


10 Years Telecooperation at TU Darmstadt



25 Years
Telecooperation Research





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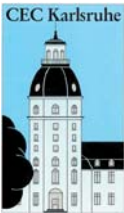
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We celebrate!



This booklet is about the Telecooperation Lab at the Technische Universität Darmstadt; we celebrate two anniversaries in 2011: twenty-five years Telecooperation research led by Prof. Dr. Max Mühlhäuser and ten years existence of the lab in Darmstadt. We cannot celebrate these events without a quick look at ...

History



25 years ago, not long after finishing his PhD at the University of Karlsruhe under Professor Gerhard Krüger, young researcher Max Mühlhäuser accepted the offer to conceive and manage the first European research center of Digital Equipment Corporation (DEC), at the time the world's second largest computer manufacturer. His center should become a role model for industrial research and technology transfer centers co-located with academic research, and serve as a blueprint for similar centers in Europe, Australia, North America, and South Africa.

What we celebrate as twenty five years of Telecooperation research in 2011, started with projects on distributed object-oriented software engineering and on e-learning, harnessing the most innovative hardware available at the time: multimedia workstations.



In 1989, Max Mühlhäuser moved back to academia, accepting a professorship position at the University of Kaiserslautern. His group grew and topics proliferated, now covering Telecooperation in the classical sense of IT supported group cooperation over distance.



Professorship offers by Université de Montréal and University of Karlsruhe followed in 1992. He accepted the latter one and started the Telecooperation Office (TecO) with support from his successors at DEC, Dr. Igor Varsek and Prof. Dr. Lutz Heuser. TecO would soon become the breeding place of Ubiquitous Computing research in Europe, with Professor Hans-Werner Gellersen starting as a PhD candidate there and taking the center to its full bloom after Professor Mühlhäuser's leave.



In 1994, Professor Mühlhäuser received professorship offers from Institut Eurécom, France, and the University of Linz. The latter included the charter to develop turn-key ready solutions for an entire floor of an exciting new center linked to the world famous Ars Electronica electronic arts festival. The entire new group in Linz worked with great zeal in 1995, and over thirty TV stations from all around the world acknowledged the results at the opening.



After a visiting professorship stopover in California, he received further professorship offers from the Universities of Klagenfurt and Darmstadt. In 2000, his move to Darmstadt began. He started by taking over and reshaping the computing services of the computer science department. By 2001, the restructuring of the Distributed Systems Lab that he had taken over was finished, too—including the official name change to Telecooperation Lab. The rest of this booklet shows what the lab looks like after ten years.



Telecooperation Lab

As part of the preparations for our 10 / 25 years anniversary, a new logo was introduced. It is intended to symbolize an even tighter integration of humans, computers (worn, embedded, or else), and „the net“.

Welcome

Telecooperation Lab

The Telecooperation Lab (TK) represents a group of well over 30 people at the Technische Universität Darmstadt, Department of Computer Science. Prof. Dr. Max Mühlhäuser is heading this group together with several senior researchers and group leaders. Juniorprofessor Dr. Thorsten Strufe is leading the adjunct group on Peer-to-Peer Networks. The RBG division is also part of the Lab, conducting e-learning research and providing computing services to the department.

Prof. Mühlhäuser is a directorate member of CASED, the Center for Advanced Security Research Darmstadt. Further duties include university wide responsibilities in e-learning projects, leading roles in European and national cooperative projects, memberships and leads in technology transfer boards, and more. Both Prof. Mühlhäuser and Prof. Strufe are members of the DFG funded research group on Quality in Peer-to-Peer Networks.

Vision and Mission

We envision the Future Internet to enable computer augmented Smart Spaces populated with smart objects; sizes range from meeting rooms to megacities and beyond; *distributed* Smart Spaces aim at a seamless experience of multiple physical spaces; *virtual* Smart Spaces reflect social or topical networks.

Our mission is the technological advancement of Smart Spaces for the benefit of humans populating them; this comprises improved *cooperation* among humans and Smart Spaces, enjoyable *interaction*, and *protection* from malicious and hazardous threats.

FB 20 & TU Darmstadt

As early as 1957, the first programming lectures were held in Darmstadt. In 1972, the Department of Computer Science was founded, one of the first in Germany. It is ranked among the top institutions of its kind in Germany, closely interwoven with IT research in the region—including the Fraunhofer institutes on Computer Graphics and on IT Security—and with the „Software Valley“ in southwest Germany.

Professors



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Dr. Michael Hartle

Further Postdocs



Dr. Leonardo Martucci



Dr. Guido Rößling



Dr. Daniel Schreiber



Cooperative Projects

Collaborative projects (selection)



Funding and cooperation (selection)



SAP AG, Lufthansa AG, Fiat CRF, EADS, Philips, AGT Germany

Research Fields

Research at Telecooperation

We conduct research and teaching in Ubiquitous (aka Pervasive) Computing, aiming at *Smart Spaces in the Future Internet*. Building upon networks of embedded and carry-on devices that surround humans anytime and anywhere, we foster integrated, situation- and user-aware environments that provide a comprehensive user experience and protect humans and assets.

Our integrated approach demands research advancements in several fields: computer networks and distributed systems (a focus of our teaching), multimodal human computer interaction, web and software engineering, security & trust, knowledge engineering, and e-learning.

Research fields

According to our mission, our research is organized into three fields:

Cooperation

This field is divided into three research areas that conduct research in

- i) middleware and software engineering support for Smart Spaces,
- ii) peer-to-peer and social networking, and
- iii) approaches to knowledge work and e-learning.

Interaction

Several research areas develop device specific interaction concepts for large surface displays, pen&paper, e-paper, and voice; others consider UI improvements *independent of* device specific concepts: proactivity, context awareness, and multi-device interaction. Finally, we investigate the integration of these new concepts with software engineering.

Protection

On one hand the ubiquitous presence of networked computers yields new challenges for privacy protection, security, and trust establishment. On the other hand, it opens new chances for improved protection of humans and assets, e.g., in critical infrastructures. Both „sides of the coin“ are investigated as part of our engagement in the CASED research center.

Research areas at Telecooperation

Peer-to-Peer Networking

- Resilience & Privacy
- P2P user models & social networks
- P2P live streaming & service distribution
- Formal analysis of overlays and protocols

Smart Environments

- Communication Middleware
- Context-aware Systems
- Service Self-organization

Ambient Learning Structures

- Digital lecture support for students and teachers
- Extending learning portals for CS education
- Algorithm and program visualization and animation

Cooperation

Model Driven Interaction

- Model Driven UI Development
- Model Driven Development of Multimodal Applications
- Model Transformations, and Languages

Tangible Interaction

- Pen-and-Paper User Interfaces
- Tabletop Interfaces
- Mixed-reality Environments

Interaction

Talk & Touch

- Voice based Interaction
- Voice for Ubiquitous Computing
- Multimodal Tabletop Interfaces

Smart Interaction

- Federated Devices
- Intelligent User Interfaces
- Interacting with Smart Products
- Context-aware User Interfaces

Smart Security and Trust

- Trust & Reputation
- Privacy
- Identity Management
- Multilateral Security
- Smart Security for Smart Products

Smart Civil Security

- Integrated infrastructures
- HCI for teams under pressure
- Sensor Networks
- Routing in Mobile Ad hoc Networks

Protection

Smart Environments



Ubiquitous Computing (UC)—often also called Pervasive Computing or Ambient Intelligence—introduces a large variety of new computing devices, vastly different in terms of size, processor speed, memory capacity, and user interface. In contrast to the PC-era, UC no longer relies on a single device: its real power emerges from the intelligent cooperation of many devices.

