# Architecture of Information Systems

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| **Full title** | Architecture of Information Systems |
| **Programme leader** | prof.dr.ir. W.M.P. van der Aalst (from September 2006)<br>prof.dr. K.M. van Hee (until September 2006) |
| **Starting date** | before 1996 |
| **Research area** | Information systems |
| **CR-classification** | H. Information Systems<br>D.2.2 Design Tools and Techniques<br>H.4.1 Office Automation<br>H.2.8 Database Applications |

**Affiliations**

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|---|---|
| research school | SIKS (Research School for Information and Knowledge Systems)<br>BETA (Research School for Operations Management and Logistics) |
| TU/e | LOIS (Logistics, Operations and their Information Systems) |

**Cooperations** (at most five per category are listed)

| | |
|---|---|
| national | prof. Geert-Jan Houben (Delft)<br>prof. Roel Wieringa (Twente)<br>prof. Farhad Arbab (CWI)<br>prof. Rinus Plasmeijer (Radboud University Nijmegen) |
| international | prof. Wolfgang Reisig and prof. Jan Mendling (Humboldt-Universität zu Berlin )<br>prof. Arthur ter Hofstede and prof. Michael Rosemann (Queensland University of Technology)<br>prof. Karsten Wolf (Universität Rostock)<br>prof. Mathias Weske (Hasso Plattner Institute)<br>prof. Kurt Jensen (University of Aarhus) |

# Mission statement

The Architecture of Information Systems (AIS) research group investigates *methods, techniques and tools for the design and analysis of Process-Aware Information Systems* (PAIS), i.e., systems that support business processes (workflows) inside and between organizations. We are not only interested in these information systems and their architecture, but also model and analyze the business processes and organizations they support.

Our mission is to be one of the worldwide leading research groups in *process modeling and analysis*, *process mining*, and *PAIS technology*. We aim at results that are highly original and applicable in real-life situations. Our motto is “Process Technology that Works”.

# 1. Leadership

The Architecture of Information Systems (AIS) group is chaired by prof.dr.ir. Wil van der Aalst. The permanent staff of AIS involved in research currently consists of dr.ir. Boudewijn van Dongen, prof.dr. Kees van Hee (0.2), prof.dr.ir. Wim Nuijten (0.2), dr. Natalia Sidorova, dr.ir. Eric Verbeek, and dr. Marc Voorhoeve. There are about five postdocs and seven PhD’s. The group has weekly meetings where the staff and postdocs discuss ongoing matters. There is another weekly meeting where one of the group members presents his/her work. There is also a regular colloquium series involving AIS, DH (the group of Paul De Bra), and the IS group in the Department of Industrial Engineering & Innovation Sciences (former group of Wil van der Aalst).

All PhD students, postdocs, and staff members are member of the School for Information and Knowledge Systems (SIKS). The PhD students follow SIKS courses, take advanced courses at TU/e, and participate in summer schools. All PhD students have weekly meetings with their promotor and in most cases also a daily supervisor is assigned. Cooperation with other groups is stimulated and group members are encouraged to submit papers to competitive conferences like Caise, BPM, ATPN, etc. and journals such as Information Systems, Distributed and Parallel Databases, IEEE Transactions on Knowledge and Data Engineering, Data and Knowledge Engineering, Fundamenta Informaticae, Acta Informatica, and Cooperative Information Systems.

There is a strong emphasis on tooling and empirical validation. We aim at techniques that actually work under realistic circumstances and are inspired by the challenges posed by practical applications of our results, cf. our motto “Process Technology that Works”. Therefore, tooling is important. Moreover, the joint development of major software systems (such as the process analysis tool ProM) stimulates and facilitates cooperation within the group.

# 2. Strategy and policy

## 2.a. Design in brief

Until 2004 the group was named *Specification and Modeling of Information Systems* (SMIS). In 2004 the group was renamed to *Architecture of Information Systems* (AIS). Within the SMIS/AIS group there is a long-standing tradition in modeling and analyzing *Process-Aware Information System* (PAISs) using *Petri nets*. A PAIS is a software system that manages and executes operational processes involving people, applications, and/or information sources on the basis of process models. Example PAISs are workflow management systems, case-handling systems, middleware platforms, enterprise information systems, etc.

