W.F.L.				0,84	1,00	0,78
	Hessen, dr. A.J. van	0,40	0,42	0,42	0,42	0,42	0,36
	Ordelman, dr. R.J.F.	0,21	1,00	1,00	1,00	1,00	
	Reidsma, dr. ir. D.						0,21
	Schooten, dr. ir. B.W. van		0,28	0,84	0,84	0,84	0,84
	Theune, dr. M.	0,14					
other junior staff (moz, twaio)	Hofs, ir. D.H.W.		0,67	0,67	0,67	0,67	0,67
	Huijbregts, ir. M.A.H.						0,34
	Jochmann-Mannak, drs. H.E.						0,60
	Melis, ir. P.E.C.	0,50					
	Nijdam, ir. N.A.					0,30	
	Oinonen, K.M.			0,26			
	Poppe, ir. R.W.			0,19			
	Reidsma, dr. ir. D.	0,24					
	Verschoor, ir. T.				0,38	0,80	0,80
	Welbergen, ir. H. van			0,11	0,38		
Total non-tenured staff		1,67	2,59	3,81	4,98	5,75	5,41
PhD Candidates							
junior staff (aio, oio, moz-p)	Bachvarova, MSc. Y.S.			0,60	0,80	0,46	
	Bosma, W.E.	0,04	0,80	0,80	0,80	0,76	

Category	Name	2003	2004	2005	2006	2007	2008
	Bui Huu Trung, dr. B.H.T.		0,13	0,80	0,80	0,80	0,66
	Bui, T.D.	0,80	0,80				
	Cao, Y.					0,73	0,80
	Fikkert, F.W.				0,80	0,80	0,80
	Froon, drs. J.M.	0,08					
	Gürkök, H.						0,20
	Hauff, C.			0,17	0,80	0,80	0,80
	Herder, E.	0,80	0,80	0,80			
	Huijbregts, ir. M.A.H.		0,33	0,80	0,80	0,80	0,46
	Jamroga, W.J.	0,80	0,53				
	Jovanovic, N.	0,80	0,80	0,80	0,80	0,26	
	Keizer, S.	0,43					
	Kiss, S.	0,37					
	Kulyk, O.			0,20	0,80	0,80	0,80
	Maat, M. ter					0,07	0,80
	Malchanau, A.V.	0,80	0,80	0,80	0,66		
	Mühl, C.					0,10	0,80
	Niculescu, A.I.				0,47	0,80	0,80
	Ordelman, dr. R.J.F.	0,50					
	Otterlo, ir. M. van	0,80	0,53	0,63			
	Oude Bos, MSc. D.						0,20
	Poppe, ir. R.W.			0,60	0,80	0,80	0,80
	Reidsma, ir. D.	0,17	0,67	0,67	0,67	0,67	0,45
	Reuderink, ir. B.					0,17	0,80
	Rienks, R.J.	0,20	0,80	0,80	0,80	0,60	
	Schooten, ir. B.W. van	0,20					
	Snoek, ir. M.	0,56					
	Straalen, drs. B. van					0,10	0,80
	Swartjes, ir. I.M.T.				0,57	0,80	0,80
	Trieschnigg, ir. R.B.			0,13	0,80	0,80	0,80
	Vyas, D.M.					0,67	0,80
	Wassink, I.			0,20	0,80	0,80	0,80
	Welbergen, ir. H. van				0,28	0,67	0,67
	Werff, drs. L.B. van der				0,73	0,80	0,80
Total PhD Candidates		7,35	6,99	8,80	12,98	14,06	14,64
Total Research Staff HMI		13,14	13,77	16,80	22,07	23,99	24,39

9. Resources, funding and facilities

9.a. Laboratory infrastructure

HMI is active within many projects and many disciplines. Consequently, hardware equipment is very diverse, including standard computing equipment, brain-computer interfacing equipment, and from server based speech recognition systems, advanced 3D vision, various sensor techniques, and 3D displays. This is accompanied by software environments that are heterogeneous as well, including all major operating systems, various specialized tools and development systems.

We have a small team of persons coordinating and facilitating our hardware and software development in a way that is compatible with the amount of freedom necessary within a research environment. Coordination means that we strive for collaboration as well as good software engineering practices. There are two strategic lines that we follow in order to

achieve this. The first line is to actively develop joint demonstrators and to produce showcases within our HMI web based show case section. This is often done within the boundaries of a single research project, but within HMI we try to combine and ameliorate results from different projects as well. The second line is to provide guidelines and tools for achieving good software engineering principles. This includes tools for common software repositories, tools for web based software project management, and systematic testing and bug tracking. The attitude is also to aim for the usage of open standards and platform-neutral systems, as far as possible.

9.b. FTE-funding

From Table 2 a clear trend in favor of more contractual funding is visible. The research funds percentage seems low percentage-wise, but given the high volume of funding (the total size of the group) we see this as quite acceptable.

Table 2: Funding at group level

HMI	2003	2004	2005	2006	2007	2008
Direct funding	80%	67%	74%	69%	62%	64%
Research funds	2%	3%	5%	9%	7%	3%
Contracts	18%	30%	22%	22%	31%	33%
Total	100%	100%	100%	100%	100%	100%

9.c. FTE-funding PhDs/Postdocs

This table shows the same trends as Table 2, amplified by the fact that the direct funding through teaching is not included here.

Table 3: Funding of PhDs/postdocs

HMI	2003	2004	2005	2006	2007	2008	Average
Direct funding	65%	31%	21%	16%	12%	11%	26%
Research funds	0%	12%	15%	20%	20%	11%	13%
Contracts	34%	57%	65%	64%	68%	78%	61%
Other	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%

9.d. List of external funds

HMI is strong in project acquisition. The topics covered by its research appear in EU and national programs that aim at promoting advanced ICT research. The diversity in funding agencies is one of the strengths of the group.

Table 4

Name project	Start	End	Sponsor
AMI: Augmented Multi-party Interaction	Jan-04	Dec-06	European Commission
AMIDA: Augmented multi-party interaction with distance access	Oct-06	Dec-09	European Commission
COST2102 - Cross-modal analysis of Verbal and Non-verbal Communication	Jun-06	Jun-10	European Commission
COST292 - Semantic Multimodal Analysis of Digital Media	Aug-05	Oct-08	European Commission
DELOS: Network of excellence on digital libraries	Oct-00	Oct-03	European Commission
ECHO: European CHronicles On-line	Feb-00	Apr-03	European Commission
EUNITE: European network on intelligent technologies for smart adaptive systems	Jan-01	Jan-04	European Commission
HAHAcronym: Humorous Agent for Humorous Acronyms	May-01	Feb-03	European Commission
HUMAINE: Human-Machine Interaction Network on Emotion	Jan-04	Dec-07	European Commission
M4: MultiModal Meeting Manager	Mar-02	Mar-05	European Commission

Name project	Start	End	Sponsor
MediaCampaign	Apr-06	Sep-08	European Commission
MESH: Multimedia semantic syndication for enhanced news services	Mar-06	Mar-09	European Commission
MUMIS: Multimedia Indexing and Searching Environment	Jul-00	Dec-03	European Commission
NiSIS: Nature-Inspired Smart Information System	Feb-05	Feb-08	European Commission
SAFIR: Speech Automatic Friendly Interface Research	Mar-04	Mar-08	European Commission
SEMAINE: Sustained Emotionally Coloured Machine-Human Interaction	Jan-08	Jan-11	European Commission
GATE: Game research for training and entertainment	Apr-06	Apr-12	ICT-Regie FES
D-coi: Dutch Language Corpus Initiative	Jun-05	Aug-06	Nederlandse Taalunie
N-Best	May-06	Sep-08	Nederlandse Taalunie
SoNaR Fase 1	Apr-08	Jan-09	Nederlandse Taalunie
SPRAAK: Speech Processing, Recognition and Automatic Annotation Kit	Dec-05	Apr-08	Nederlandse Taalunie
CHoral: Access to oral history	Mar-06	Jul-10	NWO - CATCH
IMIX/Demon: Technische integratie	Jan-05	Jan-08	NWO - IMIX
IMIX/IMOGEN: Interactive Multimodal Output Generation	Dec-03	Jan-08	NWO - IMIX
IMIX/VIDIAM: Dialogue management and the visual channel	Sep-04	Sep-07	NWO - IMIX
Angelica: A Natural-Language Generator for Embodied, Lifelike Conversational Agents	Mar-03	Mar-07	NWO - MEERVOUD
MULTI-VIS:A Multi-modal Visualization Environment	Sep-07	Mar-10	NWO - VIEW
Virtuele Jeugdbibliotheek	Jan-08	Jan-11	Openbare bibliotheken
PIDGIN Zelflerend Cross Lingual Interface	Apr-02	Dec-04	SENER
Waterland: Workflow with semi-Automatic meTadata Extraction for fully digital media pRoduction in the NetherLANDs	Jun-01	Jun-05	SENER
BioRange: A research programme to shape the future for bioinformatics in the Netherlands	Jan-04	Dec-09	SENER BSIK
ICIS: Interactive Collaborative Information Systems	Jan-04	Jan-10	SENER BSIK
MultimediaN: Semantic Multimedia Access	Jan-04	Jan-09	SENER BSIK
Persoonlijke assistent voor mobiele webdiensten	Jul-01	Dec-05	SENER IOP-MMI
Metaverse1	Oct-08	Mar-11	SENER ITEA2
BrainGain: Devices For Measuring And Modifying Brain Activity	Sep-07	Sep-13	SENER SmartMix
DRUID: Multimedia Indexing & Retrieval on the basis of Image Processing & Language and Speech Technology	Jul-03	Sep-03	Telematica Instituut
Spellingcheckers	Apr-98	Apr-03	Van Dale Lexicografie

10. Overview of the results

10.a. Key publications

Table 5

Nr	Title
1	Heylen, D.K.J. , Nijholt, A., Akker, H.J.A. op den. <i>Affect in Tutoring Dialogues</i> . Applied artificial intelligence nr: 3-4, 19, (2005). (pp. 287-310) ISSN: 0883-9514
2	Jong, F.M.G. de , Oard, D.W., Heeren, W.F.L., Ordelman, R.J.F. <i>Access to recorded interviews: A research agenda</i> . ACM journal on computing and cultural heritage nr: 1, 1, (2008, June 1). (pp. 3:1-3:27-3:1-3:27) New York ACM ISSN: 1556-4673
3	Nijholt, A. <i>Google Home: Experience, Support and Re-Experience of Social Home Activities</i> . Information sciences nr: 3, 178, (2008, March 1). (pp. 612-630) Amsterdam Elsevier ISSN: 0020-0255

Nr	Title
4	Pantic, M. , Nijholt, A., Pentland, A., Huang, T.S. <i>Human-Centred Intelligent Human-Computer Interaction (HCI): how far are we from attaining it?</i> . International journal of autonomous and adaptive communications systems nr: 2, 1, (2008, August 1). (pp. 168-187) Geneva, Switzerland Inderscience Publishers ISSN: 1754-8632
5	Reidsma, D. , Nijholt, A., Bos, P. <i>Temporal interaction between an artificial orchestra conductor and human musicians</i> . Computers in entertainment nr: 4, 6, (2008, December 1). (pp. 1-22) New York ACM ISSN: 1544-3574

10.b Numerical overview of the results in a fixed format of categories

Table 6

Category	2003	2004	2005	2006	2007	2008	
Academic publications	a. Refereed journals	6	6	8	16	7	9
	b. International conferences	45	40	68	46	62	82
	c. Book chapters	3	5	3	5	17	5
	d. Other academic publications	11	10	16	19	15	16
Total	65	61	95	86	101	112	
Monographs							
PhD-theses	4	4	1	2	2	5	
Professional publications	4	4	5	3	4	1	
Patents							
Software	1						

10.c Full outcome list

2003

Journal articles

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- Dijk, E.M.A.G. van , Akker, H.J.A. op den, Nijholt, A., Zwiers, J. *Navigation assistance in virtual worlds*. Special Series on Community Informatics.. Informing science 6, (2003). (pp. 115-125) ISSN: 1521-4672
- Korsten, M.J. , Vet, P.E. van der, Regtien, P.P.L. *Systematic and computer assisted design of measurement systems*. Measurement nr: 2, 33, (2003). (pp. 145-156) ISSN: 0263-2241
- Roosendaal, H.E. , Huibers, T.W.C., Geurts, P.A.T.M., Vet, P.E. van der *Changes in the value chain of scientific information: economic consequences for academic institutions*. Online information review 27, (2003). (pp. 120-128) ISSN: 1468-4527
- Westerveld, T.H.W. , Vries, A.J. de, Ballegooij, A. van, Jong, F.M.G. de, Hiemstra, D. A *Probabilistic Multimedia Retrieval Model and its Evaluation*. Eurasip journal on applied signal processing 2, (2003). (pp. 186-198) ISSN: 1110-8657
- Wijnhoven, A.B.J.M. , Belt, E. van der, Verbruggen, E., Vet, P.E. van *der Internal data market services: An ontology-based architecture and its evaluation*. Informing science 6, (2003). (pp. 259-271) ISSN: 1521-4672

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- Bui, T.D. , Jamroga, W.J. *Multi-Agent Planning with Planning Graph*. Proceeding of Eunite 2003 (2003, oktober 7). (pp. 558-565)
- Burghouts, G.J. , Akker, H.J.A. op den, Heylen, D.K.J., Poel, M., Nijholt, A. *An Action Selection Architecture for an Emotional Agent*. Recent Advances in Artificial Intelligence 16, (2003, mei 20 / 2003, mei 20). (pp. 293-297) Menlo Park , CA, USA AAAI Press ISBN: 1-55735-177-0
- Declerck, T. , Cunningham, H., Saggion, H., Kuper, J., Reidsma, D., Wittenburg, P. *MUMIS Advanced information extraction for multimedia indexing and searching*. In: Digital Media Processing for Multimedia Interactive Services: Proceedings of the 4th European Workshop on Image Analysis for Multimedia Interactive Services (WIAMIS'03), London, 9-11 April 2003. pp. 553-556. World Scientific, New Jersey. ISBN: 9812383557.
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11. SWOT-analysis

Strengths:

- The courage of the group to embrace new disciplines and explore new paths of research whilst retaining deep technical roots and maintaining strong expertise in the field of intelligent multi-modal interaction in its various forms and aspects.
- The excellent balance between education and research.
- Strong dissemination activity using networks of excellence and COST actions, demonstrations and presence at general public oriented ICT events in the Netherlands and abroad and interviews on radio and TV and in journals and magazines.

Weaknesses:

- Hiring post-docs and scientific programmers has hardly been done in previous years. Too much programming and system development had to be done by staff members. There have been understaffed projects because of not being able to hire people for the sometimes short duration of the projects. With the current number of senior staff members it is not possible to grasp all EU project opportunities that become available.

Opportunities:

- For Dutch national and European calls for research proposals HMI is often on the wanted list as partner.

Threats:

- Losing the ability to enter and explore new fields of research.
- Much of the research at HMI is interdisciplinary; covering Cognitive and Behavioral Computing. This makes it hard to get project funding from the more traditional funding agencies such as NWO.

Analysis:

- Over the last six years HMI has renewed itself. This has been done successfully. We need to be careful that we maintain our strength to enter new areas and to continue to become part of multidisciplinary research teams. On the other hand, some consolidation of expertise areas needs to be worked on. A more flexible hiring strategy has to be implemented where postdocs are hired for longer periods and are employed on various projects rather than on one.