One of our major aims is the development of system software for applications spanning multiple devices, thereby providing the equivalent to a classic operating system, but tailored for distributed, mobile environments and smart spaces. In addition, we investigate sensing, activity recognition, architectures, processes, and tools for the development of ubiquitous computing systems.

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As Smart Environments we consider, e.g.,

- Future command & control rooms with local positioning, interactive tabletops & walls, and other IT infrastructure.
- Mobile workplaces where assembly or maintenance work takes place, requiring hands-free & eyes-free interaction with the computer system, like in aircraft repair.
- Fully virtualized environments.

Research Topics

- Ubiquitous Computing Middleware
- Internet of Services
- Local Positioning & Indoor Navigation
- Engineering Smart Environments and Smart Products
- Sensors & Movement Recognition
- Image Processing & Object Tracking

Selected Publications

Reducing User Perceived Latency with a Proactive Prefetching Middleware for Mobile SOA Access

Daniel Schreiber, Andreas Göb, Erwin Aitenbichler, and Max Mühlhäuser
In: Journal of Web Services Research (JWSR), vol. 7, no. 4, pp. 68-85, 2010.

Application of Subject-oriented Modeling in Automatic Service Composition

Erwin Aitenbichler and Stephan Borgert
In: S-BPM ONE, vol. 85 of CCIS, pp. 71-82, Springer, 2010.

Probabilistic Model of Pianists' Arm Touch Movements

Aristotelis Hadjakos, Erwin Aitenbichler, and Max Mühlhäuser
In: Proceedings of New Interfaces for Musical Expression (NIME), pp. 7-12, 2009.

MundoCore: A Light-weight Infrastructure for Pervasive Computing

Erwin Aitenbichler, Jussi Kangasharju, and Max Mühlhäuser
In: Pervasive and Mobile Computing, vol. 3, no. 4, pp. 332-361, Elsevier B.V., 2007.

People



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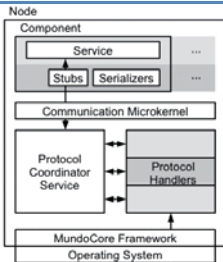
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Smart Environments: Projects

Ubiquitous Computing Middleware

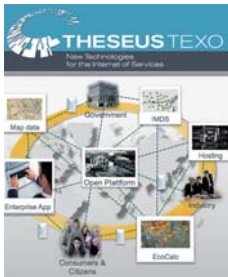


MundoCore is an open source communication middleware for developing, deploying and managing highly dynamic distributed systems.

- Applications can be composed of heterogeneous services, based on various languages (C++, Java, .NET, Objective-C) and operating systems (Windows, (embedded) Linux, Solaris, MacOS) on a wide range of devices (PCs, Android, iPhone, embedded systems).
- The major paradigms request/reply („pull“), publish/subscribe („push“), and streaming are equally supported, as well as an ORB.
- Automatic peer discovery allows peers to automatically find each other in the subnet and facilitates true ad-hoc networking.
- MundoCore is based on a microkernel design and has a highly modular architecture.

This allows us to keep the footprint very small. MundoCore is open source and available from: <http://www.tk.informatik.tu-darmstadt.de/index.php?id=mundocore>

Internet of Services – Theseus/TEXO



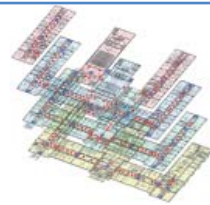
Theseus is a large-scale project funded by the German Federal Ministry of Economics and Technology to advance technologies around the Internet of Services (IoS). The subproject TEXO develops a service marketplace and tools to support all phases of the service lifecycle. Our focus in this project is on „Context-aware Service Composition“.

In contrast to today's closed SOA systems, the IoS promises an open market, where every participant is free to offer and consume services over the Internet. This gives businesses the opportunity to outsource parts of their internal processes and to replace them by using external services. The services offered will be different in many details, such as their quality and how their internal processes are realized. Consequently, B2B customers must ensure process compatibility before execution

and must be able to quickly adapt to changes in service offerings on the market. To achieve these goals, we focus on formal methods for composition, verification, and adaptation.

Local Positioning Systems & Indoor Navigation

Today, the satellite-based GPS system is the ubiquitous standard for outdoor positioning. In contrast to that, indoor positioning is still a field of active research. Because no single system can fulfill all requirements, we have integrated over a dozen of commercial systems with our middleware, developed own systems, and a simulation environment that helps to pick the right system for a given application.



Beside asset tracking, Indoor Navigation promises to be one of the first big application domains for LPS technology. Indoor navigation is considerably more complex than outdoor navigation, because it adds a spatial dimension and there are several additional factors beside „finding the shortest path“ that need to be taken into account. Our system **CoINS** (Context-aware Indoor Navigation System) includes the context and generates easily comprehensible explanations. The web-based version of CoINS can be used on any mobile device with a browser and QR code reading software.

Engineering Smart Environments & Smart Products

The **Mundo** project is concerned with general architectures, middleware, common services, and software development for Ubiquitous Computing, which brings along a large spectrum of new computing devices with vastly different characteristics. Hence, Mundo introduces the five entities (ME, US, IT, WE, and THEY) emphasizing the meaning of devices to users. The architecture is centered around the user's Personal Trusted Device, called ME. Users can extend their PAN by associating USEs, collaborate in WEs, or use infrastructure services provided by the THEY.



The Mundo Smart Environments Platform provides services and tools that support all phases of the development and application lifecycle. A different approach is taken in the Smart Products project: Instead of designing the environment on the drawing board in a top-down manner, the emphasis lies on its bottom-up construction. Smart Environments incrementally grow by adding more Smart Products to them, thereby creating higher functionalities for the users.

P2P Networks

Our main research focus lies on building reliable and secure P2P infrastructures. We are aiming at leveraging the properties that are inherent to P2P systems, like their robustness, scalability and distributed location of data, for new applications and services, like, e.g., Online Social Networks, Distributed Computing Services (aka „Cloud Computing“), Overlay Live Streaming, and Emergency First Response.

More generally, we are trying to learn more on how computer networks and distributed systems can be created to be especially robust

to failure and resilient to all types of attacks that aim at breaking their availability. In our research to provide peer-to-peer based social networking services we have gathered and analysed several data sets.