In the nineties the group worked on *ExSpect* (Executable Specification Tool, `www.exspect.com`), a specification language and corresponding toolset based on Petri nets extended with

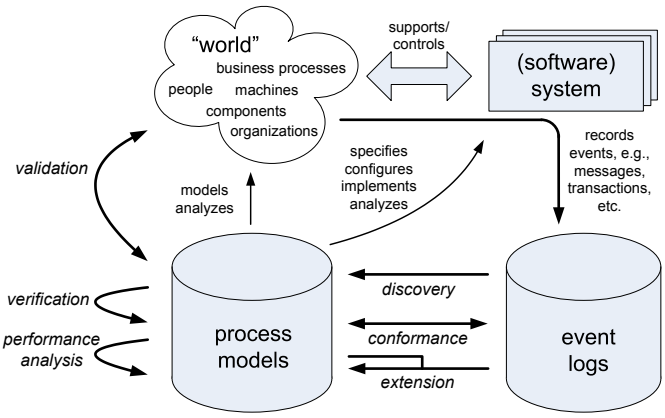


Figure 3: Positioning AIS's research.

data, time, and hierarchy. ExSpect has been used to specify a wide variety of systems (from entire supply chains to embedded software in e.g. copiers) and its simulation engine turned out to be very useful in all kinds of practical situations. In the late nineties the development moved to Bakkenist consultancy (now part of Deloitte), because most of the research challenges related to the execution and simulation of high-level Petri nets had been addressed. Despite several successful applications, Deloitte discontinued the development of ExSpect. In parallel the simulation engine of ExSpect was embedded in several other software products. Most notable is the embedding of ExSpect in Protos of Pallas Athena. Protos is the most widely used business process modeling tool in the Netherlands (over 1 million users and, for example, used by more than half of all Dutch municipalities). ExSpect is shipped with all versions of Protos and BPM|one.

Although tools such as ExSpect are highly generic and can be applied to a variety of systems and processes (e.g., embedded systems, supply chains, etc.), the main focus since the late nineties has been on PAISs (in particular workflow management systems). The AIS group was among the first groups to formalize workflow concepts in a systematic manner. Van der Aalst introduced the so-called *WorkFlow nets* (WF-nets) and a correctness criterion called *soundness*. WF-nets are a subclass of Petri nets tailored towards workflow modeling and analysis. The modeling of WF-nets and the analysis of soundness are supported by tools such as Woflan and Yasper. WF-nets and soundness have been widely adopted within the academic community and these techniques are increasingly used in all kinds of commercial software products (Protos, IBM WebSphere, etc.). Members of the AIS group worked on alternative soundness notions, verification techniques, and also applied these techniques to large sets of real-life process models. For example, we showed that more than 20 percent of the 600 process models in SAP's well-known Reference Model contain errors.

In September 2006, Van der Aalst moved from the Information Systems group in the Department of Industrial Engineering & Innovation Sciences (IEIS) to the AIS group. Before his move, he was chair of the Information Systems group, and from 2000 until 2003 he was also a part-time professor within AIS. Currently, Van der Aalst holds part-time professorships in IEIS and the BPM group at Queensland University of Technology. Because of the move of Van der Aalst, Verbeek, and Van Dongen from IEIS to AIS, the focus of AIS was extended to also include process mining. To explain the relation between process mining and the earlier work of AIS on Petri nets and workflow verification, let us consider Figure 3.

This figure shows the role of (process) models in the PAIS context. Process models can be used to describe and analyze processes and to specify, configure, or implement information systems.

The left-hand-side of Figure 3 shows some examples of *design-time analysis*: *validation* (i.e., testing whether the process behaves as expected), *verification* (i.e., establishing the correctness

of a process definition), and traditional (i.e., non-log based) *performance analysis* (e.g., using simulation to evaluate the ability to meet requirements with respect to throughput times, service levels, and resource utilization).

Traditionally, most of AIS's research focused on design-time analysis. However, more and more information about (business) processes is recorded by information systems in the form of so-called "event logs". IT systems are becoming more and more intertwined with these processes, resulting in an "explosion" of available data that can be used for analysis purposes. The goal of *process mining* is to extract process-related information from event logs, e.g., to automatically *discover* a process model by observing events recorded by some information system. However, process mining is not limited to discovery and also includes *conformance checking* (investigating whether reality conforms to a given model and vice versa) and *extension* (augmenting an existing model with additional insights extracted from some event log).

Since 2006, AIS is also focusing on process mining. In fact, Van der Aalst and his colleagues established process mining as a research field and developed the influential ProM framework. Currently, process mining is seen as one of the main innovations in business process management, and the ideas are rapidly being incorporated in commercial products (BPM|one, Futura Reflect, ARIS PPM, etc.). The combination of knowledge about PAIS technology, process modeling notations, Petri net theory, process verification, and data mining turns out to be an excellent basis for process mining research. Classical techniques in the field of data mining and the so-called Business Intelligence (BI) tools used in industry do not explicitly focus on process models. As a result, the scope is limited to data dependencies and performance measurements. *AIS's unique set of capabilities can be used to bridge the gap between process modeling and analysis on the one hand and data mining and BI on the other.* This provides an ideal starting point for scientific and technological breakthroughs in process mining.