Adjusted Goals:

- Not really

Adjusted strategy:

- The HMI financial situation and the funding possibilities allow HMI to implement a more flexible hiring strategy where postdocs are hired for longer periods and are employed on several projects. Hence being able of monitoring the societal needs and technological developments in order to enter and explore new fields of research and to maintain more coherent clusters of research and a more dictating role in research programs

Title of Research Group:

Information Systems (IS)

Research themes: Architecture, Requirements, Security

NABS code: N07

Head of Group: Prof. dr. R.J. Wieringa

Starting dates of research theme: Architecture and Requirements were started in 1998 when the IS group started, Security was started in 2005

Affiliations outside the department and other co-operations: CTIT, national research schools SIKS, IPA

1. Mission statement

Today's information systems are used in a network context, ranging from informal social networks such as professional associations, to formal alliances between profit-and-loss responsible businesses. Often these networks are decentralized, meaning that they are networks of equal partners, without a central authority, and so information systems need to be designed in accordance with the goals of a disparate set of independent stakeholders. In this context, information systems should support processes within and across organizations that may or may not be fully specified. At the same time, they should avoid harm to security and privacy of the actors involved.

The mission of the IS group is to develop methods, concepts, and tools for the efficient and effective design of information systems in decentralized networks, and to provide bachelor- and master-level teaching in these areas. The group also takes a responsibility in transferring the results of its research to society.

2. Leadership

The IS group is managed by senior research staff (Wieringa, Reichert (Oct. 2004 – Dec 2007), Van Sinderen (since June 2008)). Wieringa takes responsibility for HRM tasks and financial planning. Operational tasks concerning financial reporting, project reporting, the coordination of teaching, web page maintenance and PR have been allocated to members of the group. The permanent staff meets twice a year to develop and update a shared long-term vision of research and teaching of the group. To facilitate interaction between our different projects, the group as a whole meets once a week for a research seminar in which one research staff member gives a presentation, rotating through all permanent and non-permanent research staff. The Head of Group meets with the group secretary once a week to discuss operational matters and with the associate professor (Van Sinderen) to discuss strategy and tactics.

Project acquisition is done by senior staff (currently Wieringa and Van Sinderen) and by other staff members with coaching by senior staff. We try to influence the definition of external research programs (e.g., FP7, NIRICT, and NWO) in order to fulfill our overall vision. We have an active policy of participating in interest groups with industry, such as the Netherlands Architecture Forum, so that we keep in touch with needs and goals in society that motivate new research projects. We also maintain an excellent network with partners from academia and research at the local, national and international level, for example by participating in external boards and committees at both the national and international level. These activities have resulted in numerous collaborations with researchers and industry in externally funded projects.

3. Strategy and policy

3.a. Design in brief

Context and mission of our research

The major challenge facing users of information systems today is the design and management of the alignment between information systems and their social context. The classical social context of information systems is organizational, business as well as non-profit

and government, but with the spread of decentralized communication infrastructures the line between organizational computing and personal computing has blurred. Individuals may work as employees in different organizations, or work as independent consultants in different organizations, and employees may use their computing infrastructure for work-related as well as for personal goals. In addition, the boundaries between organizations have blurred, too. Organizations are part of value chains and have entered in a variety of cross-organizational relations, such as strategic alliances, co-makership and co-design, outsourcing, subcontracting and joint ventures.

All of this means that information systems are used in a decentralized context in which they need to be aligned with the goals of many different stakeholders. Our research mission is **to develop methods, concepts, and tools for the effective and efficient design of information systems in decentralized networks**. Examples are *methods* to assess maturity of cross-organizational IT architecture, *concepts* to model coordination processes, and *software tools* to analyze a network of service level agreements.

We perform projects in the areas of architectures, requirements and security of decentralized information systems. Our *architecture projects* focus on ways in which information systems can provide services to optimally support processes in the social context of information systems. At the organizational end of the spectrum, this concerns business process support, at the personal end of the spectrum this concerns context aware services to people. Our *requirements projects* focus on requirements specification for optimizing business value. Our *security projects*, done together with the DIES group, focus on security risk assessment for businesses operating in a value web.

Brief description of research areas

Our requirements and architecture projects look at the problem of alignment between information systems and their social context from the perspectives of business goals and of software architectures, respectively. Our third area, security, is an aspect of this alignment, that we study mostly at the requirements level.

- *Business processes, services and architectures*: information system architecture is the way the parts of an information system interact to provide services to their social context. A continuing theme is the specification and validation of guidelines for the alignment of larger-scale information system architectures with business goals and processes. When Reichert was in the IS group, many projects focused on support for the evolution of business processes. Since Van Sinderen joined the group, the number of business process support projects decreased and the design of architectures for context-aware support of tasks became more important. Two shared and constant themes, however, are the design of processes to support a decentralized set of tasks, and the alignment of IT services with goals of actors in the social context. Challenges we have addressed in our architecture research in the period 2003-2008: design of guidelines for architectural alignment, value-based IT alignment, semantic interoperability of enterprise processes, modification of business processes on the fly, IT support for learning from process changes, and dynamically allocating resources to processes.
- *Requirements Engineering (RE)*: Information system requirements are the properties that an information system needs to have in order to optimally fit the goals of the social context. Since the software infrastructure as well as the social context continually changes, RE is a continuing process that includes assessment of requirements priorities, assessment of cost and benefit of implementing the requirements, as well as IT governance. In the period 2003-2008 we have addressed the following challenges in our RE research: the relation between maintainability of information systems and architectural choices, cost estimation of cross-organizational Enterprise Resource Planning (ERP) systems, collaborative alignment of cross-organizational ERP systems, RE for ambient systems, modelling the physical context of reactive systems, and value-driven requirements engineering.

- *Security*: Cross-organizational systems bring with them new security problems, because the policy and security models and their implementations are different across organizations. To date, security has been viewed as a problem of regulating access to digital or physical spaces. To face the challenges of security in cross-organizational systems, we need to provide an integrated view of security that spans the digital and physical domain, and can relate this to business-level security policies. Because total security is impossible, the approach must take a risk management perspective. In the period 2003-2008, our security research has addressed the following topics: threat analysis and risk assessment in a network of IT assets, value-based trade-off analysis of security mitigation strategies, and risk assessment in the presence of blurring organizational boundaries.

3.b. Future development

For each of our three research areas we have identified short-term and long-term challenges that will drive our future research theme development:

- *Architecture design*: Five years from now, we should have developed techniques that allow us to configure and compose services in a decentralized network, and have developed decentralized platforms that can deliver these composite services. Ten years from now, we should have developed architectures that allow dynamic adaptation of services based on information from the context. We will explore various techniques for trade-off analysis, risk assessment and dynamic service configuration to see how far we can get in the achievement of these goals.
- *Requirements engineering*: Five years from now, we should have a sound understanding of how information system requirements can be linked to business goals and processes across organizational boundaries. Ten years from now, we should have transformed information system design into a real engineering discipline. This means that we should be able to predict the effect of requirements on the business goals to be achieved, and be able to quantify this in terms of measures of cost and benefit of different possible requirements for the business.
- *Security*: Five years from now, we should have developed techniques for assessment of information risks in large decentralized networks of organizations that hold assets, some of which may be mobile, or virtualized, or outsourced, and which are subject to security policies some of which are organization-specific. Ten years from now, we should have developed theories, methods and tools to understand and manage the relation between security and other aspects of information systems. We will explore this by combining theories and techniques from IT governance, value-based RE and information risk assessment subject to the constraints of practice, such as incomplete information and limited budget to do the risk assessment.

4. Processes in research, internal and external collaboration (max ¼ A4)

In each of our projects at least two members of our permanent staff are involved. Also, there are usually several PhD candidates working in one project. PhD candidates and postdocs working on related topics are placed in close physical proximity to each other; our security PhD candidates and postdocs share the rooms of the security researchers of the DIES group. Each PhD candidate is supervised by a permanent staff member under the final responsibility of the Head of Group, sometimes assisted by a postdoc. The supervisor has weekly meetings with the candidate, and depending on the stage and size of the project, they have monthly or quarterly meetings with the Head of Group. Larger projects involving candidates from other groups or other universities have monthly project research meetings in which the Research Group participates. Each project has a permanent staff member as research leader.

We provide a variety of opportunities to our PhD candidates to strengthen their research skills, including courses offered by SIKS on research methodology and by the UT on personal

effectiveness (technical and scientific writing, presentation). We stimulate participation in summer schools and doctoral symposia for PhD candidates.

We spend an increasing amount of time on validating what we design by means of real-world research, in particular case study and technical action research. The Head of Group (Wieringa) has given tutorials on engineering research methodology, gives a course on this to SIKS researchers every year and takes care that all PhD candidates in the IS group apply these methodological principles in their own research.

5. Academic reputation

Prof. dr. Roel Wieringa

- Scientific Director of the School of Information and Knowledge Systems (since 2006) (SIKS; www.siks.nl)
- Member of the board of governors of SIKS (2003-2005)
- Associate editor in Chief of IEEE Software (2004-2007)
- Chair of the Requirements Engineering Conference Steering Committee (2003-2005)
- Member of the Requirements Engineering Conference Steering Committee (2003-2008)
- Editorial board, Requirements Engineering Journal
- Editorial board, Journal of Software and Systems Modelling
- Editorial board, Int'l Journal of Web Engineering and Technology (IJWET, till 2004)
- Member of the board of the Nederlands Architectuurforum (NAF; www.naf.nl, till 2004)
- Member of the scientific advisory board of CARE (www.care-t.com/company/sab.asp).
- Member of the advisory board, Delft-TopTech (<http://www.delft-toptech.nl>, till 2003)
- Conferences:
 - Program chair of the IEEE Requirements engineering conference (2003)
 - PC member of the conferences on requirements engineering (RE), Advanced information systems engineering (CAISE) and Conceptual Modelling (known in the field as the ER conference).

Dr. Marten van Sinderen (Since 2008)

- Coordinator of CTIT's Strategic Research Orientation on service science (ASSIST, since 2007)
- Editorial Board, Enterprise Information Systems (EIS) Journal (since 2007)
- Guest Editor, EIS Special Issue on Challenges and Solutions on Enterprise Computing (2008)
- Steering Committee, EDOC Enterprise Computing Conference (since 2006)
- Program Committee and Monitor, BSIK Freeband projects (2004-2008)
- Managerial Board, IFIP WG5.8 on Enterprise Interoperability (since 2008)
- Conferences and workshops:
 - Co-chair of the Int'l Conference on e-Business (ICE-B'07, ICE-B'08)
 - Chair of the Int'l Workshop on Architecture, Concepts and Technologies for Service Oriented Computing (ACT4SOC'07, ACT4SOC'08)
 - Co-chair of Int'l Workshop on Enterprise Interoperability (IWEI'08)
 - Co-chair of Int'l Workshop on Personalization in Grid and Service Computing (PGSC'08)

Dr. Manfred Reichert (2004-2007)

- Member of the board of GI SIG EMISA (Special Interest Group on Development Methods for Information Systems and their Application)
- Editor in Chief of EMISA Forum (since 2006)
- Conferences & Workshops:
 - Co-chair and Co-organizer of the Annual Conference of the German Computer Society (GI), 2004
 - Co-chair of the GI Workshops on Enterprise Application Integration (EAI'04, EAI'05)
 - Co-chair of the DPM'06, Proflex'06 and TCoB'06 international workshops
 - IFIP TC2 Manfred Paul Award for "Excellence in Software Theory and Practice" (2005)

6. Internal validation

In the EWI faculty, every permanent staff member has an annual performance appraisal meeting with his or her functional boss. In the IS group, the Head of Group reviews performance on research and teaching in the past year and looks ahead with the staff member one year, 5 years and 10 years to discuss short- and long-term goals and ambitions.

PhD candidates are evaluated every six months for the first 3 years of their contract, and every year there is a go/no go decision about continuing the contract, based on the expectation whether the research of the PhD candidate will result in a PhD thesis. If the decision is negative, a joint plan of action is drawn up, supported by the HRM department of the EWI faculty. This has resulted in some terminations of PhD employment contracts. PhD candidates may contribute to master's courses if this matches their research topic.

Postdocs have a normal annual performance appraisal and are expected to contribute to supervision of PhD candidates, as well as to writing new project proposals. They may also contribute to our teaching if this matches well with their research interests and future ambitions.

7. External validation

7.a. Societal relevance

Information systems are a means to an end, not a goal in themselves. We see our societal relevance in developing techniques, methods and tools that enable organizations to better match information systems with their goals. By disseminating our research results, we strive to enable organizations to employ information systems in a more effective and efficient way. We use several channels for this: advisory boards (with members from companies and government) in our projects, case study and technical action research carried out in businesses, participation in knowledge exchange networks with practitioners and professionals (NAF, NGI), publications in professional journals and the trade press (*Informatie, Automatisering Gids*), and last but not least: around 30 MSc projects per year in companies and governmental organizations.

Relevance of research is a relation between research results and stakeholder goals. If research results help stakeholders to achieve their goals, the results are relevant for those stakeholders. Relevance is time-dependent, because what is relevant today may not be so tomorrow and vice versa, all depending on stakeholder goals. Potential relevance motivates our selection of research problems and our decisions about research direction in three ways. (1) We respond to problems experienced in society, e.g. by developing techniques for the value-driven alignment and governance of decentralized information system architectures; (2) we anticipate on possible future problems, e.g. by developing techniques for information security risk assessment in decentralized networks; (3) we develop innovative technology that allow actors to achieve future goals, such as techniques for dynamic service configuration or for context-aware applications.

7.b. Industrial contacts

- Companies and organizations participating in our research projects in the period 2003-2008: *ABN AMRO, AkzoNobel Atos Origin, Belastingdienst C/ICT, BiZZdesign, Cap Gemini, , Chess, CIBIT/SERC, Cisco Systems, Compuware, Cordys, Corus, DaimlerChrysler Research, Deloitte, DSM, ECN, Ericsson, Fox-IT, Gartner, GetronicsPinkRoccade, Gigsoft, HP, IBM Netherlands, ICTU, ING, IZIT, KLM, KPN, KWARDS, Labyrint, Logica, Lucent, Medical Informatics Group / University of Marburg, MobiHealth, MST Enschede, Nedap, Océ, OrangeWing Consulting, Orbis, OptIn Solutions, Ordina, Philips, Rabobank, Roessingh, SENA, Shell, Sogeti, Telematics Institute, Telindus, Thales, TKH Group, TNO, Twynstra Work Innovation, Unisys, VisionFlow.* Most of these companies participate in user groups of our projects, others are sites of case studies, and yet others do joint research with us in one of our projects.

- Companies and organizations where we have had MSc students in the period 2003-2008: *ABN AMRO, AFAS, AINO, AJS Business Intelligence, Akzo Nobel, Alfa and Ariss Federation, Analytico Medinet, Atos Consulting, Belastingdienst, BeValue, BiZZdesign, British Telecom, Business Objects, CapGemini, CenPRA (Brazilië), Centric, Cordys, CWI Amsterdam, DatelNet Inc., DaVinci Advies, De Belastingdienst, Deloitte & Touche, Drankenpallet Beheer Nederland, DuurzaamOost, Ebuddy.com, eMAXX, Ernst & Young, ETIRC, Euregio Service Centre for Healthcare, Fortis bank, Gemeente Den Haag, Gemeente Enschede, Getronics PinkRoccade, Het Zonnehuis Beekbergen, Hoofdbedrijfschap Afbouw en Onderhoud, IAPSO (United Nations, Danmark), IBM, InfoTopics, Interpolis, IZIT, JB-IT solutions, KNGF, Koninklijke Nederlandse Hippische Sportfederatie, KPMG, KPMG Zürich, KPN, Den Haag, LogicaCMG, Microsoft, M&I Partners, Ministerie van financiën, Newtel, NIB Capital, Novaxon, NS Internationaal, Oce, Oracle, Ordina, Pallas Athena, Philip Morris, Philips, PlantijnCasparie, Police Academy Apeldoorn, PricewaterhouseCoopers, Procter & Gamble, PSO PRO, Quinity, Rabobank, Raet, Refaja Ziekenhuis, Roessingh R & D, Royal Swets & Zeitlinger, Scania Nederland B.V., SevenStar, Shell, Siemens USA, Sogeti, Swiss Reinsurance Company (Hong Kong), Thales, TietoEnator (Finland), TNO, TNT, Den Haag, Topicus, TPG Post, UPS, UWV, VCS groep, Verdonck, Kloos and Associates, Wavin, Woningstichting Goed Wonen.*

8. Researchers and other personnel ("wp")

IS permanent staff spends approximately 40% time on research, 40% on teaching and 20% on administrative and management tasks. Research includes project acquisition and reporting. Mobility in the form of educational leave or sabbatical is encouraged, as well as short visits to research institutions in order to write joint papers or prepare project proposals.