Research Topics

- Peer-to-Peer Networking
- Resilience & Privacy
- P2P user models & social networks
- P2P live streaming & service distribution
- Formal analysis of overlays and protocols

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Selected Publications

All Your Contacts Are Belong to Us: Automated Identity Theft Attacks on Social Networks.

Leyla Bilge, Thorsten Strufe, Davide Balzarotti, and Engin Kirda

In: Proceedings of the 18th International World Wide Web Conference, pp. 551-560, 2009.

Safebook: A privacy-preserving online social network leveraging on real-life trust.

L. A. Cuttillo, R. Molva, and T. Strufe

In: Communication Magazine, IEEE, vol. 47, Issue 12, pp. 94-101, December, 2009

Optimally DoS resistant P2P Topologies for Live Multimedia Streaming.

Michael Brinkmeier, Guenter Schaefer, and Thorsten Strufe

In: Transactions on Parallel and Distributed Systems, vol. 99, pp. 831-844, 2009.

Profile Popularity in a Business-oriented Online Social Network.

Thorsten Strufe

In: Proceedings of the EuroSys Conference, pp. 1-6, 2010.

Distributed Automatic Configuration of Complex IPsec-Infrastructures.

Michael Rossberg, Günter Schäfer, and Thorsten Strufe

In: Journal of Network and Systems Management, vol. 18, pp. 300-326, 2010

GTNA - A Framework for the Graph-Theoretic Network Analysis.

Benjamin Schiller, Dirk Bradler, Immanuel Schweizer, Max Mühlhäuser, Thorsten Strufe

In: Spring Simulation Multi-Conference - 13th Communications and Networking Symposium (CNS), pp. 1-8, 2010.

Decentralizing Social Networking Services.

Thomas Paul, Sonja Buchegger, Thorsten Strufe

In: International Tyrrhenian Workshop on Digital Communications, pp. 1-10, 2010.

Leveraging Network Motifs for the Adaptation of Structured Peer-to-Peer-Networks.

Lachezar Krumov, Immanuel Schweizer, Dirk Bradler, Thorsten Strufe

In: Proceedings of IEEE GlobeCom, pp. 1-6, December 2010.

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Thomas Paul
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P2P Networks: Projects

P2P-based Social IPTV



The goal of the „P2P-based Social IPTV“ is to analyze the feasibility how future IPTV services can be provided, based on decentralized (P2P) mechanisms in a reliable and secure way. New services and possible applications making the next generation IPTV more attractive are to be identified and sketched. Next generation networking technologies will be analyzed for the possibility of cross-layer optimization in this context. The project is a cooperation between ETRI (the Electronics and Telecommunications Research Institute of Korea) and TU Darmstadt.

Safebook



Safebook is a P2P Online Social Network. Online Social Networks are currently probably the online service that is most accepted by users and that generates the largest amount of data, and of network traffic. However, knowing about a wide range of security problems of the existing Social Networking Services, with the service provider being a big brother that keeps track of all published data and uses it for commercial purposes, we aim at

creating a privacy preserving and secure social networking service, based on P2P. Safebook is a cooperation of the P2P Networks Group, TU Darmstadt, and EURECOM.

QuaP2P



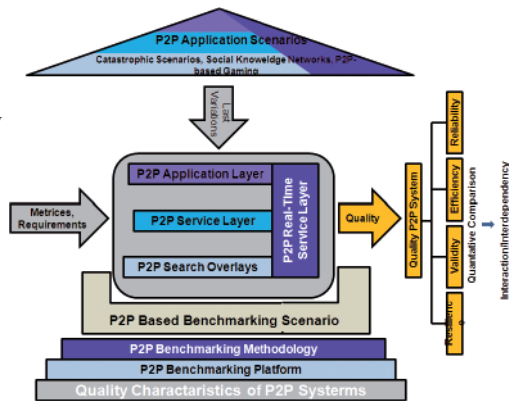
P2P applications assure their efficiency by simultaneously accomplishing a certain application service on all peers. One example are P2P file sharing networks like BitTorrent where many peers participate to distribute files to other peers. In doing so, an overlay network is created on the application layer which can be entirely independent from the search overlay network (i.e., the original version of BitTorrent did not use any P2P search overlays at all).

Therefore, the quality of an overlay on the application layer is crucial to the efficiency of a P2P application. Another example for application overlay networks are P2P live streaming applications. The efficient maintenance of such an overlay network is crucial to successfully distributing the live streams to other peers.

The fundamental functions which need to be examined on this layer regarding the multilateral interaction are the configuration, distribution and maintenance of reliable P2P applications and application-

oriented P2P services under normal conditions as well as with opportunistic and harmful behavior of peers.

This is because a malfunction of the primary P2P application has the most severe consequences and is therefore most attractive to malicious peers and attackers. We use the reference scenario „P2P based communication system for disaster operations“ of the research group as an application scenario, since in such scenarios the guarantee of the performance of services is significant and limits of the performance can be pointed out.



Ambient Learning & Knowledge Work

When learning individually, learning resources or parts thereof are put into relation in a personal knowledge graph. For example, definitions in a book thus become related with examples presented by an educator in a lecture, or with problems posed by fellow students. Yet, manual construction and maintenance of a personal knowledge graph is limited by human cognitive and mental limits; we tend to forget important aspects, or remember wrong relations. Moreover, these personal knowledge graphs typically exist only in an implicit form; benefiting from and sharing knowledge with others depends on individuals to externalize their personal knowledge graphs.



Moreover, these personal knowledge graphs typically exist only in an implicit form; benefiting from and sharing knowledge with others depends on individuals to externalize their personal knowledge graphs.

We focus on the computer-aided construction and maintenance of personal knowledge graphs through suitable tools for producers and consumers, supporting them in learning-related

processes. By acquiring, aggregating, and processing graphs from many users, the user interaction of individual users can be adapted for an improved learning experience.

Computer-aided construction and maintenance of a personal knowledge graph provides a basis for truly collaborative knowledge work, improving the individual user interactions and learning experience over the knowledge digested by many.

Research Topics

- Acquiring, aggregating, and processing semantic relations between learning resources
- Enabling semantic-driven user interaction with learning resources
- Improving collaborative forms of knowledge work in education

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Selected publications

Data Format Description and its Applications in ITSecurity

Michael Hartle, Andreas Fuchs, Marcus Ständer, Daniel Schumann, Max Mühlhäuser
In: International Journal On Advances in Security, vol. 2, no. 1., pp. 90-111, 2009.

Read/Write Lectures: Fostering Active Participation and Increasing Student Engagement in the Lecture Hall

Kai Höver and Michael Hartle

In: Proceedings of the 10th IEEE International Conference on Advanced Learning Technologies (ICALT'10). pp. 503-505, IEEE Press, 2010.

A Survey of Annotation Tools for Lecture Materials

Kai Höver and Guido Rößling

In: Proceedings of the World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2010. pp. 2533-2543, AACE, 2010.

Q&A 2.0: A system to facilitate interaction during and after a lecture

Kai Höver, Jochen Huber, Max Mühlhäuser

In: Proceedings of the World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2010. pp. 2544-2551, AACE, 2010.