## 2.b. Future Programme development

Current AIS research concentrates on formalisms for modeling and methods to discover and analyze models. On the one hand formal methods are being used, e.g., the group has a long tradition in Petri-net modeling and analysis. On the other hand, we are interested in modeling languages widely used in industry (EPCs, UML, BPMN, BPEL, etc.). Moreover, in contrast to many other research groups in this area, we do not blindly accept "man-made models" as an objective starting point, i.e., we also try to discover process models through process mining and check the conformance of models based on reality.

The goal for the next five years is to further develop the main three lines of research of AIS:

- **Research line 1: Process Modeling/Analysis.** While various types of process notations are used in industry, formal models such as Petri nets are more suitable for analysis purposes. Driven by questions from the other two research lines (process mining and PAIS technology), particular models (e.g., WF-nets, WF-nets with data and resources, history-dependent nets, open nets, nested nets, etc.) are used to answer questions related to correctness and performance. The main techniques that are used are model checking, structural techniques (invariants, etc.), simulation, and Markov (decision) processes. Moreover, quite some efforts are made to translate industry standards and proprietary languages (EPCs, UML, BPMN, BPEL, etc.) to formal models (typically Petri nets). One of the main goals in Research line 1 is to further improve *verification techniques to check various properties such as soundness, data/resource soundness, accordance, controllability, and selected temporal properties.* Here there is a need for more *empirical* research, i.e., analyzing large repositories of models like the SAP Reference Model. Moreover, pattern-based approaches can be used for correctness-by-design. Another goal is to develop *innovative simulation approaches* that better reflect reality and that can be used in an operational setting while using process mining results. A prerequisite for the above analysis approaches

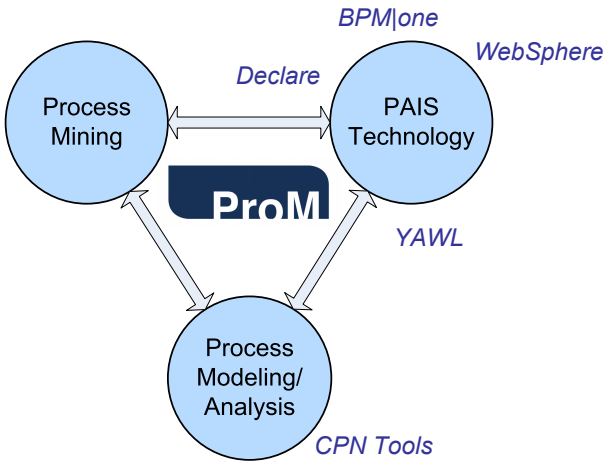


Figure 4: The three main research areas and the most relevant tools.

is the consistent integration of the different perspectives.

- **Research line 2: Process Mining.** Process mining techniques are used to extract process-related information from event logs, e.g., to automatically discover models, check conformance, and augment existing models with additional insights extracted from some event log. The main difference with Research line 1 is that *event logs play a central role* (rather than predefined process models). One goal is to significantly *improve the state-of-the-art in process discovery*. A particular challenge is to deal with less structured processes and incomplete event logs. For this we want to improve our approaches based on region theory, fuzzy models, and genetic mining. Another goal is to *advance the state-of-the-art in conformance checking*, e.g., by refining our replay strategies and to allow for on-the-fly checking. Related is the challenge to *predict problems*, i.e., provide warnings based on historic information (e.g., a case will be late or an error is likely to occur). To achieve this, we plan to use pattern analysis, correlation analysis, and trace clustering.

- **Research line 3: PAIS Technology.** PAISs are used to *manage and execute operational processes involving people, applications, and/or information sources.* Examples are WFM (Workflow Management), BPM (Business Process Management), and ERP (Enterprise Resource Planning) systems. Increasingly, these systems are driven by models (connection to Research line 1) and produce high-quality event logs (connection to Research line 2). We are interested in the artifacts used and produced by these systems (i.e., models and logs) as these are essential for testing the techniques developed in the two other research lines. For example, it is interesting to convert and verify process models expressed in some particular industry language. This enables empirical research and triggers new questions. The same holds of course for event logs. We are also studying *PAIS architectures*. Note that service-orientation plays an important role here and this new architectural style poses new research questions. Although most PAISs are used in a business setting (governments, banks, insurance companies, supply chains, etc.), we are also interested in scientific computing and grid architectures. Note that the “process of process mining” can be seen as a scientific workflow. Moreover, for large scale process mining experiments, we are using our own grid with a dedicated grid architecture. In Research line 3 we heavily rely on the workflow patterns. This helps us to understand and characterize PAISs.

The three research lines are interconnected in various ways. PAISs are process-aware, use models, and provide for event logs. These models and logs can be analyzed using the techniques

developed in Research line 1 and Research line 2. Moreover, these analysis results can be used by the PAIS, e.g., for recommendations, predictions, and diagnosis.