Table 1

Category	Name	2003	2004	2005	2006	2007	2008
Tenured staff							
professor (hgl)	Wieringa, prof. dr. R.J.	0,40	0,40	0,40	0,40	0,40	0,40
associate professor (uhd)	Grefen, dr. ir. P.W.P.J.	0,06					
	Reichert, dr. M.U.		0,05	0,40	0,40	0,40	
	Sinderen, dr. ir. M.J. van					0,17	0,40
assistant professor (ud)	Eck, dr. P.A.T. van	0,40	0,40	0,40	0,40	0,40	0,40
	Sikkel, dr. N.	0,40	0,40	0,40	0,38	0,33	0,33
	Weg, dr. R.L.W. van de	0,40					
other junior staff (moz, twaio)	Vonk, ir. J.	0,66					
Total tenured staff		2,32	1,25	1,60	1,58	1,70	1,53
Non-tenured staff							
professor (hgl)	Muntslag, prof. dr. ir. D.R.	0,05					
	Pieper, prof.ir. R.	0,05	0,05	0,03			
assistant professor (ud)	Daneva, dr. M.					0,15	0,50
	Wegdam, dr. M.					0,05	0,11
postdoctoral fellows	Bassil, dr. S.			0,25			
	Daneva, dr. M.		0,15	1,00	1,00	0,70	
	Houmb, dr. S.H.					0,41	0,95
	Pieters, dr. ir. W.						0,14
	Poniso, dr. M.L.				0,14	0,80	0,80
	Rinderle, dr. S.B.			0,25			
	Sent, dr. D.			0,17	1,00	0,36	
	Su, dr. X.			0,80	1,00	0,08	
other junior staff (moz, twaio)	Wombacher, dr. A.		0,08	1,00	0,74		
	Cleeff, drs. A. van						0,80
	Krukkert, D. ir.		0,80				

Category	Name	2003	2004	2005	2006	2007	2008
Total non-tenured staff		0,10	1,08	3,50	3,88	2,55	3,30
PhD Candidates							
junior staff (aio, oio, moz-p)	Angelov, S.A.	0,14					
	Bodenstaff, L.			0,13	0,80	0,80	0,80
	Dirgahayu, T.						0,80
	Dockhorn Costa, P.					0,07	
	Eckartz, S.M.						0,67
	Fatemi, H.						0,17
	Hordijk, drs. W.T.B.		0,31	0,34	0,34	0,34	0,34
	Ivanovic, A.		0,27	0,80	0,26		
	Jansen, D.N.	0,40					
	Kassab, M.				0,37	0,63	
	Kolos, L.		0,23	0,80	0,26		
	Li, C.					0,77	0,80
	Mantovaneli Pessoa, R.					0,34	0,80
	Marincic, MSc. J.			0,54	0,80	0,80	0,80
	Muller, D.			0,37	0,80	0,80	
	Nunes Leal Franqueira, V.			0,34	0,80	0,80	0,80
	Pumareja, D.T.	0,80	0,80	0,53			
	Racheva, Z.					0,47	0,80
	Santana Tapia, R.G.			0,54	0,80	0,80	0,80
	Sheikh, K.					0,27	
Zambon, E.					0,80	0,80	
Zarifi Eslami, M.						0,10	
Zarvic, MSc. N.			0,44	0,80	0,80	0,20	
Zlatev, Z.V.	0,80	0,80	0,80	0,20			
Total PhD Candidates		2,14	2,10	5,29	5,89	8,15	8,34
Total Research Staff IS		4,56	4,43	10,39	11,34	12,40	13,16

9. Resources, funding and facilities

9.a. Laboratory infrastructure

The IS group is well equipped to perform the research described.

9.b. FTE-funding

The data in Table 2 below shows that reliance on direct funding has steadily decreased, from 93% in 2003 to 49% in 2008. This is the result of our explicit strategy of focusing more on externally funded projects. Our goal is to stay at the levels reached in 2008, when almost half of our research (49%) was funded by direct funds. This indicates that still a considerable part of our research is directly related to teaching, in the sense that it is performed by personnel funded in the first money flow, mainly tenured (assistant and associate) professors with a considerable teaching task.

Table 2: Funding at group level

IS	2003	2004	2005	2006	2007	2008
Direct funding	93%	90%	72%	67%	66%	49%
Research funds	0%	-1%	13%	24%	28%	15%
Contracts	7%	12%	15%	8%	6%	36%
Total	100%	100%	100%	100%	100%	100%

9.c. FTE funding PhDs/postdocs

Table 3 shows the trend towards increased external funding even more clearly than Table 2, due to the fact that this table concentrates on the externally funded positions. In fact, due to the starting position where there was no external funding at all, the average does no justice to the level of funding achieved in the last few years. Also note that besides a very high percentage of research funds in 2007 and 2008, there is a respectable level of contractual funding.

Table 3: Funding of PhDs/postdocs

IS	2003	2004	2005	2006	2007	2008	Average
Direct funding	100%	69%	47%	37%	21%	19%	49%
Research funds	0%	0%	22%	46%	60%	61%	32%
Contracts	0%	31%	31%	17%	18%	20%	19%
Other	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%

9.d List of external funds

Table 4 confirms the picture already emerging from the previous tables: the IS group boasts a healthy number of projects, both from research funds and from contractual sponsors. Many of these projects were acquired in the second half of the assessment period and are still going on for a few years; this provides a good basis on which to keep up the level of non-direct funding.

Table 4

Name project	Start	End	Sponsor
COREPRO: Configuration-based Release Management Processes	Jul-05	Dec-07	DaimlerChrysler Research
Process Support for the Automotive Sector	Mar-05	Sep-05	DaimlerChrysler Research
Process Visualization and Transparency	Mar-05	Sep-05	DaimlerChrysler Research
CARES: collaborative alignment of cross organisational ERP systems	Jan-06	Jan-10	NWO
Casimir/Zieba: Reflective Middleware Support	Jan-06	Jan-09	NWO
COOP: Coordination Process Correctness and Trust Assumptions	Nov-05	Nov-09	NWO
MOCA: Modeling Control Aspects of Embedded Systems	May-05	Sep-09	NWO
Privacy and dynamics of network technologies in the health s	Jun-06	Jun-07	NWO
PROSE: Process Support in E-Health	Oct-04	Oct-07	NWO
Providing Full Life Cycle Support For Adaptive Proc	Jan-07	Jan-11	NWO
QUADRED-IS: Quality-driven requirements engineering	Jul-06	Jun-11	NWO
Value Based Hierarchical Adaptive Configuration Of IT Service Bundles	Sep-08	Oct-12	NWO
VITAL: Value-based IT ALignment	May-05	Jan-10	NWO
QUIDS: QUality Indicators in Design Spaces	Feb-04	Jan-08	Ordina
User Tailored Care Services Platform	Oct-08	Oct-12	SENER
Smart Surroundings	Apr-04	Nov-08	SENER BSIK
IPID: Integrated Policy-based Intrusion Detection	Aug-05	Aug-09	STW
The Virtual Security Perimeter	Jan-07	Jan-12	STW
Value-Based Security Risk Mitigation In Enterprise	Jun-07	Jun-11	STW
AMIGO: Ambient Intelligence for the Networked Home Environment	Jan-04	Feb-08	Telematica Instituut
Freeband/A-MUSE: Architectural Modeling for Service Enabling in Freeband	Jan-04	Dec-08	Telematica Instituut
Freeband/Awareness: context AWARE mobile NETworks and ServiceS	Jan-04	Jan-09	Telematica Instituut
GRAAL: Guidelines Regarding Architecture ALignment	Sep-02	Dec-04	Telematica Instituut
SEINE: SEmantic INteroperability support for Enterprise processes	Feb-04	Feb-08	Telematica Instituut

Name project	Start	End	Sponsor
SPICE: Service Platform for Innovative Communication Environment	Jan-06	Jun-08	Telematica Instituut

10. Overview of the results

10.a. Key publications

The following lists provides highlights for the entire period 2003-2008.

Table 5

Nr	Title
1	Daneva, M., Wieringa, R.J. (2005). Requirements Engineering for Cross-organizational ERP Implementation: Undocumented Assumptions and Potential Mismatches. <i>Int. Conf. on Requirements Engineering (RE'05)</i> , Paris, Aug. / Sept. 2005, pp. 63-72, IEEE Computer Society Press.
2	Wieringa, R. (2003). <i>Design Methods for Reactive Systems: Yourdon, Statemate, and the UML</i> . Morgan Kaufmann Publishers. ISBN: 1-55860-755-2.
3	van Eck, P., Blanken, H., Wieringa, R.J. (2004). Project GRAAL: Towards Operational Architecture Alignment. <i>Int. J. of Cooperative Information Systems</i> , 13(3):235-255, 2004, ISSN: 0218-8430.
4	Mutschler, B. , Reichert, M.U., Rinderle, S.B. Analyzing the Dynamic Cost Factors of Process-aware Information Systems: A Model-based Approach. Proceedings of the 19th International Conference on Advanced Information Systems Engineering (CAiSE 2007) Lecture Notes in Computer Science, 4495 (nr: 1), (2007, June 1). (pp. 589-603) Springer Verlag ISSN: 0302-9743
5	Quartel, D.A.C. , Sinderen, M.J. van Modelling and analysing interoperability in service compositions using COSMO. <i>Enterprise information systems</i> nr: 4, 2, (2008, November 1). (pp. 347-366) London Taylor & Francis ISSN: 1751-7575

10.b. Numerical overview of the results in a fixed format of categories

Table 6

Category	2003	2004	2005	2006	2007	2008	
Academic publications	a. Refereed journals	2	4	4	5	6	11
	b. International conferences	16	18	44	51	41	61
	c. Book chapters	2	1	2	2	1	1
	d. Other academic publications	3	4	6	5	5	6
Total	23	27	56	63	53	79	
Monographs	1					1	
PhD-theses	1				1	1	
Professional publications	1	4	7	6	4	2	
Patents							
Software	1					1	

10.c. Full outcome list

2003

Journal articles

Hu, J., Grefen, P.W.P.J., *Conceptual Framework and Architecture for Service Mediating Workflow Management* (2003). In: *Information and Software Technology* 45(13). pp. 929-939. Elsevier Science. ISSN:0950-5849.

Vonk, J., Grefen, P.W.P.J., *Cross-Organizational Transaction Support for E-Services in Virtual Enterprises* (2003). In: Distributed and Parallel Databases 14(2). pp. 137-172. Kluwer Academic Publishers, Hingham, MA, USA. ISSN:0926-8782.

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- Bondarouk, T.V. , Sikkel, N. *Explaining groupware implementation through group learning*. Information Technology & Organizations: Trends, Issues, Challenges & Solutions. Proceedings of the 2003 IRMA International Conference, 18-21 May 2003, Philadelphia, PA (2003). (pp. 463-466) Hershey, PA Idea Group Publishing
- Eck, P.A.T. van *Ontological Perspective on XML-Based Standards for E-Business Process Integration*. Electronic Commerce Research and Development (2003, oktober 16 / 2003, oktober 18). (pp. 47-54) Gdansk, Polen Drukarnia ACTEN Wejherowo ISBN: 83-88617-75-3
- Eck, P.A.T. van , Wieringa, R.J. *Requirements Engineering for Service-Oriented Computing: A Position Paper*. Proceedings of First International Workshop on e-Services (ICEC'03) (2003, september 30 / 2003, september 30). (pp. 23-28) Nederland TU Delft ISBN: 90-5638-11506
- Fan, I. , Wognum, P.M., Dodds, P. *Better enterprise systems implementation. Building the knowledge economy: issues, applications, case studies*. Proceedings of eChallenges e-2003, 22-24 October 2003, Bologna, Italy (2003). (pp. 1236-1243) IOS Press ISBN: 1-58603-379-4
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- Hu, J., Grefen, P.W.P.J., *Service Mediating Workflow Management* (2003). In: 4th International Symposium on Collaborative Technologies and Systems (CTS), Orlando, Florida, USA, 19-24 Jan 2003. pp. 23-29. Society for Modeling and Simulation International (SCS), San Diego, CA, USA.
- Jansen, D.N. , Hermanns, H., Katoen, J.P. *A QoS-oriented extension of UML Statecharts. «UML» 2003: the unified modeling language Lecture notes in computer science 2863 (nr: XIV), (2003, oktober 20 / 2003, oktober 24). (pp. 76-91) Berlin Springer ISBN: 3-540-20243-9 / ISSN: 0302-9743*
- Keulen, M. van , Vonk, J., Vries, A.P. de, Flokstra, J., Blok, H.E. *Moa and the multi-model architecture: a new perspective on NF2*. Database and Expert Systems Applications Lecture notes in computer science 2736, (2003, september 1 / 2003, september 5). (pp. 67-76) Heidelberg Springer verlag ISBN: 3-540-40806-1 / ISSN: 0302-9743
- Pokraev, S.V., Koolwaaij, J., Wibbels, M., *Extending UDDI with Context-Aware Features Based on Semantic Service Descriptions* (2003). In: The International Conference on Web Services (ICWS '03), Las Vegas, Nevada, USA, 23-26 June 2003. pp. 184-190. CSREA Press, New York. ISBN: 1892512491.
- Pumareja, D.T. *Towards a conceptual Framework for Requirements Engineering for An Evolutionary Groupware Implementation*. Proceedings of the Doctoral Symposium of the 11th Int. Requirements Engineering Conference (2003, september 8 / 2003, september 12). (pp. 2-6) Los Alamitos, CA IEEE Computer Society Press
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with the 11th IEEE International Requirements Engineering Conference, Monterey Bay, California, USA, 8-12 Sept 2003.

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Zlatev, Z.V. *Dynamic Matching of Services by Negotiation*. The First International Conference on Service Oriented Computing Doctoral Consortium Proceedings (nr: # DIT-03-0), (2003, december 15 / 2003, december 18). (pp. 17-21) Trento University of Trento

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Monographs

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Jansen, D.N. *Extensions of Statecharts with Probability, Time and Stochastic Timing*. (2003, oktober 29). 159 pp. Bern, Zwitserland Inmarks ag Thesis advisor(s): Prof.dr. R.J. Wieringa, Prof.dr.ir. J.P. Katoen. ISBN: 3-9522850-0-5

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- Hartel, P.H., Eck, P.A.T. van, Etalle, S., Wieringa, R.J., *Modelling mobility aspects of security policies (Invited paper)* (2004). Invited presentation. In: Construction and Analysis of Safe, Secure and Interoperable Smart cards (CASSIS), Marseille, France, March 10-14, 2004. pp. 172-191. Lecture Notes in Computer Science 3362. Springer-Verlag, Berlin. ISBN: 3-540-24287-2.
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- Wieringa, R.J., *Informaticaonderzoek is ontwerponderzoek* (2004). In: Automatisering Gids. pp. 15. ISSN:0165-4683.
- Wieringa, R.J., Eck, P.A.T. van, Blanken, H.M., *Afstemmen infrastructuur en gebruiksoftware tijdens ontwerp* (2004). In: Informatie 46(April). pp. 16-21. SDU, Den Haag. ISSN:0019-9907.