People



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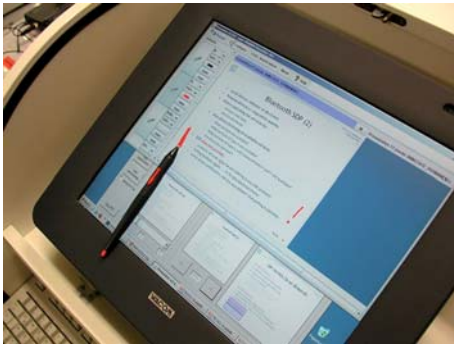
Ambient Learning & Knowledge Work: Projects

Collaborative Connected Learning Space (CCLS)



The CCLS project aims at supporting students in their learning processes, both during and after a lecture. The developed system enables students to semantically augment the provided learning material with other knowledge resources (e.g., websites, blogs, forum discussions, and pen strokes), so that a semantic knowledge graph evolves. In addition, these augmentations can be shared with co-learners. In this way, learners can benefit from the ideas and findings of other users.

Digital Lecture Hall (DLH)



The DLH project aims at supporting instructors in their presentation activities during lectures. The developed systems provide additional functionalities, such as extended annotation of lecture materials and slide history with several projectors, valuable for both instructors and students. In addition, lectures can be recorded in order to support, e.g., students who missed a class, exam preparation, or rehearsal by means of CCLS.

Research

Technical advances allow us to use computers in an increasing number of usage contexts. Not only is the device variety increasing, but user interfaces must also adhere to the situation the device is used in. For example, working with a cellular phone while riding the train is different from using it while walking through a crowded inner city. How should such a variety of user interfaces be developed—cost efficiently, consistently, and adapted to the usage context at hand? We are convinced that this challenge for software engineering will become more urgent in the years to come.

Our group puts forward the use of **model driven engineering** techniques to address this

challenge. We investigate models that—in contrast to traditional programming languages—allow a tighter interweaving of the various user interfaces created for different usage contexts. Hereby, a holistic approach is followed, considering **user interface descriptions both in terms of layout and behavior**. This tight integration is, in our opinion, necessary to be able to address the upcoming diversity of user interfaces in ubiquitous computing scenarios. Developer focused for tools concepts are crucial to the applicability and acceptance of the approach; this need is equally reflected in our research.

Projects

In the **SoKNOS** project, our approach was applied to the development of interaction concepts for a crisis management system that applies novel interaction modalities. Project **Emode** aimed at providing an efficient software development process for multimodal

applications, leveraging a model-driven approach. **Mapache** is a framework and research platform for model driven development of user interfaces developed in our group, following our vision outlined above.

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Tangible Interaction



Graphical user interfaces have long been the dominant interface paradigm. Yet, the future of ubiquitous computing requires novel types of interfaces. We investigate novel user interfaces and interaction techniques that make computing more natural, more playful and more seamlessly integrated into the real world.

Tangible user interfaces tightly couple computing with the physical world. We use digitally-augmented physical objects (e.g., digital pen and paper) and we augment traditional digital devices by physical capabilities (e.g., tabletop displays with tangible objects; rollable and foldable displays). We particularly focus on social interfaces that offer support for communication and collaboration.

We are convinced that in this field, novel contributions require a comprehensive approach to interaction design. We therefore conduct field studies as an empirical grounding for our work, we generalize our findings to theoretical models, we design and implement user interfaces and interaction techniques, we develop software toolkits and we continuously evaluate our approaches in user studies.

Research Topics

- Paper-centric user interfaces
- Interactive surfaces
- Interfaces for mobile and handheld devices
- Paper-like displays

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Selected Publications

Xpaaand: Interaction Techniques for Rollable Displays

Mohammadreza Khalilbeigi, Roman Lissermann, Max Mühlhäuser, Jürgen Steimle
Proceedings of the 29th international conference on Human factors in computing systems (CHI 2011), ACM Press, to appear, 2011.

CoScribe: Integrating Paper and Digital Documents for Collaborative Knowledge Work

Jürgen Steimle, Oliver Brdiczka, and Max Mühlhäuser
In: IEEE Transactions on Learning Technologies, 2(3), pp. 174-188, IEEE Press, 2009.

Towards More Efficient User Interfaces for Mobile Video Browsing: An In-Depth Exploration of the Design Space

Jochen Huber, Jürgen Steimle, and Max Mühlhäuser
In: Proceedings of ACM Multimedia, ACM Press, pp.341-350, 2010.

Physical and Digital Media Usage Patterns on Interactive Tabletop Surfaces

Jürgen Steimle, Mohammadreza Khalilbeigi, Max Mühlhäuser, and James D. Hollan
In: Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces 2010 (ITS 2010), ACM Press, pp. 167-176, 2010.

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Tangible Interaction: Projects

CoScribe: Integrating Paper and Digital Documents



Even though computing is more than ever part of our private and professional activities, paper is still ubiquitous and plays an important role in knowledge work. In this project, we have developed CoScribe, a collaborative platform for knowledge workers which tightly integrates interaction with printed and digital documents. The project is grounded on an ecological perspective of knowledge work. Based on several field studies on how students learn at universities, we have designed generic interaction concepts, which leverage electronic Anoto pens, paper and tabletops.

CoScribe includes concepts for collaborative handwritten annotations, cross-media hyperlinks, and paper-based tagging. Results of several evaluation studies show that the integration of paper and digital documents in a seamless interaction technique and system enhances both work performance and user satisfaction.

Interacting with Paper-like Displays



Future displays will be thin, lightweight and flexible, very much like traditional paper. This enables novel types of tangible input, such as bending, rolling or folding the display. In this project, we develop novel interaction techniques for such paper-like displays. For this purpose, we simulate such displays using a passive display approach. The 3D position of the display is tracked in real-time, and content is projected accordingly. This allows us to investigate interaction with future displays already today.

Xpaaand, our first prototype, is a mobile device featuring a rollable display. Its display size and its form factor can be dynamically changed. We introduced a set of novel interaction techniques for rollable displays. These support basic actions, such as scrolling, panning and zooming, but also navigation in hierarchies or hypertexts as well as switching between applications. Evaluation results show that physical resizing of the display has a considerable potential to improve the way we interact with digital content on mobile devices. In ongoing and future work, we address bending and folding interactions and examine how the novel techniques can be effectively integrated into work processes.

Mobile Navigation in Video Collections

Increasingly powerful mobile devices like Apple's iPhone are dramatically changing how we perceive multimedia when being on the move. Users are able to access a constantly increasing number of video streams almost anytime and anywhere. Mobile video browsing differs from classical video browsing in a desktop setting in several aspects. On the one hand, mobile devices have severe restrictions due to their form factor (e.g., small displays), but on the other hand, they do also offer support for novel innovative forms of input.