Tools play a crucial role in the development of the three research lines. As Figure 4 shows, *ProM* is the central tool for realizing and evaluating our ideas. New techniques related to process mining and process modeling/analysis will be realized in ProM. ProM subsumes the functionality of *Woflan* (workflow verification) and *Yasper* (workflow modeling and analysis). Other relevant tools are *Declare* and *YAWL*. These are two open-source workflow management systems that are (partly) developed within AIS. Declare is a system aiming at more flexibility using a declarative style of modeling grounded in temporal logic. YAWL is a highly expressive workflow management system based on the workflow patterns and a result of our joint research with QUT. Both Declare and YAWL are tightly connected to ProM, e.g., ProM can analyze the logs and models of YAWL and Declare. Figure 4 also mentions some software systems not developed within AIS. In our teaching and research we are heavily using *CPN Tools*. CPN Tools is a standard Petri net tool for modeling and analyzing high-level nets. We are mainly using CPN Tools for simulation and conceptualizing ideas. *BPM|one* of Pallas Athena and *Websphere* of IBM are two commercial PAISs were we will continue to invest in. Both BPM|one and Websphere have adopted results from our research and are interesting commercial platforms for testing research ideas.

# 3. Processes in research, internal and external collaboration

As indicated earlier, there are two weekly group meetings. In one meeting, the permanent staff and the postdocs discuss the research strategy, the educational program, and operational matters related to research and teaching. In the other meeting, one of the AIS members presents ongoing work with the goal to get feedback from the rest of the group. There are also several other colloquia where AIS is involved in (e.g., the colloquium of both IS groups and the Computer Science Colloquium). There is also a biweekly ProM Developers Meeting and a monthly ProM Users Meeting. Hence, there are ample opportunities to exchange ideas.

Externally funded research projects are very important for realizing the research goals. Therefore, all AIS members are encouraged to submit proposals to NWO, STW, IOP, etc., and these proposals are discussed internally.

AIS works together with several organizations (universities, research institutes, software vendors, consultancy firms, and end-user organizations). Most notable are the cooperation with the Humboldt-Universität zu Berlin and Universität Rostock in the context of the B.E.S.T. program (Berlin - Rostock- Eindhoven Service Technology Program) and the cooperation with the BPM group of Queensland University of Technology. This is reflected by joint papers, joint PhD projects, and a continuous exchange of staff.

# 4. Academic reputation

*W. van der Aalst*

- Published about 190 papers since 2002 according to DBLP. Many of these papers are highly cited as is indicated by his Hirsch Index of 61 (Publish or Perish, July 2009) and, according to the Essential Science Indicators (based on the ISI Web of Science, July 2009), he is the highest ranked Dutch Computer Scientist.
- Associate editor of several journals, including *IEEE Transactions on Services Computing*, *IEEE Transactions on Industrial Informatics*, *International Journal of Business Process Integration and Management*, *International Journal on Enterprise Modelling and Information*

*Systems Architectures*, *Computers in Industry*, and *Transactions on Petri Nets and Other Models of Concurrency*.
- Series Editor of *Lecture Notes in Business Information Processing* (LNBIP) by Springer.
- Member of the editorial board of *Distributed and Parallel Databases* and *Business & Information Systems Engineering*.
- Member of several steering committees, including *International Conference Series on Business Process Management* (chair), *International Conference Series on Application and Theory of Petri nets* and *International Workshop Series on Web Services and Formal Methods*.
- Organizer/PC chair of several conferences: *IEEE SCC 2008* (General chair with Calton Pu), *IEEE SCC 2007* (PC chair with Liang-Jie Zhang), *BPM 2005* (PC chair with B. Benatallah and F. Casati), *COOPIS 2004* (PC chair with A. Gal and C. Bussler), *Petri Nets 2003* (PC chair with E. Best), and *BPM 2003* (PC chair with A. ter Hofstede, M. Weske).
- Program committee member of about 120 workshops and conferences since 2002.
- Keynote lectures at various conferences including: *Gartner BPM Summit 2009*, *BIS 2009*, *ICEIS 2007*, *ACSD 2007*, and *CSCWD 2005*.
- Invited lectures at various conferences including: *Caise 2009*, *(ICGT 2008*, *Medinfo 2004*, and *Petri nets 2002*.

*K. van Hee*

- Program committee member of several conferences, including: *Petri Nets* 2005, 2006, 2007, 2008, 2009 (co-chair), *Business Process management* 2005, 2006, 2007, 2008, 2009, *PNSE*, 2006, 2007, 2008.
- Member of the editorial board of the International Journal of Business Process Integration and Management.
- Member of the editorial board of Transactions on Petri Nets and Other models of Concurrency.