2005

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11. SWOT-analysis

Strengths

- We have a stable set of research themes that match societal relevance to our research competences
- Our research is well-embedded in the research community as well as in society
- Scientific production of the group has been prolific. Our project proposal and proposal acceptance rates are high.

Weaknesses

- Prolific growth in the form of the usual small projects (1-2 PhDs in the IS group per project) has led to coordination and reporting overhead.
- There is currently no core research product, such as a model or a tool set, that can be presented as integrated result of our past research.
- We are currently not participating in European projects.

Opportunities

- There is a growing need for IT architecture alignment guidelines in decentralized networks.
- There is still a growing need for decentralized IT solutions in health care.
- The EU has created new funds for research on the Internet of services.

Threats

- The field of Information Systems integrates technical as well as organizational research topics and runs the danger of being considered foreign to a technical faculty.

Analysis

- Our set of research themes is stable, relevant and manageable and should remain the same.
- However, fragmentation of our time, both a current weakness and a current and future threat (shared with all groups), may cause us to miss opportunities or even to reduce our performance.

Adjusted goals

- Some goals remain the same, i.e. we will maintain our research themes and continue expanding our research in e-health.
- More than in the past we will search for ways to avoid fragmentation.

Adjusted strategy

- Expand our capacity in business processes and architecture research
- Search opportunities for funding larger projects
- Withdraw from networks that do not contribute to our research goal
- We will define our future research goals in terms of a small set of long-term deliverables

Title of the Research Group:

Pervasive Systems (PS)

Research theme: architectures and protocols for ubiquitous systems

NABS code: N07

Heads of Group: prof. dr. Ed Brinksma (2008); dr. P.J.M. Havinga (2008)

Starting date: 1-1-2008 formal foundation of the group

Formal affiliations outside the department and other formal cooperations: CTIT, NIRICT, ASCI, SIKS, ARC Research Network on Intelligent Sensors, Sensor Networks and Information Processing

1. Mission statement

Research area

The Pervasive Systems (PS) group investigates new distributed systems paradigms for bringing the flexibility of information technology to bear in every aspect of daily life. It foresees that people will be surrounded by embedded and flexibly (wirelessly) networked systems that provide easily accessible yet unobtrusive support for an open-ended range of activities, to enrich daily life and to increase productivity at work.

These networked embedded systems contain a mixture of hardware and software: their scope may be as simple as a sensor, or as complex as a portable device, or even an entire building or city. Cooperation is a necessity, to perform their tasks with sufficient quality or efficiency, and to reach the required functionality and support real time interactions. The specific nature of these systems require them to be open, scalable, adaptable and dependable, while integrating heterogeneous devices ranging from tiny actuators to larger computers.

Mission

In this context our mission is:

to design, develop, implement and evaluate architectures, protocols, and mechanisms that support effective and efficient interactions between devices, people, and the environment.

2. Leadership

In January 2008 the group has been branched out from the research groups CAES (Paul Havinga) and DIES (Hans Scholten). During the period while the group had a vacancy for full professor (the whole of 2008), prof. dr. Ed Brinksma has been acting as part-time interim head.

Pervasive Systems is an internationally recognized research group with a reputation of original and advanced research. PS is in the core of the CTIT SRO Wise (Wireless and sensor systems). It coordinates the NIRICT SRA Ambient Intelligence. It initiated and coordinates the ICT Innovation Platform (IIP) Sensor Networks, and the SmartXP lab, which is now part of the NIRICT 3TU Smart Environment labs.

Operational tasks concerning financial, reporting, project reporting, the coordination of teaching, web page maintenance and PR have been allocated to members of the group. To facilitate interaction between our different projects, the group as a whole meets once a week for a research seminar in which one research staff member gives a presentation, rotating through all permanent and non-permanent research staff.

Pervasive Systems has initiated and coordinated several national and international research projects on wireless sensor networks and ubiquitous computing. The group is very active in giving invited lectures and talks, keynotes, organizing conferences and workshops, and in the organization of summer/spring schools.

The group participates in establishing the new bachelor degree program "Creative Technology" that offers a multidisciplinary education, through integration of design, smart sensor and new media technologies.

Group members are editors of several journals and magazines, serve as program committee chairs and members, and reviewers for many conferences and workshops. Moreover, they regularly serve as independent experts for review and evaluation of international research projects for the EU, the US, and other international research associations.

3. Strategy and policy

3.a. Design in brief

In pervasive systems a vast number of components cooperate to support an application as unobtrusively as possible (transparency), making efficient use of scarce resources independent of growth (scalability), and in such a way that the system adapts to a dynamically changing environment (evolvability). Mainly due to resource constraints, devices and connections are inherently unreliable, yet the system should be able to provide reliable services (dependability). Users, applications and devices will compete for resources such as processing time, memory, communication bandwidth, and sensors/actuators, and will need to be able to negotiate access (competition), and there will be many different types of nodes (heterogeneity). Most of the processing will take place in the network as the number of nodes is too large for centralized control and distributed data processing.

All of this means that the supporting architectures should be open, distributed and scalable, naturally integrating heterogeneous devices ranging from tiny actuators to large computers.

Our mission is to design, develop, implement and evaluate architectures, protocols, and mechanisms that support effective and efficient interactions between devices, people, and the environment.

Currently the research themes are focused on the following topics and their interaction:

- *Wireless embedded networking*, dealing with the networking aspects of pervasive systems, and
- *Distributed data processing and reasoning*, dealing with the processing and interpretation of distributed data.

The interaction between these two themes has led to the development and evaluation of various cross-layer solutions, which has shown to be beneficial and better meeting the requirements of pervasive systems. The common theme in these areas is the development of large-scale, heterogeneous, wireless, and distributed systems. Research covers a wide design space including architectures, protocols, programming paradigms, algorithms, deployment, and applications.

3.b. Future developments

For each of our two research areas we have identified the major challenges that will drive our future development:

Wireless Networked Embedded Systems

In this research area we (i) investigate new distributed mechanisms for medium access, routing, localization, and adaptive sensor sampling, and (ii) evaluated their feasibility through experimentation. These mechanisms operate in a challenging environment of self-organizing, collaborative, networked embedded systems where nodes move or fail, and energy is a scarce resource. The main thrust of the work is therefore towards the development of new distributed algorithms for sensor networks. Focus areas are energy-efficient protocols that take properties of power sources based upon energy harvesting

technologies into account, scalability of sensor networks (industrial applications with >1M nodes), data mule-ing for remote networks. Further, research will be carried out on deployment issues of large scale networked embedded systems e.g. distributed assessments of the deployment, robustness against topology dynamics and node mobility.

Distributed data processing and reasoning

Traditionally, management of data and context has been carried out using a central approach, in which data is initially collected from various sources and stored at a central location. The data is then processed centrally to extract the required information. Due to excessive transmission overhead and since it is also preventing users from accessing real-time streaming data, this model is highly unsuitable for pervasive distributed systems. The only viable alternative is to migrate from off-line processing to processing the data within the network as close to the data source as possible, i.e., in-network data processing. Moreover, since the ultimate goal of pervasive systems is reliable and real-time sensing and actuating, distributed and real-time reasoning and making sense of large volumes of data collected by various devices is essential. To this end, scalability, reliability, support for dynamics and heterogeneity are imposing great challenges. This research area covers topics such as outlier detection, event detection, activity recognition, data aggregation and sensor fusion.

We will develop an open environment to which external parties can easily connect. Examples are the SmartXP lab, which is now part of the NIRICT 3TU Smart Environment labs, the development of an open database containing detailed measurements from our wireless monitoring environment, and an open campus-wide testbed.

4. Processes in research, internal and external collaboration

The general research vision we have is that a multidisciplinary approach is necessary, as many of the identified challenges need to be addressed in an all-inclusive way that considers systems, environment and user in close correspondence. Therefore, in the research of the group, fundamental research activities that address the need for new methods, models, and tools are interwoven with experimental projects. The members share the view that the imminent challenge is to move the field forward from ad hoc prototyping of experimental applications to provision of integrated and sustainable systems, requiring a concerted multidisciplinary effort.

To enable this multidisciplinary research, we collaborate through joint projects with other CTIT research groups in particular with: CAES (Smit), DIES (Hartel), SAS (Slump), DWMP (Hurink), DB (Apers), Control Engineering (Stefano Stramigioli), and BSS (Hermens).

We have excellent lab facilities in which we co-operate with several other groups. All the lab facilities will be integrated in the SmartXP which is currently being set up in the context of the 3TU/NIRICT. Additionally, we have the availability of a wireless sensor network testbed (approx. 200 sensor node network), with concrete plans to move it towards a campus wide area.

Internal collaboration

PS is an international group with which all other groups praise for their lively and stimulating atmosphere. PS PhD candidates are member of the ASCI or SIKS research school, and they participate in their regularly organized symposium and schools. As part of the standard training we send our PhD candidates to relevant international summer schools. We have weekly seminars in which the group members can present their results, share their work, and discuss new research areas.

Staff, postdocs and PhD candidates are encouraged to visit other universities and research labs and attend internship programs. Examples of these visits are ETH Zurich, Melbourne University, the Australian Institute of Marine Science (AIMS), the University of Padova, and the University of Southern California.

Group members are encouraged to initiate master thesis and design project assignments. This is specially beneficial for the PhD candidates to be able to closely work with graduate students and advance their research. Most PhD candidates also play a role in education by lecturing in a course, or by assisting during practical assignments.

All PhD candidates meet their promoter on at least a monthly basis, and their daily supervisor on at least weekly basis. Research results are presented during the weekly seminars. Papers written by PhD candidates are read and discussed with their supervisors. Each PhD candidate is expected to publish at least 5 papers in journals or good conferences to form the basis of the PhD thesis. In their final year of studies, PhD candidates are expected to help with the writing of research proposals on a subject which is in line with their work. This enables them to get some experience in this highly important aspect of their potential future academic carrier. These proposals can guide research directions and stimulate that their research results will be used and continued in future, and it helps the group in getting new funding.

On the PS website we have a Blog in which all activities of the PS group are shown. These include the formal activities such as PhD defenses, reports from project meetings and conferences, but also our outings during the year.

External collaboration

The group is leading the NIRICT SRA Ambient Intelligence, the SmartXP lab, and the national ICT Innovation Platform (IIP) Sensor Networks. It plays a key role in the CTIT SRO Wise and its joint PhD programs. The group collaborates with Sensor Universe, a group of companies in the Netherlands, all working on sensor technologies.

The research group participates in the national research schools ASCI and SIKS. Internationally, the group works closely together with other European research institutes and beyond. Examples include ETH Zurich, Melbourne University, the Australian Institute of Marine Science (AIMS), the University of Padova, and the University of Southern California. With all these groups we have internship programs.

On the national scale, Pervasive Systems group has initiated and lead BSIK Smart Surroundings (2004-2009) on ambient intelligence, NWO Consensus (2003-2007) on fundamental aspects of distributed collaborative algorithms and data management, NWO @Home Anywhere (2002-2006) on service discovery in home environment, STW Featherlight (2004-2008) on very lightweight distributed system support for small devices, the PointOne project Harsh (2007-2008) on wireless communication in harsh environments, and the Pieken in de Delta project Wireless Food Sensor System (2007-2008).

On the European scale, the group has participated in TEAHA (2004-2007), a STREP project in the FP6 framework on home networking, in COBIS (2004-2006), a STREP project in the FP6 framework on Collaborative Business Items, in Embedded WiSeNts (2004-2006), a Coordinated Action project in the FP6 framework on Cooperating Embedded Systems for Exploration and Control featuring Wireless Sensor Networks, in e-SENSE (2006-2008), an IP project in the FP6 framework on capturing ambient intelligence for beyond 3G mobile communication systems through wireless sensor networks, in AWARE (2006-2009), an STREP project in the FP6 framework on providing the middleware and the functionalities required for the cooperation among aerial flying objects, i.e. autonomous helicopters, and a ground sensor-actuator wireless network, and in SENSEI (2008-2011), an IP project in the FP7 framework on integrating the physical with the digital world of the network of the future.

The group is actively participating in the Australian ARC Research Network on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP).

5. Academic reputation

The PS group is nationally and internationally leading the development of wireless sensor networks, and distributed data processing and interaction for ubiquitous computing.

Awards:

- Maria Lijding, STW valorization grant phase 2, 2008
- Maria Lijding, Nirvana Meratnia, STW valorization grant phase 1, 2007
- Paul Havinga, ICT Regie Innovation Award 2007
- Paul Havinga, Van den Kroonenbergprijs 2007

Dr. ing. P.J.M. Havinga

Management

- Coordinator ICT Innovation Platform Sensor Networks, IIPSN (2007 – present)
- Scientific leader NIRICT SRA Ambient Intelligence (2006 – present)
- Project manager national projects Bsik project Smart Surroundings (2004 – 2009), STW/PROGRESS project Featherlight (2004 - 2008), NWO project Consensus (2002 – 2008)
- EU project EYES, (2002 – 2005),
- CEO, CTO and co-founder Ambient Systems B.V. (2004 – present)

Steering committees and advisory board

- Program committee member STW program Autonomous Sensor Systems ASSYS (2008)
- Technical Steering Group EU project Sensei (2008-2010)
- Advisory board of the EU project Cruise (2006 –2008)
- Steering Committee EU project e-Sense (2006-2008)
- Steering Committee European Conference on Smart Sensing and Context, EuroSSC (2006 – present)
- Member of the NWO Beoordelingscommissie Informatica (BCI) (2005 –present)
- NOAG-ICT coordinator theme “De onzichtbare computer”, (2005)
- Advisory board Freeband Communications project AWARENESS (2005 – 2008)
- Steering Committee IEEE DEST International Workshops on Signal Processing for Sensor Networks (2004 – present)
- Steering Committee International Workshops on Networked Sensing Systems, INSS (2004 – present)
- NSF advisory board “Wireless Sensor Networks for environmental monitoring” (2003).

Evaluator and reviewer

- **Editor of journals:** Associate Editor of the Journal “Ad hoc networks” (Elsevier) (since 2004), Associate Editor of the “Journal of Mobile Multimedia” (Rinton Press) (since 2004), Guest Editor of a special issue of IEEE Wireless Communications on sensor networks (December 2004).
- **Evaluator and reviewer** of many projects within the EU 5th, 6th and 7th Framework, ITEA, Medea+, NWO (since 2000), Evaluator of many projects for the Belgium, Italian, Norwegian, Israeli, Austrian, Australian, and Qatar research councils.
- **Program committee chairs:** ICWSN 2005, International congress for Wireless Sensors & Networks 2005, Intelligent Sensors, Sensor Networks and Information Processing, 10th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2005), EWSN 2005, 2nd European Workshop on Wireless Sensor Networks, INSS 2005, Second International Workshop on Networked Sensing Systems, DEST International Workshop on Signal Processing for Sensor Networks 2004, European Conference on Smart Sensing and Context (EuroSSC)

Ir. J. Scholten

- Management
- Project manager national NWO project @Home Anywhere, (2002 – 2006)

- CEO and co-founder Rollermate (2007 -)
- Steering committees and advisory board
- Steering Committee EU project TEAHA (2004-2007)
- Steering Committee international conferences IDMS and PROMS (2000 – 2005)
- Evaluator and reviewer
- Editor of journals: Editorial board of the International Journal on Advances in Networks and Services (IARIA) (2009 -)
- Evaluator and reviewer of projects for the Belgium research council (IWT).
- Program committee chairs: Organizer and program chair IDMS 2000, program chair student program ICNP 2004.