In this project, we explore the design space of mobile video browsers. We have developed various user interfaces, ranging from GUI-inspired interfaces to more innovative concepts, such as gesture-based and tangible interfaces. They support the efficient navigation in individual video segments, larger videos and collections of inter-related videos.



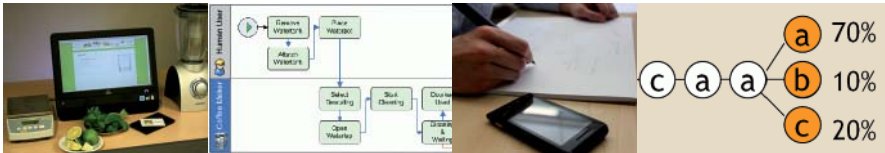
Hybrid Interactive Surfaces

Interactive tabletop displays are increasingly wide-spread. They provide very natural ways of interacting with digital media. We explore a hybrid setting in which both types of media are used in combination on the same surface. An example scenario of hybrid use is a desk of the future. On this desk, people concurrently work with books, printed articles, and sticky notes as well as with digital media, such as e-mails or web pages.



In this project, we examine the affordances of this hybrid setting with in-depth user studies. Results of our studies allowed us to identify usage patterns and to derive implications for the design of tabletop systems. One main challenge of hybrid use is physical occlusion of screen contents. Our results show in which situations occlusion is problematic, but also point out that users intentionally create occlusion in order to express meaning in spatial arrangements. Based on these findings, we design novel interaction techniques for hybrid tabletops. In particular, we provide support for the efficient selection of occluded items as well as for hybrid grouping and sorting of physical and digital documents.

Smart Interaction



Applications and products steadily increase in terms of their complexity and in the amount of features they offer. Interaction with these applications and products takes more and more often place in dynamic environments—i.e., ubiquitous computing settings—in which the set of available input and output devices is constantly changing and often limited. Both trends are a threat to the usability of applications and products, which needs to be addressed with smart interaction techniques.

In the Smart Interaction group, we tackle these problems by applying artificial intelligence techniques and by supporting the dynamic federation of available input and output devices. Thus, our main research focuses on *Intelligent*

User Interfaces for Post-Desktop Interaction. We further investigate how context can be used for enhancing the interaction and how these techniques can be applied to smart products that usually only provide a very limited set of interaction possibilities: e.g. a coffee machine usually has only a small display and a few buttons.

Research Topics

- Interaction with Smart Products
- Post Desktop Interaction
- Context Awareness
- Intelligent User Interfaces
- Multi-Device Interaction
- Pen based interaction

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Selected Publications

Towards Interactionflows for Smart Products

Marcus Ständer

In: ACM Symposium on Applied Computing (SAC 2010), pp. 1234-1235, March 2010.

Letras: An Architecture and Framework For Ubiquitous Pen-and-Paper Interaction

Felix Heinrichs, Jürgen Steimle, Daniel Schreiber, Max Mühlhäuser

In: ACM SIGCHI symposium on Engineering Interactive Computing Systems (EICS 2010), pp. 193-198, June 2010.

AUGUR: Interface Adaptation for Small Screen Devices

Melanie Hartmann, Daniel Schreiber

In: Advances in Ubiquitous User Modelling, pp. 94-110, Springer, 2010.

AUGUR: Providing Context-Aware Interaction Support

Melanie Hartmann, Daniel Schreiber

In: ACM SIGCHI symposium on Engineering Interactive Computing Systems (EICS 2009), pp. 123-131, June 2009.

MundoMonkey: Customizing Interaction with Web Applications in Interactive Spaces

Daniel Schreiber, Melanie Hartmann, Max Mühlhäuser

In: ACM SIGCHI symposium on Engineering Interactive Computing Systems (EICS 2009), pp. 258-290, June 2009.

People



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Area Head



Felix Heinrichs
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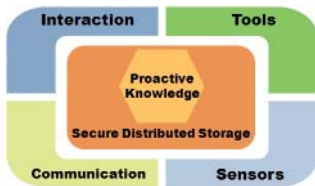
Dr. Daniel Schreiber
Researcher



Marcus Ständer
Researcher

Smart Interaction: Projects

Smart Products



A smart product is an autonomous object designed for self-forming embedding into different environments in the course of its lifecycle, supporting natural and purposeful product-to-human interaction. Smart products proactively approach the user, leveraging sensing, input, and output capabilities of the environment: they are self-, situation-, and context-aware. The related knowledge and functionality is shared by and distributed among multiple smart products and emerges over time.

In the collaborative project Smart Products (<http://www.smartproducts-project.eu>), we investigate the technological and scientific basis for building these smart products. Thereby, our group focuses on providing a natural human product interaction by making use of the dynamically changing amount of sensing and interaction capabilities available in the environment. Smart Products is an integrated project (IP) within the 7th research framework program of the EU in which we act as scientific coordinator.

AdiWa



AdiWa is a project funded by the German Ministry for Education and Research (BMBF), dedicated to exploring the potential of the Internet of Things and smart interaction for enabling intelligent and more efficient business processes. Many practices in contemporary business processes involve using paper artifacts due to their unique affordances documenting, delegating and managing processes. On the one hand, paper use leads to disruptive media transitions in interacting with business process

management systems. On the other hand, a complete replacement of paper artifacts is not feasible in the foreseeable future. Instead of aiming to replace paper artifacts completely, it is therefore envisioned to integrate these artifacts with the Internet of Things and to allow direct interaction (via a digital pen) with the business process management system through these artifacts.

Letras

In modern everyday life, traditional paper artifacts coexist with electronic data, inevitably leading to an integration problem: the „Digital-Physical Gap“. One way to bridge this gap is to employ digital pen technology, so called Pen-and-Paper Interaction (PPI).

To support the rapid development of PPI–based applications in ubiquitous computing settings, we developed an extensible platform called Letras, empowering application developers to base on a common infrastructure and processing model. Letras supports multiple platforms and operating systems, e.g. MS Windows, Mac OS X and Android, and has been successfully employed in a set of PPI based applications.



MundoMonkey

MundoMonkey is a web browser extension for connecting the browser to its environment. Thereby, MundoMonkey combines the ease of end-user scripting for the web with the power of the MundoCore middleware (p. 14). MundoMonkey can be used to adapt web pages to the particular environment they are accessed in, e.g., providing voice interaction capabilities or multi-cursor pointing. MundoMonkey provides an easy to use way for implementing adaptive and multimodal interfaces based on web technology.



AUGUR

Today's applications become more and more complex. User interfaces try to reduce the complexity, but it is difficult to design one user interface that fits the needs of all possible users and device sizes. To counter this effect, we need user interfaces that support the user in performing her tasks in a proactive way. Such Proactive User Interfaces support the user's interaction in various ways: e.g., they can provide guidance through an application, adapt the interface to the user's needs and devices, or assist the user in entering information.