*N. Sidorova*

- PC member of the following conferences and workshops: APNOC09 (co-chair), CASE 2009 (Associate Editor), FM 2009, PNSE09, OrgMod09, PNDS08 (co-chair), WS-FM 2008, EOMAS 2008, Confenis 2007, MSVVEIS'07, MSVVEIS'06, MSVVEIS'05.
- 12 publications in international peer-reviewed journals and 42 publications in international peer-reviewed conferences.
- Invited lecture: Second International Symposium on Formal Methods for Components and Object (FMCO 2003).
- Member of organizing committees of the following conferences: PaCT 97 and ICATPN2003

*B. van Dongen*

- PC member of the following conferences: IEEE EDOC (2007, 2008, 2009), BPM, Intelligence Workshop (2007, 2008, 2009), BPM (Demonstration Track 2009).
- Published about 28 papers since 2002 according to DBLP.

# 5. Internal evaluation

See Part A.8

# 6. External validation

## 6.a. Societal relevance

AIS researchers have worked on a wide range of topics including workflow management, process mining, simulation, Petri nets, business process management, process modeling, and process analysis. This resulted not only in landmark publications but also in software products and true impact in industry.

The notion of soundness has been widely adopted. Moreover, it is now possible to analyze the models used in industry (BPMN, EPCs, Protos, etc.). For example, we analyzed the entire SAP Reference Model and found that about 20 percent of its EPCs (Event-driven Process Chains) are flawed. This raised quite some interest from industry. For example, the German magazine for IT professionals (iX) featured an article “SAPs Referenzmodell: Sand im Getriebe” presenting our findings. Similar articles appeared in the Automatisering Gids, Computable, BPTrends, etc. and have made practitioners aware of the need for verification.

The Workflow Patterns initiative has influenced several standardization processes and has become a standard tool for the selection of WFM/BPM technology. In the last decade hundreds of patterns have been collected and these are distributed via the website `www.workflowpatterns.com`. This website was set up by Van der Aalst and has been the most visited website in the workflow area for many years. On a typical working day the site is visited by more than 500 unique visitors, thus illustrating the practical interest in the workflow patterns. Standards like BPEL, BPMN, etc. are influenced by the patterns. Moreover, several vendors have extended their systems based on the patterns (IBM, Staffware, Pallas Athena, JBoss, BizAgi, Pectra, etc.).

More recently, the work on process mining had significant impact on the BPM field. The ProM tool, developed by members of the AIS group, has been applied in dozens of companies. Many of the ideas in ProM have been re-implemented in commercial tools such as Protos, BPM|one, Futura Reflect, ARIS PPM, etc. The work on process mining done at TU/e is seen as one of the most important innovations in the BPM field by Gartner. This is illustrated by the fact that Futura Process Intelligence and Pallas Athena were recently selected as “Cool Vendor 2009” by Gartner, because of their process mining capabilities. Both tools use genetic process mining algorithms developed for ProM. The work on process mining done within AIS was also nominated for the ICTregie Award 2009 because of the many real-life applications of ProM.

AIS also plays an important role in LaQuSo (Laboratory for Quality Software) where process mining is one of the main services. Through LaQuSo several process mining projects have been conducted in industry.

## 6b. Industrial contacts

Industrial contacts of AIS: Pallas Athena (NL): process mining, simulation, case handling, and process configuration, Futura Process Intelligence (NL): process mining and process discovery, Fluxicon (NL/Germany): process mining and conformance checking, Philips Healthcare (NL): process mining based on event logs of medical devices, IBM Research (Switzerland/US): workflow patterns and analysis, IBM Development (Germany/US): case handling and process mining in WebSphere, SAP AG (Germany/Australia): semantic process mining of ERP systems, Océ (NL): Petri-net-based modeling and analysis of copiers, Thales (NL): adapter generation and interface discovery in systems of systems, IDS Scheer (Germany): process mining and social network analysis, Academisch Medisch Centrum (NL): workflow management and process mining for hospitals, ING Group (NL): process redesign and analysis in investment banking, ILOG/IBM (France): optimization and planning, and Deloitte (NL): IT support for auditing using process mining and process modeling.