Dr. ir. N. Meratnia

Management

- Technical co-manager BSIK Smart Surroundings (2004-2009)
- Workpackage leader for FP6 framework projects, e-SENSE (2006-2008), CoBIs (2005-2006), Embedded WiSeNts (2005-2006)
- Evaluator and reviewer
- **Regular reviewer** of Journal of Data and Knowledge Engineering (DKE)
- **Program committee chairs** of European Conference on Smart Sensing and Context (2006), CompGeo (2008,2009), EMSN(2008)

6. Internal evaluation

The group is managed by the senior staff with frequent informal consultation of other staff. We have a weekly management meeting with the staff in which we have informal evaluation and continuous discussion of research topics. The group has a weekly seminar, in which all research staff members have the opportunity to present and discuss their research ideas and progress. The web site is up to date, with all research and educational aspects, and contains a blog of the activities of the group. We make sure to submit to high-profile conferences and journals. New ideas are encouraged to be shaped as proposals in competitive funding schemes (STW, NWO, Vidi/vici, EU).

Every month the Head of Group has an individual meeting with the staff members, technicians, postdocs and PhD candidates, to discuss their role in research and education. Each year, the Head of Group has a formal appraisal meeting with each member of staff, postdoc, and PhD. Supervisors are normally present at the appraisal meetings with the PhD candidates and postdocs. The progress of PhD candidates is monitored, and in case of expected or observed slow progress carefully documented.

7. External validation

7.a. Societal relevance

The shift from personal computing to pervasive systems is a motor for innovation expected to transform ICT business over the next 10 years. The strong increasing penetration of networked embedded systems in products and services creates huge opportunities for all kinds of enterprises and institutions. At the same time the fast pace of penetration poses an immense threat for most of them. It concerns enterprises and institutions in such diverse areas as agriculture, environment, health care, energy conservation, road construction, security, medical appliances, etc. They all need to respond timely in mastering the following technological and market challenges:

- Wide diversity and increasing complexity of applications and needs
- Increasing number of non-functional constraints
- Increasing degree of integration and networking
- Increasingly multi-disciplinary nature of products and services
- Growing importance of flexibility and software
- Shrinking time-to-market

Our research produces results on mastering the complexity of pervasive systems and exploring various settings and application domains in which they can play a role. We closely cooperate with institutes and industry at large as to keep the direction and the results of our efforts relevant.

The principal aim is to provide the long-term research needed to understand the core structure and behavior of the future pervasive systems that will be required to realize the application potential, and to make this understanding manifest in readily applicable hard- and software frameworks and sound conceptual foundations.

7.b. Industrial contacts

The group has been successful in joint research projects. This has resulted in much collaboration with external industrial and academic parties. Pervasive Systems group of the University of Twente has successfully transferred its knowledge and innovative results to its established spin-offs.

- **Ambient Systems B.V.** (ambient-systems.net) is a spin-off from (former) CAES/PS-members founded in 2004. After successful completion of the EYES project, Ambient Systems B.V. continued to commercially exploit wireless sensor network knowledge and created various innovative products. It has grown in its short existence to a 25 people company and it has won many innovation awards. It recently received additional funds from professional investment funds. The company closely collaborates with the University of Twente in many research projects. Its prime focus areas are logistics and transport and asset management.
- **Smart Signs Solutions B.V.** (www.smartsigns.nl), established in November 2008, is developing an electronic signposting system, providing personalized guidance and messaging called Smart Signs. Smart Signs combine the advantages of traditional signage, which subsumes traditional directional signs and messages, with the re-activeness and flexibility of personal services, such as navigational support, and SMS. The Smart Signs system uses contexts such as a user's mobility limitations, the weather, and possible emergency situations like fire or medical needs to optimize routes and messaging.
- **Inertia Technology B.V.** (www.inertia-technology.com), established in December 2008, develops a new set of user centric services based on the analysis of human motion and the interaction among users and their surroundings. The core technology is based on low power wireless sensor nodes, equipped with inertial measurement units. The sensor nodes are attached to people and objects for measuring their movement characteristics. The Inertia system is a collection of sensor nodes that represents a self-organizing wireless mesh network. Using the wireless medium as the main communication channel, the system processes data in real-time and gives feedback on which is the current activity and performance of the user.

We have active collaboration with several national and international companies working in the domain of Pervasive Systems. The following companies and organizations are participating in our current research projects on a local scale (Twente), and on a national and international scale.

- Local: Ambient Systems, Livio, Roessingh R&D, TI-WMC, Telematica Instituut, Inertia Technology, Smart Signs Solutions, Thales, Demcon, Indes
- National: Chess, Philips Research, NXP, Logica CMG, Nedap, Oce, Thales, TNO, Holst Centre, GreenPeak, Sensor Universe, Sun Microsystems, HP, ESI, e.novation, Microflown, Centric
- International: BP, Bell Labs, Nokia Research, Telefonica, Trialog, Philips Medical Systems, Thales, Alcatel Lucent, IBM, Shell, SAP, Infineon Technologies, Selex, Flying-Cam, Iturri, CEA-LETI, NEC, Ericsson, Teco

8. Researchers and other personnel ("wp")

Table 1

Category	Name	2003	2004	2005	2006	2007	2008
Tenured staff							
professor (hgl)	Brinksma, prof. dr. H						0,00
associate professor (uhd)	Havinga, dr. P.J.M.						0,40
assistant professor (ud)	Scholten, ir. J.						0,40
Total tenured staff		0,00	0,00	0,00	0,00	0,00	0,80
Non-tenured staff							
professor (hgl)	Mullender, prof. dr. S.J.						0,11
postdoctoral fellows	Dulman, dr. S.O.						0,50
	Hoesel, dr. ir. L.F.W. van						0,50
	Lijding, dr. M.E.M.						1,00
	Meratnia, dr. N.						1,00
other junior staff (moz, twaio)	Chatterjea, S.						0,80
	Marin Perianu, M.						0,10
	Marin Perianu, R.S.						0,10
Total non-tenured staff		0,00	0,00	0,00	0,00	0,00	4,12
PhD Candidates							
junior staff (aio, oio, moz-p)	Bahrepour, M.						0,17
	Bosch, ir. S.						0,43
	Durmaz, O.						0,80
	Erman-Tüysüz, A.						0,80
	Evers, ir. L.						0,80
	Kavitha Muthukrishnan, ir. K.						0,80
	Marin Perianu, M.						0,66
	Marin Perianu, R.S.						0,66
	Zhang, ir. Y.						0,80
Total PhD Candidates		0,00	0,00	0,00	0,00	0,00	5,92
Total Research Staff PS		0,00	0,00	0,00	0,00	0,00	10,84

9. Resources, funding and facilities

9.a. Laboratory infrastructure

We have excellent lab facilities, such as the wireless sensor network testbed, for performing PS research. All these lab facilities will be integrated in the SmartXP which is currently being set up in the context of the 3TU/NIRICT. Additionally, we have the availability of a wireless sensor network testbed (approx. 200 sensor node network), with concrete plans to move it towards a campus wide area.

9.b. FTE-funding

As the group only came into existence in the beginning of 2008, no trends can yet be identified. Clearly, the group benefits from a very high percentage of contractual funding, in line with the strong industry contacts listed above. Furthermore, though the research funds percentage is low, note that Table 4 below lists three STW projects (whose volume however, was relatively low in the assessed period). In the future we intend to emphasize the group's strength in acquiring contractual funding, but complement it with national research funds.

Table 2: Funding at group level

PS	2003	2004	2005	2006	2007	2008
Direct funding						46%
Research funds						1%
Contracts						53%
Total						100%

9.c. FTE-funding PhDs/postdocs

The funding situation with respect to the PhDs and postdocs (Table 3) is comparable to that of the funding at group level (Table 2), except that the balance is even more extreme in favor of contractual (3rd money flow) funding.

Table 3: Funding of PhDs/postdocs

PS	2003	2004	2005	2006	2007	2008	Average
Direct funding					0%	0%	0%
Research funds					11%	6%	9%
Contracts					89%	94%	91%
Other					0%	0%	0%
Total					100%	100%	100%

9.d. List of external funds

The table of external funds, in which especially European projects are prominently represented, clearly reflects the huge international interest in the research themes of the PS group.

Table 4

Name project	Start	End	Sponsor
E-sense: Capturing Ambient Intelligence for Mobile Communications through Wireless Sensor Networks	Jan-06	Jan-08	European Commission
SENSEI: Integrating The Physical With The Digital World Of The Network Of The Future	Jan-08	Jan-11	European Commission
AWARE: Platform for Autonomous self-deploying and operation of Wireless sensor-actuator networks cooperating with aerial objects	Jun-06	Jun-09	European Commission
Smart Surroundings	Jan-04	Nov-08	SENTER BSIK
Featherlight Distributed Systems: A platform for the next generation of ambient systems	Sep-04	Jun-09	STW
My Way	Aug-07	Aug-08	STW Valorization 1
Smart Sign Solution	Sep-08	Sep-10	STW Valorization 2

10. Overview of the results

10.a. Key publications

Table 5

Nr	Title
1	Chatterjea, S., Nieberg, T., Meratnia, N., Havinga, P.J.M., <i>A Distributed and Self-Organizing Scheduling Algorithm for Energy-Efficient Data Aggregation in Wireless Sensor Networks</i> (2008). In: ACM Transactions on Sensor Networks 4(4). pp. 1-41. ACM, New York. ISSN:1550-4859.

Nr	Title
2	Erman-Tüysüz, A., Hoesel, L.F.W. van, Havinga, P.J.M., Wu, Jian, <i>Enabling Mobility in Heterogeneous Wireless Sensor Networks Cooperating with UAVs for Mission-Critical Management</i> (2008). In: IEEE Wireless Communications 15(6). pp. 38-46. IEEE Communication Society. ISSN:1536-1284.
3	Marin-Perianu, R.S., Scholten, J., Havinga, P.J.M., Hartel, P.H., <i>Cluster-based service discovery for heterogeneous wireless sensor networks</i> (2008). In: International Journal of Parallel, Emergent and Distributed Systems 23(4). pp. 325-346. Taylor & Francis, UK. ISSN:1744-5760.
4	Durmaz Incel, O., Krishnamachari, B., <i>Enhancing the Data Collection Rate of Tree-Based Aggregation in Wireless Sensor Networks</i> (2008). In: 5th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks, 2008. SECON '08., San Francisco, USA, 16-20 June 2008. pp. 569-577. IEEE Computer Society Press, Los Alamitos. ISBN:978-1-4244-1777-3.
5	Marin-Perianu, M. and Lombriser, C. and Amft, O. and Havinga, P.J.M. and Troster, G. (2008) <i>Distributed Activity Recognition with Fuzzy-Enabled Wireless Sensor Networks</i> . In: Distributed Computing in Sensor Systems, 11-14 Jun 2008, Santorini, Greece. pp. 296-313. Springer Verlag. ISBN 978-3-540-69169-3 Dulman, S.O. and Rossi, M. and Havinga, P.J.M. and Zorzi, M. (2006) On the hop count statistics for randomly deployed wireless sensor networks. International Journal of Sensor Networks, 1 (1/2). pp. 89-102. ISSN 1748-1287

10.b. Numerical overview of the results in a fixed format of categories

It should be noted that, as a consequence of the rule prescribing the assignment of PhD theses to the first supervisor, the table below does not list any PhD theses for the PS group. However, the following theses were the result of projects of which the head of the PS group, Paul Havinga, was the principal investigator.

Chatterjea, S. *Distributed and Self-Organizing Data Management Strategies for Wireless Sensor Networks. A Cross-Layered Approach*. nr: CTIT Ph.D.-thesis Series No. 08-127, (2008, September 26). 194 pp. Zutphen Woormann Print Service Thesis advisor(s): dr.ir. G.J.M. Smit, dr. P.J.M. Havinga. ISBN: 978-9-03652-721-7

Marin Perianu, R.S. *Wireless Sensor Networks in Motion - Clustering Algorithms for Service Discovery and Provisioning*, (2008, November 6). 202 pp. Thesis advisor(s): prof. dr. P.H. Hartel. ISBN: 978-90-365-2745-3

Marin-Perianu, M. Collaborative *Wireless Sensor Networks in Industrial and Business Processes*. (2008, November 6). 198 pp. Thesis advisor(s): dr.ir. G.J.M. Smit, dr. P.J.M. Havinga. ISBN: 978-90-365-2746-0

Table 6

Category		2003	2004	2005	2006	2007	2008
Academic publications	a. Refereed journals						3
	b. International conferences						17
	c. Book chapters						
	d. Other academic publications						
Total							20
Monographs							
PhD-theses							
Professional publications							
Patents							
Software							

10.c. Full outcome list

2008

Journal articles

- Chatterjea, S., Nieberg, T., Meratnia, N., Havinga, P.J.M., *A Distributed and Self-Organizing Scheduling Algorithm for Energy-Efficient Data Aggregation in Wireless Sensor Networks* (2008). In: ACM Transactions on Sensor Networks 4(4). pp. 1-41. ACM, New York. ISSN:1550-4859.
- Erman-Tüysüz, A., Hoesel, L.F.W. van, Havinga, P.J.M., Wu, Jian, *Enabling Mobility in Heterogeneous Wireless Sensor Networks Cooperating with UAVs for Mission-Critical Management* (2008). In: IEEE Wireless Communications 15(6). pp. 38-46. IEEE Communication Society. ISSN:1536-1284.
- Marin-Perianu, R.S., Scholten, J., Havinga, P.J.M., Hartel, P.H., *Cluster-based service discovery for heterogeneous wireless sensor networks* (2008). In: International Journal of Parallel, Emergent and Distributed Systems 23(4). pp. 325-346. Taylor & Francis, UK. ISSN:1744-5760.