Talk & Touch Interaction

Technological evolution made Human Computer Interaction pervasive in our daily life—our cars, homes and smart-phones surround us with interaction prompts. Ever decreasing sizes of displays and the fact that mobile computers do not receive our full attention require new concepts for interacting with these devices. Automatic speech recognition and text-to-speech technology offer a promising alternative, substituting or augmenting more conventional user interfaces we grew accustomed to. Multi-touch technology is one of the most interesting graphical interaction concepts, gaining popularity with the newer generation of smart phones. The combination of multi-touch and voice recognition has the

potential to dramatically speed up workflows. But there are challenges that arise when using the modality of voice, as experienced with more traditional deployments in telephony and desktop environments. These challenges can be met by a profound knowledge about the design of voice user interfaces on the one hand, and the combination of different modalities on the other. In addition, our research aims at supporting the development of multimodal applications in pervasive environments. Investigated scenarios include meeting rooms, smart cars, and smart homes. Another important aspect of our research includes the social aspects or interaction in our home environments.

Research Topics

- How can multimodality help to overcome the VUI-inherent challenges and how can multitouch benefit from using speech?
- Which dialog strategies/models are best suited to be used for VUI in pervasive environments?
- How can application dialog states and social networks form a basis for social awareness and context information?
- How can we increase the potential of sociability among non-colocated TV viewers?

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Talk & Touch Interaction: Projects

SmartVortex



The goal of Smart Vortex is to provide a technological infrastructure for real time handling of massive product data streams. The project aims at a comprehensive suite of interoperable tools, services, and methods for intelligent management and analysis of such massive data streams, enabling better collaboration and decision making in

large-scale collaborative projects concerning industrial innovation engineering. Smart Vortex is an Integrated Project (IP) of the 7th research Framework Program of the EU.

MundoSpeech API



The idea of having voice based input and output on wearable devices is not simply achieved, by deploying the speech recognition and synthesis engines and running them. The limitations of the platform, especially computational power and memory, pose strong limitations that cannot be handled by conventional implementations. The support of multiple audio input and output devices, multiple text-to-speech engines and speech recognizers with different capabilities in a given environment is the focus of our research towards a ubiquitous computing speech API „Mundo Speech API“.

People



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Sensor and Media Interaction



Movement variability due to mechanical interaction

Human movement is variable. Even when a person repeats a task under identical conditions, slight movement variations are inevitable. This leads to challenges when analyzing human movement. Numerous works have concerned themselves with the recognition of gestures in order to allow a user to interact with a computerized environment, and with the recognition of human activities in order to adapt the environment to the activity the user is currently performing.

Goal-directed movements in one part of the body lead to slight movements in other parts of the body that are beyond direct conscious control. These unintended movements, which we call „secondary movements“, are one source of variability that is evident in sensor recordings of human movement. Being able to estimate the amount of secondary movement that is present at a certain moment in time is significant in two ways:

- To improve current gesture and activity recognition methods: A preprocessing step

could eliminate secondary movement from the sensor signal and reduce the variability between movements that belong to the same gesture or activity. In consequence, the recognition task would be simplified.

- Sensor-based feedback: Feedback that depends noticeably on movements beyond conscious control may feel erratic to the user.

Based on a probabilistic model of human movement and statistical methods, we developed a method that estimates the amount of present secondary movement.

Sensor-based feedback

In recent years, motion sensing hardware has become cheaper and more performing in terms of accuracy and power consumption, making it feasible to include it in consumer products like the Nintendo Wii. However, sensor technology is currently not widely used in fields like rehabilitation, ergonomics, and sports. One of the reasons for this situation is that current

movement analysis methods are not able to cope with the requirements in these fields. This makes research on movement analysis methods a potentially rewarding field of scientific study. There are many potential application fields that could benefit from sensor-based feedback. We have spent particular attention on providing sensor-based feedback for piano pedagogy, cooperating with pertinent institutions for field studies.

Personal Orchestra

Personal Orchestra is an exhibit in the Vienna House of Music, jointly developed by TK and the media computing group at RWTH Aachen. Personal Orchestra has been a major attraction at this highly frequented museum since almost ten years, offering visitors a conductor's podium where they can explore their talent with the famous Vienna Philharmonics. Despite the fact that this world renowned orchestra plays off a large video screen, an electronic conducting baton puts visitors in control of velocity, loudness, and instrument balance. The exhibit was

In order to find acceptance in piano pedagogy, a field with hundreds of years of tradition, it is important to find connection points in existing pedagogical practices. A survey of the field revealed that there exist movement notations, which were used as a basis for our approach. Of several movement notation systems, we used a system developed by the piano pedagogue Bernstein and were able to support existing movement exercises with our sensor-based feedback system.

recently upgraded, now featuring an electronic music stand developed by TK: on an embedded LCD screen, the user can now see the orchestra music score that is the foundation for any orchestra director's work. To make things easier, a moving, highlighted marker bar automatically indicates the note column actually conducted and played. Furthermore, automatic, 3D animated page-turning and additional highlighting of accentuated instrument groups is provided.

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Smart Security and Trust

Computer and the Internet become ever more closely interwoven with our daily life, raising novel security challenges in the fields of **privacy**, **trust**, and **usable security** and hence in areas of IT security that go beyond Confidentiality, Integrity & Availability (CIA).

The Future Internet—embracing the Internet of Things & Services, the Internet of People and Crowds, as well as Cloud Computing—aims at becoming the best integrated infrastructure for supporting people in their everyday life, as well as companies in their everyday business. It will be „the space“ where economical transactions and social interactions work hand in hand. This vision needs much more than just a reliable and secure communication infrastructure; it requires that the supporters of this vision tailor the Future Internet to the manifold interests and needs of its participants.

In particular, we provide novel solutions for the following challenges:

- Evaluating and enforcing the trustworthiness of complex systems.
- Protecting privacy in a world where avoiding digital interactions is not a true option.
- Designing security mechanisms that can be used by casual users.
- Supporting the security requirements of multiple stakeholders (e.g., privacy vs. accountability).

Research Topics:

- Trust and Reputation Management
- Privacy & Identity Management
- Access Control Management
- Usable & Multi-lateral Security

Application Areas:

- Future Internet
- Cloud Computing
- Smart Products
- Disaster Management

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Selected Publications

Extending Bayesian Trust Models Regarding Context-Dependence and User Friendly Representation

Sebastian Ries

In: ACM Symposium on Applied Computing (ACM SAC 2010), pp. 1294-1301, ACM Press, 2009.

Identifiers, Privacy and Trust in the Internet of Services

Leonardo A. Martucci, Sebastian Ries, and Max Mühlhäuser

In: 4th IFIP International Conference on Trust Management (IFIPTM 2010), pp. 81-88, 2010.

Multilaterally Secure Ubiquitous Auditing

Stefan G. Weber, Max Mühlhäuser

In: Intelligent Networking, Collaborative Systems and Applications—Studies in Computational Intelligence, vol. 329, pp. 207-233, Springer, December 2010.

Interactive Access Rule Learning: Generating Adapted Access Rule Sets.

Matthias Beckerle, Leonardo A. Martucci, and Sebastian Ries

In: 2nd International Conference on Adaptive and Self-adaptive Systems and Applications (ADAPTIVE 2010), to appear, 2010.