# 7. Researchers and other personnel

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|
| **Full professor** | | | | | | | |
| van Hee, prof.dr. K.M. | 0,32 | 0,32 | 0,36 | 0,22 | 0,16 | 0,16 | 0,16 |
| van der Aalst, prof.dr.ir. W.M.P. | | | | | 0,11 | 0,32 | 0,32 |
| **Associate professor** | | | | | | | |
| Houben, prof.dr.ir. G.J.P.M. | 0,40 | 0,40 | 0,40 | 0,18 | 0,10 | 0,10 | 0,08 |
| **Assistant professor** | | | | | | | |
| Sidorova, dr. N. | 0,40 | 0,40 | 0,40 | 0,27 | 0,40 | 0,30 | 0,27 |
| Voorhoeve, dr. M. | 0,40 | 0,40 | 0,40 | 0,40 | 0,40 | 0,40 | 0.3 |
| **Total tenured staff** | **1,52** | **1,52** | **1,57** | **1,06** | **1,17** | **1,28** | **0,82** |
| **Full professor** | | | | | | | |
| van der Aalst, prof.dr.ir. W.M.P. | 0,10 | 0,08 | | | | | |
| **Associate professor** | | | | | | | |
| Somers, dr. L.J.A.M. | 0,10 | 0,10 | 0,10 | 0,10 | 0,10 | 0,10 | 0,10 |
| **Assistant professor** | | | | | | | |
| Verkoulen, dr.ir. P.A.C. | 0,08 | | | | | | |
| Thiran, dr. P.A.P. | | 0,17 | 0,40 | 0,23 | | | |
| Broekstra, dr. J. | | | | 0,03 | 0,20 | 0,12 | |
| **Postdoc** | | | | | | | |
| van Dongen, dr.ir. B.F. | | | | | | 0,50 | 1,00 |
| Mooij, dr.ir. A.J. | | | | | | 0,25 | 1,00 |
| Pesic, dr. M. | | | | | | | 0,28 |
| Trcka, dr. N. | | | | | | | 1,00 |
| **Researcher** | | | | | | | |
| Günther, dr. C.W. | | | | | | | 0,08 |
| **Total non-tenured staff** | **0,28** | **0,35** | **0,50** | **0,37** | **0,30** | **0,97** | **3,46** |
| **PhD student** | | | | | | | |
| van der Toorn, drs. R.A. | 0,40 | 0,13 | | | | | |
| Zerguini, L. | 0,80 | 0,73 | | | | | |
| Boender | | 0,07 | 0,60 | | | | |
| Oanea, O.I. | | | 0,40 | 0,80 | 0,80 | 0,80 | 0,40 |
| Hakobyan, L. | | | | 0,45 | 0,80 | 0,60 | |
| van der Werf, ir. J.M.E.M. | | | | | 0,27 | 0,80 | 0,80 |
| Bratosin, C.C. | | | | | | 0,80 | 0,80 |
| Schonenberg, ir. M.H. | | | | | | 0,80 | 0,80 |
| Verdonk MSc, M.C. | | | | | | 0,01 | 0,08 |
| Kannan MSc, V. | | | | | | | 0.28 |
| Nakatumba MSc, J. | | | | | | | 0,67 |
| Rantham Prabhakara ME, J.C.B. | | | | | | | 0,58 |
| Zhengxing MSc, H. | | | | | | | 0,76 |
| **Total PhD students** | **1,20** | **0,93** | **1,00** | **1,25** | **2,13** | **3,81** | **4,91** |
| **Total research staff** | **3,00** | **2,80** | **3,07** | **2,68** | **3,60** | **6,05** | **9,19** |

# 8. Resources, funding and facilities

## 8.a. Laboratory infrastructure

The AIS group has an excellent IT infrastructure for conducting research on process modeling and analysis, process mining, and PAIS technology. Many vendors have donated their software, e.g., we are frequently using WebSphere of IBM, BPM|one of Pallas Athena, Staffware of Tibco, etc. To effectively use these packages, we have several powerful server machines. Moreover, for our process mining research we have set up a computer grid in 2008. This allows us to do the large scale experiments needed for evaluating various genetic process mining techniques, simulating redesign strategies, workflow planning techniques, workflow testing, verification, etc.

## 8.b Funding

| *Percentage %* | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | average |
|---|---|---|---|---|---|---|---|---|
| Direct funding | 94% | 89% | 90% | 82% | 80% | 70% | 56% | 76% |
| Research funds | 6% | 0% | 7% | 18% | 15% | 21% | 19% | 14% |
| Contracts | 0% | 11% | 4% | 0% | 5% | 9% | 26% | 10% |

Table 11: Funding of AIS.

| *Percentage %* | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | average |
|---|---|---|---|---|---|---|---|---|
| Direct funding | 100% | 93% | 40% | 64% | 50% | 20% | 6% | 31% |
| Research funds | 0% | 7% | 60% | 36% | 38% | 54% | 40% | 39% |
| Contracts | 0% | 0% | 0% | 0% | 13% | 26% | 34% | 21% |
| Other | 0% | 0% | 0% | 0% | 0% | 0% | 21% | 8% |

Table 12: Funding of postdocs/PhD's.

## 8.c. List of external funds

Below the external funds are listed with for each project the researchers that are (partially) funded from the project.