Conference proceedings

- Brandenburg, R. van, Horst, A., Burgers, B., Meratnia, N., *Game Development Framework Based Upon Sensors and Actuators* (2008). In: On the Move to Meaningful Internet Systems: OTM 2008 Workshops, Monterrey, Mexico, 9-14 Nov 2008. pp. 861-872. Lecture Notes in Computer Science 5333. Springer Verlag, Berlin. ISBN:978-3-540-88874-1.
- Chatterjea, S., Havinga, P.J.M., *An Adaptive and Autonomous Sensor Sampling Frequency Control Scheme for Energy-Efficient Data Acquisition in Wireless Sensor Networks* (2008). In: 4th IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS), Santorini, Greece, 11-14 Jun 2008. pp. 60-78. Lecture Notes in Computer Science 5067. Springer Verlag, Berlin. ISBN:978-3-540-69169-3.
- Chatterjea, S., Havinga, P.J.M., *Algorithms for energy efficient data extraction from wireless sensor networks for environmental monitoring applications* (2008). In: Proceedings of International Workshop Sensing a Changing World 2008, Wageningen, The Netherlands, 19-21 Nov 2008. pp. 15-18. CGI report CGI-08-005. Wageningen University and Research Centre, Wageningen. ISSN:1568-1874.
- Dulman, S.O., Baggio, A., Havinga, P.J.M., Langendoen, K.G., *A geometrical perspective on localization* (2008). In: Proceedings of the first ACM International Workshop on Mobile Entity Localization and Tracking in GPS-less Environments, San Francisco, California, USA, 19 Sep 2008. pp. 85-90. ACM, New York. ISBN:978-1-60558-189-7.
- Durmaz Incel, O., Jansen, P.G., *Characterization of multi-channel interference* (2008). In: 6th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks and Workshops, 2008. WiOPT 2008., Berlin, Germany, 1-3 April 2008. pp. 429-435. IEEE Computer Society Press, Los Alamitos. ISBN:978-963-9799-18-9.
- Durmaz Incel, O., Krishnamachari, B., *Enhancing the Data Collection Rate of Tree-Based Aggregation in Wireless Sensor Networks* (2008). In: 5th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks, 2008. SECON '08., San Francisco, USA, 16-20 June 2008. pp. 569-577. IEEE Computer Society Press, Los Alamitos. ISBN:978-1-4244-1777-3.
- Evers, L., Lijding, M.E.M., Kuper, J., *Generic Multi-Packet Communication through Object Serialization* (2008). In: Proceedings of the 3rd international workshop on Middleware for sensor networks, Leuven, Belgium, 1-5 december 2008. pp. 25-30. ACM, New York. ISBN:978-1-60558-366-2.
- Fischer, C., Muthukrishnan, K., Hazas, M., Gellersen, H., *Ultrasound-Aided Pedestrian Dead Reckoning for Indoor Navigation* (2008). In: Proceedings of the first ACM international workshop on Mobile entity localization and tracking in GPS-less environments, Co-located MOBICOM 2008, San Francisco, USA, 15-19 September 2008. pp. 31-36. ACM, New York. ISBN:978-1-60558-189-7.

- Hoesel, L.F.W. van, Erman-Tüysüz, A., Havinga, P.J.M., *Ideas on Node Mobility Support in Schedule-based Medium Access* (2008). In: Fourth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP-2008), Sydney, 15-18 Dec 2008. pp. 593-544. IEEE Computer Society, Los Alamitos. ISBN:978-1-4244-3822-8.
- Horsman, M., Marin-Perianu, M., Jansen, P.G., Havinga, P.J.M., *A Simulation Framework for Evaluating Complete Reprogramming Solutions in Wireless Sensor Networks* (2008). In: 3rd International Symposium on Wireless Pervasive Computing, Greece, 7-9 May 2008. pp. 6-10. IEEE Computer Society Press. ISBN:978-1-4244-1653-0.
- Marin-Perianu, M., Chatterjea, S., Marin-Perianu, R.S., Bosch, S., Dulman, S.O., Kininmonth, S., Havinga, P.J.M., *Wave Monitoring with Wireless Sensor Networks* (2008). In: The 2008 International Conference on Intelligent Sensors, Sensor Networks and Information Processing, Sydney, Australia, 15-18 Dec 2008. pp. 611-616. IEEE Computer Society Press, Los Alamitos. ISBN:978-1-4244-2957-8.
- Marin-Perianu, M., Lombriser, C., Amft, O., Havinga, P.J.M., Troster, G., *Distributed Activity Recognition with Fuzzy-Enabled Wireless Sensor Networks* (2008). In: Distributed Computing in Sensor Systems, Santorini, Greece, 11-14 Jun 2008. pp. 296-313. Springer Verlag. ISBN:978-3-540-69169-3.
- Marin-Perianu, R.S., Hurink, J.L., Hartel, P.H., *A Generalized Clustering Algorithm for Dynamic Wireless Sensor Networks* (2008). In: Proceedings of the International Symposium on Parallel and Distributed Processing with Applications (ISPA-08), Sydney, Australia, 10-12 Dec 2008. pp. 863-870. IEEE Computer Society Press, Los Alamitos. ISBN:978-0-7695-3471-8.
- Marin-Perianu, R.S., Lombriser, C., Havinga, P.J.M., Scholten, J., Tröster, G., *Tandem: A Context-Aware Method for Spontaneous Clustering of Dynamic Wireless Sensor Nodes* (2008). In: Proceedings of the First International Conference on Internet of Things (IOT2008), Zürich, Switzerland, March 2008. pp. 341-359. Lecture Notes in Computer Science 4952. Springer Verlag, London. ISBN:978-3-540-78730-3.
- Scholten, J., Dijk, H.W. van, *Home Network Security* (2008). In: ICN2008, The Seventh International Conference on Networking, Cancun, Mexico, 13-18 Apr 2008. pp. 249-255. IEEE Computer Society Press, Los Alamitos. ISBN:978-0-7695-3106-9.
- Zhang, Yang, Meratnia, N., Havinga, P.J.M., *An Online Outlier Detection Technique for Wireless Sensor Networks* (2008). In: Third IEEE European Conference on Smart Sensing and Context, EuroSSC 2008, Zurich, Switzerland, 29-31 October 2008. pp. 25-26. ETH Zurich, ETH Zurich. ISBN:978-3-909386-76-5.
- Zhang, Yang, Meratnia, N., Havinga, P.J.M., *An Online Outlier Detection Technique for Wireless Sensor Networks using Unsupervised Quarter-Sphere Support Vector Machine* (2008). In: Fourth International Conference on Intelligent Sensors, Sensor Networks and Information Processing, ISSNIP 2008, Sydney, Australia, 15-18 Dec 2008. pp. 151-156. IEEE Computer Society, Sydney, Australia. ISBN:978-1-4244-2957-8.

11. SWOT-analysis

Strengths

- Leading role in setting up national research agenda on pervasive computing
- Strong relation between education and research, active cooperation with CTIT research groups and other research institutes
- Excellent knowledge transfer to industry & highly successful in creating spin-off companies
- Very successful in project acquisition

Weaknesses

- Given the fact that the group has just formally established and did not have a permanent full time professor, some time is needed to stabilize
- Low number of Master students during the start-up phase of PS in 2008

Opportunities

- There are ample opportunities for funding of research in Pervasive Systems: e.g. nationally STW, NWO, Point-One, and internationally EU-FP7 and Artemis. The research theme of the group is one of the focus areas of the CTIT and EU-FP-7
- Active participation in the founding of the new educational program Creative Technology that will start in September 2009 gives opportunities for new research ideas, collaborations, and attracting students

Threats

- Slight overlapping between research areas within other research groups of the faculty
- Research might become (short term) commercially driven, due to increased number of spin-offs.
- Re-organization of educational program by moving Embedded Systems courses out of the focus can have negative implications on visibility and research

Analysis

- We need more master students, and have them involved in the research activities
- It has been shown that our research does benefit from multidisciplinary work, and have fundamental research activities that address the need for new methods, models, and tools interwoven with experimental projects

Adjusted goals

- Establishing a leading role in European research in the area of pervasive computing
- Making the group more visible and attractive to students by introducing Pervasive Systems and its research areas more clearly in the faculty and in courses,
- Make efficient use of SmartXP, and establish the testbed facilities, and the integration in the NIRICT Smart Environment labs. Facilitate and encourage other groups to share this infrastructure, and to share and showcase their results

Adjusted strategy

- Emphasize the effectiveness of the interaction among the two major research areas of the group, namely, Wireless embedded networking and Distributed data processing and reasoning
- Create an attractive environment for students to study, and perform research in for their projects
- Putting more emphasis on organizing major events, such as international conferences and summer schools

Title of the Research Group:

Software Engineering (SE)

Research themes themes: none

NABS code: N07

Head of Group: prof. dr. ir. M. Aksit

Starting date: none

Formal affiliations outside the department and other formal co-operations: IPA research school, CTIT

1. Mission statement

SE focuses on *Quality-Oriented Software Engineering*. The group addresses the problems that affect the main stakeholders of software systems by developing and applying techniques that increase the quality of software models and products. Quality factors addressed by the group are, amongst others, compositionality, correctness, dependability, evolvability, traceability, open-endedness and flexibility. The application areas addressed by the group include embedded systems and highly distributed (large-scale) systems. Our mission is:

To model, implement and optimize software engineering processes for specifying, designing, implementing, verifying and optimizing software artifacts at various abstraction levels for the purpose of fulfilling the stakeholders' requirements of software systems.

2. Leadership

The group is managed by the scientific staff. From 2003 to 2008, the following staff members have been involved in the management of the group: Aksit, Van den Berg, Van den Broek, Ferreira Pires (since 10-2007), Bergmans (until 9-2008), Rensink (until 7-2005) and Tekinerdogan (until 9-2008). The scientific staff meets regularly (normally one a week) to discuss the daily management issues. Aksit acts as the Head of Group. Some administrative tasks, such as, for example, organizing regular talks and keeping track of the equipment inventory, are shared among the group members (also PhD candidates).

Some staff members have followed management courses in the last years in order to improve their management skills and leadership. The staff members interact extensively by participating in common projects, jointly supervising PhD candidates and through informal channels. Since Aksit is involved in all research activities, he functions as the coordinator of these activities in order to foster synergy and mutual fertilization.

Coherence and exchange of information in the group are also enforced by having weekly presentations from group members (staff members, PhD candidates and Master students) followed by detailed technical discussions.

The group aims at internal research cooperation through the CTIT research institute, and external research cooperation through European and Dutch national projects with strong industrial emphasis. Since 2004, the group has been successful in acquiring national and international projects. This has resulted in increased research capacity, and high-quality conference and journal publications.

Due to intensive cooperation with software industry and successful technology transfer projects, the group has increased the industrial relevancy of its research and built-up experience in empirical software engineering. With its industrial courses and projects, the group is now among the key players of the software engineering groups in the Netherlands.

3. Strategy and policy

3.a. Design in brief

The Software Engineering group has effectively started with the appointment of Aksit as Head of Group in 11-2000. Aksit has built up the SE group from scratch, since the chair was vacant

for more than 10 years. Initially, the group had few externally financed projects, but the group has invested a substantial amount of time in the acquisition of new projects and has been successful in this endeavor, as it can be seen in Section 9c. Consequently the number of PhD candidates has grown considerably from 2 in 2001 up to 15 in the beginning of 2008. This growth has provided sufficient financial support and research capacity to sustain the research activities. All these projects are integrated within the context of the CTIT research institute.

The SE group has structured its research activities in complementary and partially overlapping research areas, identified by considering abstraction levels (from programming to architectures), application domains (from embedded to distributed systems), and relevant quality factors and supporting techniques. These areas have also been identified taking into consideration the expertise and interest of the scientific staff, and have allowed the group to acquire national and international projects. These research areas are:

Programming Languages (Bergmans (until 9-2008)):

In this area we define and implement expressive and intuitive programming language constructs so that adaptability and evolvability of software systems are enhanced, and complexity of software systems are reduced, while enabling reasoning about its correctness. For example, aspects improve the modularity of crosscutting concerns. In the reporting period, the topic has been supported by the projects AOSD-NoE, IDEALS and OCTOPUS. The keywords of this topic are: components, aspects, composition, and robustness.

Since beginning of the 90's, the group has been a pioneer in aspect-oriented language concepts through the programming languages Sina and Composition Filters. During the last years, the group has extended this work, among others to reduce potential conflicts among aspects, support reasoning about (undesired) behavior of composed aspects, and provide an infrastructure for the convenient creation of new software composition mechanisms.

Architecture design (Van den Berg and Tekinerdogan (until 9-2008))

In this area we define effective and intuitive problem analysis, solution synthesis and restructuring processes for transferring stakeholders' requirements into software architectures, so that the desired quality factors can be effectively fulfilled, and we define expressive, scalable and reusable model transformation techniques to cope with (non-structure preserving) evolutions, to enable traceability and to enhance portability of software architectures and model-driven development. In the reporting period the area has been supported by the projects AOSD-NoE, AOSAD, TRADER, DARWIN, and QUADREAD. The keywords of this research activity are: software architecture design, model-driven engineering, aspect-oriented architecture, traceability, and evolvability.

Our research contributions in software architecture have been the introduction of new architectural styles and a set of tools for designing fault-tolerant systems, and the development of methods for separation and composition of crosscutting concerns in software architecture. In model-driven engineering, we have developed a way to structure the Meta Object Facility (MOF) meta-modeling architecture based on a simple and uniform representation of all model elements no matter at which level they are defined, and have presented a transformation language based on this framework which is independent of the instantiation and generalization mechanism specific for a given model. Furthermore, we have proposed formal semantics for relationships between requirements in a requirements meta-model, enabling reasoning over requirements models and change impact analysis.

Service architectures (Ferreira Pires (since 10-2007))

In this area we design, deploy and compose service-oriented architectures by using techniques like model-driven development and ontologies, improving the effectiveness of the service design and the flexibility and correctness of the resulting services. In the reporting period, the topic has been supported by the projects AWARENESS, A-MUSE, AMIGO and

SPICE. The keywords of this topic are: service composition, and service-oriented model-driven engineering.

This work builds upon the work on architectures and services started in the Architecture and Services of Network Applications (ASNA) group. In this work the main results have been a foundation ontology, a model-driven methodology for the development of context-aware service-oriented applications, a service-oriented context-aware framework and a service composition platform and algorithm (contributed to the SPICE project).

Verification and optimization ((Rensink (until 7-2005) and Van den Broek)

In this area we define expressive and scalable (software engineering) models for the verification of the software qualities correctness of service and software composition, run-time verification, reliability & fault tolerance and quality trade-off techniques, and we define expressive models for processes and products at different levels of abstractions and to specify effective and scalable optimization algorithms with respect to the quality constraints in the presence of imperfect information (uncertainty and impreciseness). In the reporting period the topic has been supported by the projects GROOVE, GRASLAND, AOSD-NoE, DARWIN and AMPLE. The keywords of this topic are: correctness in software design, graph transformation, software model checking, model transformation, dependability of software, evolvability of software architectures, traceability of software product line architectures, quality-trade off techniques and application of soft-computing techniques to software engineering.

3.b. Future development

Below, we elaborate on the future program development from the short and long term perspectives.

Short-term perspective

The research activities that are carried out in cooperation with the Embedded Systems Institute (ESI) are classified under the CTIT SRO UBRICKS program. These projects address problems that are specific to embedded system design (Software for TV, MRI Scanners, Lithography scanners and Copying machines).

Research activities are also being carried out in cooperation with the IS group and the IS&CM group of the School of Management and Governance in the scope of the SRO ASSIST in the area of Service Science. In the scope of this activity, a postdoc will be funded and allocated to this group. The remaining research activities of the group are more general in nature and are also classified under SRO ASSIST. Since the group has reached its full research capacity with the necessary number of PhD candidates and postdocs, the research output of the group is approaching its optimal level. The group has been successful in recruiting new projects, so that we expect that this level of research output will be sustained in the future.

In 2008 Tekinerdogan left the group and Bergmans got a part-time assignment of 0.2 fte. To compensate the reduced capacity, in 2009, the group has been extended with the staff members Christoph Bockish (Programming languages) and Hasan Sozer (Architecture design and Verification and optimization).

Long-term perspective

Most ongoing research activities are focusing on certain quality factors at various abstraction levels. Examples are recoverable architectures, robust composition of software modules and services, verification of concurrent software modules at design time and run-time, the correctness of evolvable architecture and software modules, optimal design of architecture with respect to system constraints, and optimization of trade-off conditions. In addition, appropriate methods are developed to utilize these quality measurement enhancement techniques. Along these accomplishments, we observe the following general trends:

- Domain specific models are developed to address specific functional problems.

- Each research activity on a certain quality factor results in a dedicated requirement specification language, a model for measuring the quality factors based on a certain design artifact (i.e. service, architecture, or software), and a value system to express and compare the measurements.
- Dedicated algorithms and tools are developed to support the requirement specification and measurement activities, possibly using relevant open source tools.
- Workbenches, and design and programming environments are built to support the method developed for supporting a certain quality model.
- Code generation techniques are developed to map abstract models to executable programs, if appropriate.