People



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**Sheikh Mahbub
Habib**
Researcher



Matthias Beckerle
Researcher



Sascha Hauke
Researcher

Smart Security and Trust: Projects

Trust & Reputation



Following the visions of the Internet of Services, the Future Internet, and Cloud Computing, IT systems become highly distributed, dynamically composed, and managed and hosted by multiple parties. Therefore, the evaluation of the trustworthiness of complex systems and the enforcement of trustworthy behavior are two of the major challenges in current IT research.

Our goal is to develop new reputation and trust models for the Internet of the Future. The models have to be based on solid mathematical background, they have to be resilient to attacks, and they have to be capable of dealing with different sources of trust (e.g., direct experiences, third party recommendations, certificates, and accreditations). Complementary to the evaluation of trust, we also aim at developing novel concepts for the enforcement of trustworthy behavior.

Privacy & Identity Management



Protecting the users' privacy in a highly dynamic and interconnected digital world is certainly one of the most important, if not the most challenging, problem of today's digital society, taking into account not only information and communications technology aspects, but also social and legal aspects.

Our efforts are targeted at the area of informational privacy, which is related to a person's right to determine when, how and to what extent information about him or her is communicated to others. In this area, we design new privacy-enhancing technologies, especially novel digital identifiers and identity management systems. In particular, we designed identifiers that combine conflicting security and privacy requirements, such as privacy-preserving identifiers that are accountable, or can be used together with reputation and trust models. Our long term goal is to design and implement new privacy-enhancing technologies to protect users' privacy in the Internet of the Future.

Multilaterally Secure Pervasive Cooperation

This project is concerned with enabling cooperative interactions between locally distributed, mobile, diverse and possibly nameless parties and entities in pervasive networks in a multilaterally secure manner, i.e., in the face of conflicting security requirements.

In the long run, pervasive information sharing and dissemination—key means to enable digital cooperation—can only come to pass if the participating entities may trust that digital interactions bear little risks and threats. Considering that the actual usage happens as part of organizations, within legal systems and in real life contexts,

we devise novel mechanisms that support multilaterally secure pervasive computing approaches. We introduce appropriate trust anchors to enable a seamless cooperation and provide concepts to reconcile conflicting privacy and accountability requirements as well as support for user-friendly, end-to-end secure communication. Our concepts are exemplarily applied in the domain of disaster management, where demanding security requirements have to be satisfied.



Security for Smart Products

Smart products represent a new class of devices that bridge the gap between the real and the virtual world. They provide a natural and purposeful product-to-human interaction and context-aware adaptivity. Especially, they need access to private information, such as user preferences, which they might store or exchange with other trusted smart products.

Our goals are to secure smart products in such a way that casual users are able to understand what is happening without overstraining them, and to enable users to build proper access rules that fulfill their security expectations regarding their security requirements.

To achieve these goals, we apply a mixture of semantic knowledge, automation, and machine learning techniques.



Smart Civil Security

Research and development efforts around public and civil security have substantially increased—in the U.S., these efforts are subsumed under the thematic umbrella „homeland security“. A majority of the efforts aim at the use of Information Technology, with a special emphasis on using IT „in the field“ (sensor networks, ad hoc communication, wearable IT

for first responders, etc.). Much less emphasis is put on command and control centers and on holistic approaches. However, the need to gather and use distributed information and resources in responding to catastrophes demands an integrated framework that can support large-scale collaboration efforts.

Research Topics

The Smart Civil Security area focuses on the following strategic assets:

1. Integrated mechanisms: The holistic approach aims at integration of heterogeneous services from acquisition via decision to execution.
2. Control center oriented approach: all gathered data is bound to serve the fastest, most well-founded, and most effective decisions.
3. Human centered approach: Operations depend on humans working under heavy stress and ever increasing information load. A human centered approach is crucial for successful crisis response and management.
4. Self-Organizing Infrastructure: In the hostile environment typical for post-crisis situations, the IT-infrastructure needs to incorporate the remaining functional communication resources or might even provide a self-contained ad-hoc communication approach.

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Selected Publications

PathFinder: Efficient Lookups and Efficient Search in Peer-to-Peer Networks

Dirk Bradler, Lachezar Krumov, Max Mühlhäuser, Jussi Kangasharju

In: Distributed Computing and Networking: 12th International Conference, ICDCN 2011, to appear, July 2011.

Leveraging Network Motifs for the Adaption of Structured Peer-to-Peer Networks

Lachezar Krumov, Immanuel Schweizer, Dirk Bradler, Thorsten Strufe

In: IEEE GLOBAL COMMUNICATIONS CONFERENCE, to appear, 2010

Interaction techniques for hybrid piles of documents on interactive tabletops

Mohammadreza Khalilbeigi, Jürgen Steimle, Max Mühlhäuser

In: International conference extended abstracts on Human factors in computing systems (CHI), pp. 3943-3948, 2010

People



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Mohammadreza Khalilbeigi
Researcher



Kamill Panitzek
Researcher

Smart Civil Security: Projects

PROGNOSE



PROGNOSE captures the physical and current situation of a major crisis event with multiple data sources (humans, sensors, voice, satellite data, etc.). Each piece of the captured information contributes to a detailed assessment of the situation, which is presented in an interactive wall display. Crisis actors have to carefully anticipate the evolution of a crisis, in order to provide the desired number of resources and processes at the right place and time.

PROGNOSE offers an innovative decision-support concept to the crisis actors, based on the acquired physical situation combined with novel machine learning technologies. The most likely evolution of the crisis within the next hours up to three days is calculated and presented in the command and control center.

PROTECT



The need to gather and use distributed information and resources in response to catastrophes demands an integrated framework that can support large-scale collaboration efforts.

The advent of the new information and communication technology has created new areas of research and new potential solutions for disaster response. This project focuses on developing new holistic approaches in such emergency management scenarios.

More precisely, PROTECT (Protecting Public and Private Life with Ubiquitous Information) targets civil protection command and control centers in disaster and emergency response situations, facilitating communication and collaboration among those centers and first responders in the field.

SoKNOS

SoKNOS developed and evaluated concepts to support governmental agencies, organizations, and companies in providing public security in emergency situations (e.g., floodings, large fires, huge accidents). Novel service-oriented solutions enable ad-hoc information sharing and process integration among all relevant actors. Context information and sensor data are fused to provide all actors with a common relevant operational picture. The projects also developed new human-computer interaction strategies to support distributed decision making, command and control. A number of different devices ranging from wall-sized multi-touch display in control centers to small but robust mobile devices carried in the field are integrated in a seamless way (cf. p. 23).



QuaP2P



which allows for investigating the quality aspects of existing P2P systems.

The term benchmark describes a test or a group of tests which were designed to compare the performance of a system to other (already existing) systems. Through the utilization of benchmarking and its methodology, basic P2P mechanisms from different layers of a P2P system are evaluated while also quantifying and characterizing the multilateral dependencies between the different quality aspects.