| *period* | *external funding (2002–2008): research grant* | *budget (k€)* |
|---|---|---|
| 2003–2008 | NWO (OC) : MOVEBP – Modelling and verification of business processes<br>Boender, Oanea | 218 |
| 2005–2009 | NWO (OC) : STRESS – Statistical testing and reliability estimation of software systems<br>Hakobyan | 168 |
| 2007–2010 | NWO(OC) : Providing full life cycle support for adaptive process by advanced mining approaches<br>Schonenberg M.H. | 170 |
| 2007–2010 | NWO(OC) : Workflow Management for Large Parallel and Distributed Applications<br>Bratosin, Trcka | 295 |
| 2008–2012 | STW : Controlling Dynamic Real Life Workflow Situations with Demand Driven Workflow Systems<br>Pesic | 170 |

| *period* | *external funding (2002–2008) : Contracts* | *budget (k€)* |
|---|---|---|
| 2006–2010 | Deloitte Consultancy BV: PhD-research<br>Van der Werf | 256 |
| 2007–2010 | IBM Germany: Supporting case handling in Websphere process server and portal<br>Van der Aalst | 75 |
| 2007–2012 | BSIK (Embedded system Institute - Research Project) : OCTOPUS<br>Van der Aalst, Kannan, Voorhoeve | 184 |
| 2007–2012 | BSIK (Embedded system Institute- Research Project) : Poseidon<br>Van der Aalst, Günther , Voorhoeve, Mooij | 392 |
| 2007–2011 | Nuffic (Strengthening ICT training and research cap. in the 4 public univ.in Uganda)<br>Nakatumba | 167 |
| 2008–2011 | Senter (Remote Robotics)<br>Majdodin | 202 |
| 2008–2012 | Philips: Process Mining cardio Vascular ( Innovation Service)<br>Rantham Prabhakara | 287 |

# Overview of the results

## 9.a. Key publications

1. **W.M.P. van der Aalst**, A.H.M. ter Hofstede, B. Kiepuszewski, and A.P. Barros. *Workflow Patterns.* Distributed and Parallel Databases, 14(1):5-51, 2003. (1177 citations).
(This paper describes the first set of 20 control-flow patterns. This triggered a new line of research where patterns are being documented based on their actual use in practise. The paper has had a tremendous impact. The workflow patterns are known by all researchers in the workflow and BPM space. Moreover, the work is used in standards and triggered the modification of many workflow management systems.)

2. **W.M.P. van der Aalst** and **K.M. van Hee**. *Workflow Management: Models, Methods, and Systems.* MIT press, Cambridge, MA, 2002. (894 citations).
(This book has become one of the standard reference books in this area. It has been translated into Chinese, Dutch, Russian, and Portuguese. The book stimulated researchers and practitioners to use Petri nets for the modeling and analysis of workflow systems. It is used as a textbook at many universities all over the world.)

3. **W.M.P. van der Aalst** and A.H.M. ter Hofstede. *YAWL: Yet Another Workflow Language.* Information Systems, 30(4):245-275, 2005 (442 citations).
(This was the first paper on YAWL. The paper defines operational semantics for YAWL and shows its support for the workflow patterns. Since then, many researchers have used YAWL as a formal foundation for their work. Moreover, the software supporting the YAWL is one of the most widely used open-source workflow systems. The paper triggered a lot of research as is illustrated by the YAWL book published by Springer (in print).)

4. **W.M.P. van der Aalst**, B.F. van Dongen, J. Herbst, L. Maruster, G. Schimm, and A.J.M.M. Weijters. *Workflow Mining: A Survey of Issues and Approaches.* Data and Knowledge Engineering, 47(2):237-267, 2003 (345 citations).
(This paper provides an early survey on process mining and defines a tool independent XML format to store logs (MXML). It compares different approaches and identifies important challenges. It triggered new research and several research groups (including AIS) are still working on challenges identified in this paper. Moreover, MXML is still the standard format to store and structure events logs.)

5. **W.M.P. van der Aalst**, A.J.M.M. Weijters, and L. Maruster. *Workflow Mining: Discovering Process Models from Event Logs.* IEEE Transactions on Knowledge and Data Engineering,

16(9):1128-1142, 2004 (265 citations).
(This paper provides a theoretical analysis of the $\alpha$ algorithm developed by the authors. It shows which classes of processes can be discovered and which cannot be discovered. The $\alpha$ algorithm was the starting point for the process mining initiative at TU/e and resulted in the development of ProM, which is now the core tool within AIS.)

## 9.b. Numerical overview

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | total |
|---|---|---|---|---|---|---|---|---|
| **1. Academic publications** | | | | | | | | |
| a. in refereed journals | 5 | 12 | 2 | 2 | 11 | 26 | 27 | 85 |
| b. in refereed proceedings | 22 | 18 | 17 | 13 | 50 | 49 | 57 | 226 |
| c. book chapters | 1 | | | 1 | 5 | 2 | 4 | 13 |
| d. other | 1 | | | | 1 | 1 | 3 | 6 |
| **Total** | **29** | **30** | **19** | **16** | **67** | **78** | **90** | **329** |
| **2. Monographs** | 1 | 1 | 2 | | | | | 4 |
| **3. Ph.D. theses** | 1 | | 1 | | | 1 | | 3 |
| **4. Profess. publ. & products** | | | | | | | | |
| a. publications | | | | | | | | |
| b. software | | 1 | 2 | | | | | 3 |
| **Total** | | **1** | **2** | | | | | **3** |
| Patents | | | | | | | | |

## 9.c. List of publications

**Academic publications : refereed journals**

2002.