Based on these trends, in the coming years we will increasingly emphasize the following aspects:

- *Combination of multiple techniques for the same quality factor*
Due to complexity of software systems, it is generally not possible to utilize a single method and technique to determine a quality factor with precision. Therefore we will continue to adopt combinations of methods and techniques. Examples are static analysis, model checking and runtime verification techniques for verifying the correctness of models, time performance analysis of software systems at both architecture and software levels using a combination of scenario-based heuristic, analytical, and simulation based techniques, etc.
- *Integration of methods and techniques to reason about multiple quality factors*
In realistic situations, multiple quality requirements must be satisfied at the same time. This requires methods and techniques that can support multiple quality factors. In addition, if necessary, support for trade-off decisions in the design process must be provided. This requires mapping the value systems of multiple quality factors to a common value system, and the definition of new trade-off techniques such as optimization techniques.
- *Integration of different software engineering techniques*
There is a trend of integrating various historically separated research areas so that the best of these research areas can be combined. We will investigate the following possibilities: (a) to integrate techniques from service architectures, model-driven engineering, software architecture and programming languages; (b) to utilize software engineering techniques such as architectural styles, design patterns, components and domain specific languages together with the techniques developed in specialized areas such as dependable computing; (c) to utilize feedback control techniques to increase the adaptability of software systems, by changing the structure of software utilizing dynamic learning techniques if needed; (d) to combine techniques from areas such as fuzzy logic and probability theory (for dealing with uncertainty), and operational research (for trade-off analysis and optimization), with the software engineering modeling techniques.
- *Integration of models defined at different abstraction levels*
The group develops models at different abstract levels, such as requirements specifications, services, software architecture and software. Since a typical software design process involves multiple of such models, it is important to develop methods and tools to smoothly refine abstract models towards the more concrete ones (and vice-versa in reengineering processes). Along this line, we will emphasize design traceability within and across different abstraction levels, and software composition techniques that allow models to be integrated.

4. Processes in research, internal and external collaboration

The research in the group covers the areas mentioned in Section 3a, integrated through the common theme of *Quality-Oriented Software Engineering*. In general, each staff member is responsible for his own research area, including acquisition, strategy, research, and daily supervision of PhD candidates, postdocs and MSc students. The Head of Group is involved in

all these activities, both organizational, strategic and content-wise; as a result he can coordinate interactions among different activities within the group. Collaborations among the people working on different areas occur naturally since the work within subtopics tends to show certain overlapping subjects, such as aspect-oriented software development, software development processes, service-oriented architectures, traceability, verification, etc.

External collaborations are generally the result of active participation in projects and events. The group has been a major contributor to the Embedded Systems Institute, with four projects. This contribution has led to several follow-ups, involving many group members. Furthermore, the group continues its tradition of giving industrial courses, and has carried out two large technology transfer projects to industry (ASML) for the purpose of exploiting its research contributions. The participation of many group members in the Network of Excellence on AOSD has also been an important form of external collaboration, and a source for new collaborations.

The group members also collaborate with the members of other groups of the university (particularly FMT and IS, and the IS&CM group of the School of Management and Governance) and through national (CTIT, ESI, TI) and international projects.

5. Academic reputation

Prof. dr. ir. Mehmet Aksit

- Keynote and invited talks at conferences
 - "Challenges in Applying the Concept of Model Driven Architecture", OMG Information Days, Amsterdam, February 18, 2003
 - "7 Concepts for Creating Living Software", UYMK (First National Conference on Software Engineering), Izmir, October 23, 2003
 - "Principles of Aspect-Oriented Programming Languages, Design Dimensions and the Composition Filters Approach", Invited talk at Languages et modèles à objets, March 17, 2004. Lille.
 - "Design Language Trade-Offs", Software Engineering Properties and Aspect Technologies Workshop, at AOSD'2005 Conference, Chicago, March 15, 2005
 - "Challenges in Designing High-Quality Software Systems", Biltek (Informatics Technology Conference), Eskisehir, June 10, 2005.
 - "Aspect-oriented modeling the past, present and the future: The Compose* experience", UYMK (Second National Conference on Software Engineering), Ankara, September 24, 2005
 - Key factors in Sharing Competence and Interoperability, Distinguished speaker at the International Conference on Systems Integration (CSI'08), November 9, 2008, Brasília, Brasil, 2008.
 - Measuring and Balancing Software Quality, Keynote talk at the Conference for Tools for Developing and Improving Software Quality (Yazilim Kalitesi ve Yazilim Gelistirme Araclari Sempozyumu (YKGS'2008)), October 9, 2008, Istanbul, Turkey.
 - Software Engineering Methods and Techniques for success in International Competition, Keynote talk at the Conference for Managers for Computer Centre (Bilgi İşlem Merkezi Yöneticileri Semineri (BİMY)), April 5, 2008, Çesme, Turkey.
 - The 7'Cs for Creating Living Software, Invited talk at the Aspect-Oriented Modeling Workshop, April 1, 2008, Brussels, Belgium.
 - Software Composition: from Inheritance to Aspect-Oriented, Keynote talk at the 7th International Symposium on Software Composition 2008, March 29, 2008, Budapest, Hungary.
- Program Chair of AOSD (ACM Conference Aspect-Oriented Software Development) 2003.
- Program Co-Chair of MDAFA (Workshop on Model Driven Architecture: Foundations and Applications, 2003.
- Organizing Co-Chair of Distributed Auto-Adaptive and Reconfigurable Systems, 2003, 2004.
- Workshop co-Organizer of "AOP goes .NET", 2005.

- Organizing Co-Chair of the 1st. and 2nd. Workshop on Aspect-Based and Model-Based Separation of Concerns in Software Systems, 2005, 2006.
- Founding Member of International Foundation on Aspect-Oriented Software Development
- Voting Member of the European Foundation on Object-Oriented Systems (AITO) 2002-2007.
- Co-Editor-in-Chief of Transactions on Aspect-oriented Software Development (Springer Verlag).
- Co-editor of the special journal issue: Computational Intelligence in Software Engineering, Journal of Fuzzy Sets and Systems, 2004.
- Co-editor of the special issue: Experiences with Auto-adaptive and reconfigurable systems, Software: Practice and Experience, 2006.
- Co-editor of the special issue: Foundations and Applications of Model-Driven Architecture, Elsevier, Science and Computing programming 2008.

Dr. ir. Lodewijk Bergmans

- Doctoral Symposium Chair ECOOP 2003 (European Conference on Object-Oriented Programming)
- Workshop Chair of AOSD 2002 (Aspect-Oriented Software Development Conference)
- 'Expert' role at Student Extravaganza of AOSD 2005
- Workshop co-organizer of SPLAT2003-2008 workshop series on "Software-engineering Properties of Languages and Aspect Technologies"
- Workshop co-organizer of ADI2006-2008 workshops on "Aspects, Dependencies and Interactions"
- Workshop co-organizer of "Joint Belgian and Dutch AOP workshop" 2003
- Workshop co-organizer of "AOP goes .NET", 2005
- Workshop co-organizer of EWAS 2006, "European Workshop on Aspects in Software"
- Guest editor special issue Journal of Object Technology, 2008

Dr. Pim van den Broek

- Chair of Special Session "Soft Computing Applied to Software Engineering" at NAFIPS 2004 (North American Fuzzy Information Processing Society), Banff, Canada, June 2004.
- Chair of High Quality Architecture Design Symposium, Enschede, the Netherlands, July 6th, 2007

Dr. Luís Ferreira Pires (from 01-2008)

- Co-chair of the 3M4EC 2008 workshop (in conjunction with EDOC 2008, Munich)
- Co-chair of the MDEIS 2008 workshop (in conjunction with ICEIS 2008, Barcelona)
- Co-presenter of the tutorial 'Model-Driven Architecture: Core Technologies, Models and Application' at ACM SAC 2008 (Fortaleza, Brazil)
- Project proposal review for ESC (Estonian Science Foundation, 2008)

Dr. Ivan Kurtev

- Organizer of Workshop on Composition of Model Transformations (CMT) at ECMDAFA 2006
- Invited talk at AGTIVE 2007

6. Internal evaluation

The group uses the standard yearly performance appraisal of the Faculty to measure the quality (and quantity) of the research output, and to take measures aiming at increasing this quality. Each group member (staff, post-doctoral fellows and PhD candidates) is evaluated once a year.

In addition to that, each PhD candidate has a personal project plan that is constantly monitored and adjusted by the PhD supervisors. This personal project plan contains the list of courses to be followed by the PhD candidate and the activities this PhD candidate is supposed to perform. In the first year a PhD candidate is evaluated twice (every six months); a

negative evaluation in the first year can cause the discontinuation of the PhD project. The Head of Group participates in the supervision of all PhD candidates, and forms a constant factor in their evaluation.

7. External validation

7.a. Societal relevance

For more than a decade the group has adopted an industry-as-laboratory approach in which research problems are grounded in practical problems. The research ideas are refined through the medium of continual and incremental case studies. This approach is clearly visible in the projects that the group has carried out in the reporting period. The gross of these projects are externally funded and in close cooperation with the industry. For example:

- The IDEALS project has aimed at developing a software design methodology that realizes the structured composition of software from separate modules, while handling system-wide interacting aspects of a problem domain. The results of this project are essential for the engineering of next generation complex embedded systems. In this project, the SE group, Eindhoven University of Technology, CWI and ASML have co-operated with the Embedded Systems Institute.
- The TRADER project aims to develop methods and tools for ensuring reliability of consumer electronic products. This should result in minimizing product failures that are exposed to the user. Within this project we are in close cooperation with NXP and the Embedded Systems Institute.
- The DARWIN project aims to develop methods and tools for optimizing system evolvability. This should result in a faster time to market for product iterations while maximizing technology reuse. Hereby we focus on the industrial sector of medical imaging, in particular that of MRI scanners.
- The QUADREAD project aims at improving the integration of requirements engineering and architectural design. The better alignment of these two disciplines will reduce maintenance costs in evolving software systems.
- The A-MUSE and AWARENESS projects have been quite complementary, in that service-oriented model-driven techniques developed in A-MUSE have been applied in the context-aware service platform developed in AWARENESS. The AWARENESS context-aware platform has also been contributed to the IST AMIGO project through our participation (in cooperation with the Telematica Instituut). In IST SPICE we have started with the development of our service composition framework and its supporting algorithm.

Software assets

The Research Group maintains the following tools for public usage:

- GROOVE, for graph transformation-based state space exploration and model checking (together with FMT): see <http://groove.sf.net>
- Compose*, for supporting aspect-oriented programming through the composition filters model: see <http://composestar.sf.net>
- Ceduf, for handling imperfect information in the software design process: see <http://www.comp.lancs.ac.uk/~noppen/tools/>

7.b. Industrial contacts

- 3T (NL): software design methods
- AMB-IT (NL) design patterns
- Aselsan (TR): software architecture
- ASML: aspect-oriented software
- AVV Rijkswaterstaat (NL): architecture design and evaluation
- Belastingdienst Apeldoorn (NL): architecture design and evaluation
- BizzDesign (NL): business process modeling, model-driven architecture

- Cap Gemini (NL): service-oriented architectures
- Chess Information Technology (NL): traceability of requirements and architectures
- Cybersoft (TR): architecture design
- Da Capo AI Fine (NL) architecture design and evaluation
- Embedded Systems Institute (NL): evolvable software architectures, fault-tolerant architectures, adaptable architectures, aspect-oriented techniques
- Ericsson (NL): context-aware mobile services platforms
- Getronics PinkRocade (NL): traceability of requirements and architectures
- Grundig (TR): software architecture design
- HOLOS (P): traceability and change impact analysis
- IBM (UK): Aspect-oriented programming
- Logica CMG (NL): business process modeling, traceability of requirements and architectures
- Microsoft Redmond (USA): aspect-oriented programming
- Milsoft (TR): software architecture design
- Mobilaria (NL): mobile applications
- NedForce (NL): web applications and service-oriented architectures
- NXP Semiconductors (NL): software reliability and fault tolerance
- Oce (NL): adaptable software systems
- Ordina (NL): service-oriented architectures
- Philips Research (NL): evolvability of software architectures
- Rohill Technologies Nederland
- SAP AG (Germany): software product line engineering
- Siemens Aktiengesellschaft (Germany): software product line engineering
- TAI (TR): software architecture
- Telematica Instituut (NL): model-driven architectures, service-oriented architectures, context-aware applications
- Thales (N): model-driven engineering
- TI-WMC (NL): context-aware mobile applications
- Topicus (NL): traceability of requirements and architectures

8. Researchers and other personnel

Table 1

Category	Name	2003	2004	2005	2006	2007	2008
Tenured staff							
professor (hgl)	Aksit, prof. dr. ir. M.	0,40	0,40	0,40	0,40	0,40	0,40
associate professor (uhd)	Ferreira Pires, dr. L.					0,17	0,40
	Rensink, dr. ir. A.	0,40	0,40	0,20			
assistant professor (ud)	Berg, dr. ir. K.G. van den	0,40	0,40	0,40	0,35	0,40	0,40
	Bergmans, dr. ir. L.M.J.	0,40	0,40	0,40	0,40	0,40	0,29
	Broek, dr. P.M. van den	0,40	0,40	0,40	0,40	0,40	0,40
	Tekinerdogan, dr. ir. B.		0,20	0,40	0,40	0,40	0,26
Total tenured staff		2,00	2,20	2,20	1,95	2,17	2,15
Non-tenured staff							
assistant professor (ud)	Tekinerdogan, dr. ir. B.	0,25	0,25				
postdoctoral fellows	Ivanov, dr. MSc. I.K.				0,08	1,00	1,00
	Noppen, dr. ir. J.A.R.					0,17	
	Sathyanathan, dr. P.W.			0,29			
	Shishkov, dr. B.B.					0,80	0,49
other junior staff (moz, twaio)	Byelas, H.		0,06	0,54			
	Gülesir, dr. G.						0,54
	Hendriks, ir. M.F.H.					0,26	0,80
Total non-tenured staff		0,25	0,31	0,94	0,08	2,23	2,83

Category	Name	2003	2004	2005	2006	2007	2008
PhD Candidates							
junior staff (aio, oio, moz-p)	Alagöz, A.				0,27	0,60	
	Bijl, ir. H.M. van der	1,00	1,00	0,49			
	Bonino da Silva Santos, L.O.					0,34	0,80
	Ciraci, S.			0,07	0,80	0,80	0,80
	Daniele, L.M.					0,34	0,80
	Durr, ir. P.E.A.		0,50	0,80	0,80	0,80	0,40
	Galvao, I.					0,70	0,80
	Glandrup, ir. M.H.J.	1,00	0,60	0,14			
	Göknil, A.				0,07	0,80	0,80
	Gomes Ludermir, P.			0,13	0,80	0,07	
	Goncalves da Silva, E.M.					0,34	0,80
	Gülesir, G.		0,64	0,80	0,80	0,80	0,16
	Hatun, K.						0,20
	Havinga, ir. W.K.			0,44	0,80	0,80	0,80
	Hofmann, C.			0,47	0,80	0,80	0,80
	Ivanov, MSc. I.K.	0,80	0,80	0,40			
	Kastenberg, ir. H.		0,33	0,39			
	Kleppe, drs. A.G.			0,11			
	Krechetov, I.			0,20	0,60		
	Malakuti Khah Olun Abadi, S.					0,67	0,80
Nagy, I.	0,80	0,80	0,80	0,45			
Noppen, ir. J.A.R.	0,80	0,80	0,80	0,80	0,39		
Roo, ir. A.J. de					0,13	0,80	
Sözer, H.			0,73	0,80	0,80	0,80	
Staijen, ir. T.			0,54	0,80	0,80	0,80	
Total PhD Candidates		4,40	5,47	7,20	8,59	9,98	10,36
Total Research Staff SE		6,65	7,98	10,34	10,62	14,38	15,34

9. Resources, funding and facilities

9.a. Laboratory infrastructure

Apart from the usual desktop and laptop systems, for more intensive processing tasks the group uses a server cluster that is shared with the FMT and DACS groups.