The area „Smart Civil Security“ is chartered to a linking QuaP2P research with pertinent disaster response scenarios investigated by the research team.

Events (Selected)

Outreach (Examples)

BEST PAPER AWARDS:

- IEEE ICALT
- ECML PKDD
- ICCGI
- ICEIS
- PVW
- DeLFI

RESEARCH PARTNERSHIPS:

- UC San Diego, PA Research Center
- FXPAL
- University of Queensland
- University of Sheffield
- Eurécom Sophia Antipolis
- CMI

EDITORIAL BOARDS:

- IJPCC
- JUCS
- IWE

CONFERENCE/WORKSHOP (CO-)CHAIRS:

- IEEE ISM
- ACM Multimedia
- DeLFI
- SAINT
- ICSC
- UIC
- AMI

AWARDS:

GI Dissertation Award, KiVS Awards, TUD Best E-Teaching Award, IGM UIMA Innovation Award; Finalist: Medida Prix, Europe A

MEDIA COVERAGE:

- DLF
- Tagesthemen
- DW-World TV
- FAZ
- Hessischer Rundfunk

List of Researchers promoted to PhD and/or Professorship

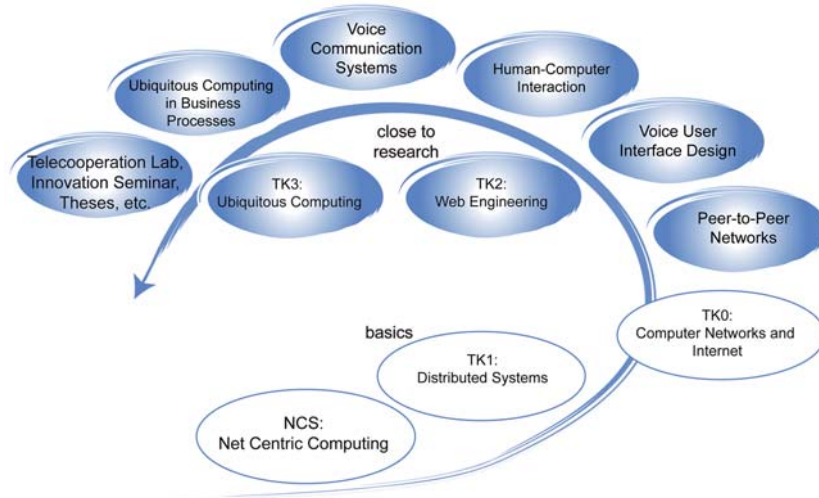


The following researchers were supervised by Professor Mühlhäuser and obtained a PhD or Professorship. Names are followed by current affiliations (to our knowledge). Those preceded by an asterisk indicate members of Professor Mühlhäuser's very first Post-Doctoral research group, who were at the time formally supervised by his late and highly respected lab director, Prof. Dr. Dr. h.c. mult. Gerhard Krüger.

- Dr. Bruno Achauer, data becker
- Dr. Erwin Aitenbichler, TK
- Dr. Henning Bär, infoteam
- Prof. Dr. Gerold Blakowski, FH Stralsund
- Prof. Dr. Jan Borchers, RWTH Aachen
- Dr. Dirk Bradler, TK
- Dr. Elmar Braun, Consultant
- Prof. Dr. Matthias Dehmer, UMIT Innsbruck
- Dr. Peter Dettling, IBM
- Prof. Hannelore Frank, FH Furtwangen
- Dr. Oliver Frick, SAP AG
- Prof. Dr. Hans-Werner Gellersen, Uni Lancaster
- Dr. Wolfgang Gerteis, SAP AG
- Dr. Stefan Gessler, NEC Research
- Dr. Michael Hartle, TK
- Dr. Melanie Hartmann, TK
- Prof. Dr. Andreas Heinemann, Dual Uni Mannheim
- Dr. Sven Hessler, Zumtobel AG
- * Prof. Dr. Lutz Heuser, SAP Research
- Dr. Tobias Klug, SAP Research
- Dr. Thorsten Leidig, SAP Research
- Dr. Tobias Limberger, TU Darmstadt
- Dr. Knut Manske, SAP Research
- Dr. Martin Richartz, Vodafone
- Dr. Sebastian Ries, TK
- Dr. Peter Rösch, Avid Technologies Inc.
- Prof. Rimbart Rudisch, FH Hagenberg
- Prof. Dr. Tom Rüdebusch, FH Offenburg
- Dr. Joachim Schaper, SAP Research
- * Prof. Dr. Dr. hc. Alexander Schill, TU Dresden
- Dr. Dirk Schnelle-Walka, TK
- Dr. Daniel Schreiber, TK
- Dr. Jürgen Steimle, TK
- Dr. Todor Stoitsev, SAP Research
- Dr. Anja Syri, Commerzbank
- Dr. Markus Weimer, Yahoo Research
- Prof. Dr. Michael Welzl, University of Oslo
- * Dr. Christian Zeidler, ABB AG

Teaching

Overview



Teaching in Network Centric Computing

Most of our courses are part of the teaching cluster „Net Centric Computing“ (NCS). In a turn taking schedule, we teach the basic course „**Introduction to NCS**“ about fundamental principles and models of computer networks and multimedia.

„**TK0: Computer Networks - Internet**“ is a crash course about principles and concrete examples of computer networks beyond the NCS contents, offered as a block lecture in irregular intervals. It emphasizes Internet protocols and principles used in the data link, network, and transport layer.

„**TK1: Distributed Systems**“ offers both a software engineering and a distributed algorithms perspective on this fundamental field of computer science. Two out of five hours per week are devoted to exercises.

„**TK2: Web Engineering**“ emphasizes practical issues of this up to date topic in a condensed two hour per week format.

Among the TK series of fundamental courses, „**TK3: Ubiquitous Computing**“ is closest to our research. It provides a comprehensive introduction to topical approaches and links them to our research fields described in this booklet: cooperation, interaction, and protection. Exercises constitute half of the four hour per week course.

„**Ubiquitous Computing in Business Processes**“ provides an enterprise software perspective on our main research field. Practical examples, taken from real use cases, illustrate the approaches taught.

„**Peer-to-Peer Networks**“ provides an insight into the internal mechanisms used in the latest content sharing systems and shows why and how these principles gain ever wider spread.

Finally, a variety of offerings provide hands-on experience in our field: our „telecooperation lab practical work“ is much in demand, the „innovation seminar“ guides students towards their own technical innovations, dozens of Bachelor and Master theses are carried out every year—and this list is noninclusive.

Human Computer Interaction courses

As a tribute to our interaction field of research, we added three more courses in recent years.

„**Human Computer Interaction**“ is an excellent introduction for every computer scientist willing to learn how to build computers and software for humans, not just for tech nerds.

„**Voice Communication Systems**“ and „**Voice User Interface Design**“ provide a technology view and an HCI view, resp., on the most exciting complement to graphical user interfaces, which plays a decisive role in the challenge to support non-desktop interaction.



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