**W.M.P. van der Aalst**[10], **K.M. van Hee**, **R.A. van der Toorn** (2002). Component-based software architectures : a framework based on inheritance of behavior.*Science of Computer Programming*, 42(2–3), 129–171.

**W.M.P. van der Aalst**, **K.M. van Hee**, **R.A. van der Toorn** (2002). Compositionality of projection inheritance (Erratum). *Science of Computer Programming*, 44(3), 343–344.

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**W.M.P. van der Aalst**, A.A. Basten (2002). Inheritance of workflows : an approach to tackling problems related to change. *Theoretical Computer Science*, 270(1–2), 125–203.

A. Kumar, **W.M.P. van der Aalst**, H.M.W. Verbeek (2002). Dynamic Work Distribution in Workflow Management Systems: How to Balance Quality and Performance? *Journal of Management Information Systems*, 18(3), 157-193.

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**W.M.P. van der Aalst**(2003). Inheritance of Interorganizational Workflows: How to agree to disagree without loosing control? *Information Technology and Management Journal, 4(4)*, 345-389.

**W.M.P. van der Aalst**(2003). Don't go with the flow: Web services composition standards exposed. *IEEE Intelligent Systems*, 18(1), 72-76.

[10]Names of authors participating in the research programme AIS are printed in boldface.

**W.M.P. van der Aalst**, B.F. van Dongen, J. Herbst, L. Maruster, G. Schimm, A.J.M.M. Weijters(2003). Workflow Mining: A Survey of Issues and Approaches. *Data and Knowledge Engineerin*g, 47(2), 237-267, 2003.

**W.M.P. van der Aalst**, A.H.M. ter Hofstede, B. Kiepuszewski, A.P. Barros(2003). Workflow patterns. *Distributed and Parallel Databases*, 14(1), 5-51.

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**W.M.P. van der Aalst**, M. Stoffele, J.W.F. Wamelink(2003). Case Handling in Construction. *Automation in Construction*, 12(3), 303-320.

**W.M.P. van der Aalst**, M. Weske, G. Wirtz (2003). Advanced Topics in Workflow Management: Issues, Requirements, and Solutions. *Journal of Integrated Design and Process Science*, 7(3), 49-77.

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H. Reijers, J. Rigter, **W.M.P. van der Aalst**(2003). The Case Handling Case. *International Journal of Cooperative Information Systems*, 12(3), 365-391.

A.J.M.M. Weijters, **W.M.P. van der Aalst**(2003). Rediscovering Workflow Models from Event-Based Data using Little Thumb. *Integrated Computer-Aided Engineering*, 10(2), 151-162.

**R. Vdovják**, F. Frasincar, **G.J.P.M. Houben**, **P. Barna** (2003). Engineering semantic web information systems in Hera. *Journal of Web Engineering*, 2(1–2), 3–26. (also listed under DH)

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L.M. Aroyo, P.M.E. De Bra, **G.J.P.M. Houben**, R. Vdovják (2004). Embedding information retrieval in adaptive hypermedia: IR meets AHA! *New Review of Hypermedia and Multimedia*, 10(1), 53–76. (also listed under DH)

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**W.M.P. van der Aalst**, M. Beisiegel, **K.M. van Hee**, D. König, **C. Stahl** (2007). An SOA-based architecture framework. International Journal of Business Process Integration and Management, 2(2), 91-101.

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F. Gottschalk, **W.M.P. van der Aalst**, M.H Jansen-Vullers, M. La Rosa (2008). Configurable workflow models. *International Journal of Cooperative Information Systems*, 17(2), 177-221.

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J.B. Jørgensen, K.B. Lassen, **W.M.P. van der Aalst**. (2008). From task descriptions via colored Petri Nets towards an implementation of a new electronic patient record workflow system. *International Journal on Software Tools for Technology Transfer*, 10(1), 15-28.

P. Massuthe, A. Serebrenik, **N. Sidorova**, K. Wolf (2008). Can I find a partner? Undecidability of partner existence for open nets. *Information Processing Letters*, 108(6), 374-378.

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A. Rozinat, **W.M.P. van der Aalst** (2008). Conformance checking of processes based on monitoring real behavior. *Information Systems*, 33(1), 64-95.

A. Rozinat, R.S. Mans, M. Song, **W.M.P. van der Aalst** (2008). Discovering colored Petri nets from event logs. *International Journal on Software Tools for Technology Transfer*, 10(1), 57-74.

N. Russell, **W.M.P. van der Aalst** (2008). Workflow resource patterns as a rule to support OASIS BPEL4People standardization efforts. *BPTrends*, March 2008.

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M.S. Song, **W.M.P. van der Aalst** (2008). Towards comprehensive support for organizational mining. Decision Support Systems, 46(1), 300-317.

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