9.b. FTE-funding

Table 2 clearly shows the strong ability of the SE group to acquire externally funded projects. Especially the level of contractual funding has grown in the assessment period.

Table 2: Funding at group level

SE	2003	2004	2005	2006	2007	2008
Direct funding	71%	81%	69%	64%	60%	54%
Research funds	10%	15%	9%	8%	12%	6%
Contracts	19%	4%	23%	29%	28%	41%
Total	100%	100%	100%	100%	100%	100%

9.c. FTE-funding PhDs/postdocs

Table 3 shows the same trends as Table 2, though amplified since this table is restricted to personnel hired on temporary projects. In particular, it can be seen that, in the second half of the assessment period, all such projects were externally funded.

Table 3: Funding of PhDs/postdocs

SE	2003	2004	2005	2006	2007	2008	Average
Direct funding	45%	40%	13%	1%	0%	2%	17%
Research funds	32%	39%	33%	20%	25%	22%	28%
Contracts	23%	21%	54%	79%	75%	76%	55%
Other	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%

9.d. List of external funds

The list of projects confirms the very strong funding position of the SE group. As it has been made clear in the previous sections, especially the projects performed in cooperation with industry, via the Embedded Systems Institute, are good examples of the type of research the group prides itself in.

Table 4

Name project	Start	End	Sponsor
ESI/DARWIN: Designing Highly Evolvable System Architectures	Oct-05	Oct-09	Embedded Systems Institute
ESI/TRADER: Television Related Architecture and Design to Enhance Reliability	Aug-04	Aug-09	Embedded Systems Institute
Octopus System Adaptability	Jul-07	Jul-11	Embedded Systems Institute
AOSD-EUROPE: European Network of Excellence on Aspect-Oriented Software Development	Sep-04	Sep-08	European Commission
AMPLE: Aspect-oriented Model-driven Product Line Engineering	Oct-06	Oct-09	European Commission
EASYCOMP: Easy Composition in Future Generation Component Systems	Jun-00	Jun-03	European Commission
Aspect oriented, model-driven product line engineering	Oct-06	Oct-09	Lancaster University
AOSAD: Aspect-Oriented Software Architecture Design	Jul-03	Jun-09	NWO
CEDUF: Dealing with Conflicting and Evolving Designs Using Fuzzy Logic	Jul-03	Jul-07	NWO
GRASLAND: Graphs for Software Language Definitions	Apr-05	Jul-05	NWO
GROOVE: Graphs for Object-Oriented Verification	Aug-04	Jul-05	NWO
QUADREAD: Quality-Driven Requirements Engineering	Nov-06	Dec-10	NWO
ESI/IDEALS: Idiom Design for Embedded Applications on Large Scale	Mar-03	Feb-08	SENER
A Tool For Effort Reduction And Fault Prevention	Mar-08	Jan-09	STW
ATOMYSTE: Atom splitting in embedded Systems testing	Apr-02	Jul-05	STW
Architecture Modelling Utility For Service Enabling	Jan-04	Jan-09	Telematica Instituut

10. Overview of the results

10.a. Key publications

Table 5

Nr	Title
1	Noppen, J and van den Broek, P. and Akşit, M. (2008) <i>Software Development with Imperfect Information</i> . Soft Computing - A Fusion of Foundations, Methodologies and Applications 12 (1), pp. 3-28.
2	Andrade Almeida, J.P. and Dijkman, R.M. and Ferreira Pires, L. and Quartel, D.A.C. and van Sinderen, M.J. (2006) <i>Model-driven design, refinement and transformation of abstract interactions</i> . International journal of cooperative information systems, 15 (4). pp. 599-632.

Nr	Title
3	Kurtev, I. and van den Berg, K.G. and Jouault, F. (2007) <i>Rule-based modularization in model transformation languages illustrated with ATL</i> . Science of computer programming, 68 (3). pp. 111-127.
4	Tekinerdogan, B. and Sözer, H. and Aksit, M. (2008) <i>Software Architecture Reliability Analysis using Failure Scenarios</i> . Journal of systems and software, 81 (4). pp. 558-575.
5	Havinga, W.K. and Bergmans, L.M.J. and Aksit, M. (2008) <i>Prototyping and Composing Aspect Languages: using an Aspect Interpreter Framework</i> . In: Proceedings of 22nd European Conference on Object-Oriented Programming (ECOOP 2008), 7-11 July 2008, Paphos, Cyprus. pp. 180-206. Lecture Notes in Computer Science 5142/2008. Springer Verlag.

10.b. Numerical overview of the results in a fixed format of categories

Table 6

Category		2003	2004	2005	2006	2007	2008
Academic publications	a. Refereed journals		2	1	3	5	4
	b. International conferences	10	18	20	24	15	21
	c. Book chapters	1	2	1		3	1
	d. Other academic publications	2	8	3	4	4	8
Total		13	30	25	31	27	34
Monographs							
PhD-theses				1	1	1	2
Professional publications			1	1		3	
Patents							
Software		2		1	1	1	

10.c. Full outcome list

2003

Conference proceedings

- Aksit, M., Choukair, Z., *Dynamic Adaptive and Reconfigurable Systems Overview and Prospective Vision* (2003). In: Workshop on Distributed Auto-adaptive Reconfigurable Systems (DARES) - International Conference on Distributed Computing Systems (ICDCS), 23rd International Conference on Distributed Computing Systems Workshops (ICDCS'03 Workshops), Rhode Island, Providence, USA, 19-22 May 2003. pp. 84-89. IEEE Computer Society. ISBN: 0-7695-1921-0.
- Broek, P.M. van den *Comparison of two approaches to approximate reasoning*. Proceedings of the Third Conference of the European Society for Fuzzy Logic and Technology (2003, september 10 / 2003, september 12). (pp. 512-516) Zittau, Germany European Society for Fuzzy Logic and Technology (EUSFLAT) ISBN: 3-9808089-4-7
- Kurtev, I., Berg, K.G. van den, *A synthesis-based approach to transformations in an MDA software development process* (2003). In: First Workshop on Model Driven Architecture: Foundations and Applications, Enschede, the Netherlands. pp. 121-126. Centre for Telematics and Information Technology, University of Twente, Enschede. ISSN:1381-3625.
- Kurtev, I., Berg, K.G. van den, *Model driven architecture based XML processing* (2003). In: Proceedings of the 2003 ACM symposium on Document engineering, Grenoble, France, Nov 2003. pp. 246-248. ACM Press, New York. ISBN: 1-58113-724-9.
- Kurtev, I., Berg, K.G. van den, Aksit, M., *UML to XML-Schema transformation: a case study in managing alternative model transformations in MDA* (2003). In: Forum on specification and Design Languages (FDL2003), Frankfurt, Germany. 12 pp. ECSI. ISSN:1636-9874.

- Nagy, I. , Bergmans, L.M.J., Aksit, M. *Composition Graphs: a Foundation for Reasoning about Aspect-Oriented Composition*. FOAL 2003 Proceedings-Foundations of Aspect-Oriented Languages (nr: TR-03-05), (2003). (pp. 1-9) Iowa State University, USA
- Rensink, A., *Towards model checking graph grammars* (2003). In: Workshop on Automated Verification of Critical Systems (AVoCS), Southampton, UK. pp. 150-160. Technical Report DSSE-TR-2003-02. University of Southampton, Southampton.
- Tekinerdogan, B. ASAAM: *Aspectual Software Architecture Analysis Method*. Proceedings of Aspect-Oriented Requirements Engineering and Architecture Design Workshop (2003, maart 17 / 2003, maart 17). 8 pp. Boston, USA
- Tekinerdogan, B. *Formalizing Agile Software Development Methods*. Proceedings of Impact of Software Process on Quality Workshop (2003, juni 6 / 2003, juni 6). 8 pp. Ankara, Turkey
- Tekinerdogan, B. , Aksit, M. *Managing Variability in Product Line Scoping using Design Space Models*. Proceedings of Workshop Software Variability Management (2003, februari 13 / 2003, februari 14). (pp. 5-12) Groningen, the Netherlands Rijksuniversiteit Groningen

Books - chapter

- Tekinerdogan, B. , Aksit, M. *Fuzzy Evaluation of Domain Knowledge. Studiess in Fuziness: Software Engineering with Fuzzy Theory* (2003). 10 pp. Berlin Springer-Verlag ISBN: 3-540-00472-6

Other academic publications

- Aksit, M. (ed.), *Proceedings of the 2nd International Conference on Aspect-Oriented Software Development* (2003). In: AOSD 2003, Boston, USA, 17-21 March 2003. 198 pp. AOSD 2003. ACM, New York. ISBN: 1-58113-660-9.
- Aksit, M. , Menzini, M., Unland, R. Objects (eds.), *Components, Architectures, Services and Applications for a Networked World*. LNCS nr 2591, (2003). 430 pp. Berlin, Germany Springer-Verlag ISBN: 3-540-00737-7 (Editor(s))

Software

- Compose**: *Supporting aspect-oriented programming through the composition filters model*, Lodewijk Bergmans, Istvan Nagy, Pascal Durr, Wilke Havinga, Michiel Hendriks. URL: <http://composestar.sf.net>
- GROOVE*: *Graph transformation-based state space exploration and model checking*, Arend Rensink, Iovka Boneva, Harmen Kastenberg, Tom Staijen. URL: <http://groove.sf.net>

2004

Journal articles

- Marcelloni, F. , Aksit, M. *Fuzzy Logic-Based Object-Oriented Methods to Reduce Quantization Error and Contextual Base Problems in Software Development*. Fuzzy sets and systems nr: 145, (2004). (pp. 57-80) ISSN: 0165-0114
- Noppen, J.A.R. , Aksit, M., Nicola, V.F., Tekinerdogan, B. *Market-Driven Approach Based on Markov Decision Theory for Optimal Use of Resources in Software Development*. IEE proceedings- software nr: 2, 151, (2004). (pp. 85-94) ISSN: 1462-5970

Conference proceedings

- Bijl, H.M. van der , Rensink, A., Tretmans, G.J. *Compositional based testing with ioco*. Formal approaches to software testing Lecture notes in computer science 2931 (nr: VIII), (2003, oktober 6). (pp. 86-100) Berlin Springer ISBN: 3-540-20894-1 / ISSN: 0302-9743
- Broek, P.M. van den, Noppen, J.A.R., *Approximate Reasoning with Fuzzy Booleans* (2004). In: Information Processing and Management of Uncertainty in Knowledge-Based Systems (IPMU 2004), Perugia, Italy, 4-9 July 2004. pp. 1429-1434. Editrice Universita La Sapienza, Italy, La Sapienza. ISBN: 8887242542.
- Distefano, D.S. , Katoen, J.P., Rensink, A. *Who is pointing when to whom?*. FSTTCS 2004: foundations of software technology and theoretical computer science Lecture notes in

- computer science 3328 (nr: XVI), (2004, december 16 / 2004, december 18). (pp. 250-262) Berlin Springer ISBN: 3-540-24058-6 / ISSN: 0302-9743
- Jones, V.M. , Rensink, A., Ruijs, T.C., Brinksma, H., Halteren, A.T. van *A formal MDA approach for mobile health systems*. Second European workshop on model driven architecture (MDA) (nr: 17-04), (2004, september 7 / 2004, september 8). (pp. 28-35) Canterbury, UK University of Kent, Computing laboratory
- Kurtev, I. , Berg, K.G. van den *A Language for Model Transformations in the MOF Meta-Modeling Architecture*. Proceedings of Model-Driven Architecture: Foundations and Applications 2004 (2004, juni 10 / 2004, juni 11). (pp. 29-46) Research Center for Intergrational Software Engineering
- Kurtev, I., Berg, K.G. van den, *Unifying approach for model transformations in the MOF metamodeling architecture* (2004). In: Model-Driven Architecture with Emphasis on Industrial Applications, Enschede, the Netherlands. pp. 105-114. Centre for Telematics and Information Technology, University of Twente, Enschede. ISSN:1381-3625.
- Nagy, I. , Bergmans, L.M.J. *Towards Semantic Composition in Aspect Oriented Programming*. 1st european interactive workshop on aspects in software (2004).
- Nagy, I. , Bergmans, L.M.J., Aksit, M. *Declarative Aspect Composition*. 2nd software engineering properties of languages and aspect technologies (2004).
- Noppen, J.A.R. , Aksit, M. *A Case Study in Optimization of Resource Distribution to Cope with Unanticipated Changes in Requirements*. Proceedings of the 6th International Workshop on Economics-Driven Software Engineering Research (nr: 6), (2004). (pp. 39-42) ISBN: 0-86341-424-9
- Noppen, J.A.R. , Broek, P.M. van den, Aksit, M. *Dealing with Fuzzy Information in Software Design Methods*. Annual Meeting of the North American Fuzzy Information Processing Society (2004). (pp. 22-27) IEEE ISBN: 0-7803-8376-1
- Rensink, A. *Canonical Graph Shapes*. Programming Languages and Systems Lecture notes in computer science 2986, (2004). (pp. 401-415) Springer Verlag ISSN: 0302-9743
- Rensink, A. *Representing First Order Logic Using Graphs*. International conference on graph transformations Lecture notes in computer science 3256, (2004). (pp. 319-335) Springer Verlag ISSN: 0302-9743
- Rensink, A., *The GROOVE Simulator: A Tool for State Space Generation* (2004). In: Applications of Graph Transformations with Industrial Relevance (AGTIVE). pp. 479-485. Lecture Notes in Computer Science 3062. Springer Verlag, Berlin. ISBN: 978-3-540-22120-3.
- Rensink, A. , Schmidt, A., Varro, D. *Model Checking Graph Transformations: A Comparison of Two Approaches*. LNCS Lecture notes in computer science 3256, (2004). (pp. 226-241) Springer Verlag ISSN: 0302-9743
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11. SWOT-analysis

Strengths

- The group showed the ability to attract external funding.
- The group is at the centre of the object-, aspect-, and architecture research communities.
- The group has strong collaboration with industry and government, among others through the Embedded Systems Institute, the Ministry of Transport, Public Works and Water Management, and the Tax Administration.
- The group is the base for a spin-off company using a patent that has been derived from a PhD research project (showing the industrial relevance of the research).

Weaknesses

- in the beginning of the reported period the group had few PhD students, so that not many PhD theses have been delivered in this period.
- The group has experienced many changes in the staff.

Opportunities

- There is an increasing demand in industry for expertise on the methods and techniques in which the SE group has conducted pioneering research and is a recognized leader. The group is thus in a good position to attract industrial research funding.
- The group has developed several tools which have been adopted by industry. This also will increase the chance of industrial research projects.

Threats

- No group-specific threats (beyond those already mentioned in Part A)

Analysis

- Based on the SWOTs presented above, there is no need to change the research objectives.
- However, there is a strong need to ensure funding of research projects enabling the employment of highly qualified staff.

Adjusted goals and strategy

- The raising of funds for research projects will be facilitated through the (temporary) employment of researchers with the specific task of preparing and managing research proposals.