Ubiquitous Computing

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organized by

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Processors are becoming so small and inexpensive that they will be embedded in almost everything. Everyday objects will be infused with computational power, enabling them as information artifacts and smart devices. Most of these new emerging smart devices will be small and therefore highly mobile; some might even be wearable and be worn much as eyeglasses are worn today. Low-cost transceivers will allow to interconnect these devices in spontaneous ways, and to link them into the global information infrastructure. Connected together and exchanging appropriate information, these smart devices will then form powerful systems enabling new emerging functionalities.

When the world is populated with small computing devices that typically do their work in the background, without explicit user intervention, information and computational services will become continuously available, wherever the action is. Moreover, embedded sensors and actuators will enable smart devices and computing to become contextually embedded in real-world situations. This will give rise to situated computer applications that blend with the real tasks people care about instead of introducing computer-centric tasks of high complexity.

Ubiquitous computing therefore induces a paradigm shift in the way we use computers: Instead of bringing the world into the computer (the Virtual Reality paradigm), computational power is now brought to the objects of the physical world. Eventually, the vision of Ubiquitous Computing induces a new way of thinking about computers in the world, one that takes into account the natural human environment and allows the computers themselves to vanish into the background.

Over the last years, established research communities have begun to relate their fields to the vision of ubiquitous computing, and new communities have emerged to investigate specific perspectives of the development. Researchers begin to consider the enabling technologies and infrastructures required, the new applications and services that may emerge, and the interfaces and human interaction models for ubiquitous computing.

The growing ubiquitous computing community is fed from different classical areas, mostly from within computer science, but also from electrical engineering, material science, product design, and some other disciplines. Hence, insights currently evolve from many different perspectives, but often in parallel and with little interaction.

The Dagstuhl seminar should provide an opportunity to improve this situation by bringing scientists from various relevant disciplines together to jointly discuss the challenges, opportunities, and pertinent research themes of ubiquitous computing. Many participants have their roots in the classical computer science system domains (distributed and mobile computing, networking, architecture, middleware), others will be interested in technologies for smart devices (such as embedded and wearable computing, perception, or knowledge processing), and some will be concerned with application domains and human factors (such as context-aware computing, domestic applications, human- computer interaction, and design).

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1 10 Lessons Learned about Ubiquitous Computing

Roy Want, Intel Research

In the last ten years, many forays have been made into Ubiquitous Computing and a number of early lessons have been learned at various levels of system design. These projects have explored component technologies, architectures, user interfaces, and applications. In this presentation I describe a number of the early systems built at Olivetti Research and at the Xerox Palo Alto Research Center (PARC) that explore, and have contribute to, this still nascent body of knowledge. Projects described include the (1) Active Badge Location System, a system for locating people in an office building; (2) PARCTab, one of the first context-aware computers, and a set of early context-based applications. Deployment of these technologies in a real user community allowed us to study how users responded to context-ware capabilities. In ten years, we have made considerable technological progress and this experience is now directly relevant to new systems being designed, and as a result here I report on ten of the most valuable lessons learned from the earlier work.

2 The Role of a Context Service in a System that aims at integrating the Digital with the Real World

Fritz Hohl, Sony Research, Germany

One aspect of Ubiquitous Computing is the one of integrating the Digital and the Real World. A corresponding system that aims at supporting this integration has to consider three aspects. First, it has to be possible to represent Real World objects and their attributes in the Digital World. Second, changes in the Real World have to be reflected in the Digital World. Third, it should be possible that some aspects of the Real World can be changed by the Digital World.
The second aspect and some parts of the first aspect can be covered by a Context Service. A Context Service is able to gather, process, store, and support context data to other components. Context data is "any information that can be used

to characterize the situation of an entity," where an entity is e.g. a mobile user. Context data therefore always relate to such a focus entity, is of a certain type, and occurs in a certain format. In this talk, such a Context Service is roughly sketched and its relation to the overall system discussed.

3 Providing Infrastructure-Level Support for the Building of Context-Aware Applications

Anind Day, UC Berkeley and Intel Research

Context is poorly understood and is difficult to use in interactive applications. Using a software engineering approach, we have decomposed the process of building context-aware applications and features that are common across them that can be factored out of the application design. We designed the Context Toolkit, a software infrastructure that makes it easier for programmers to build context-aware applications. It uses simple abstractions, widgets (similar to GUI widgets that encapsulate the output of a sensor), aggregators (context repositories for people, places, and things), and interpreters (translators of context), to simplify the programming process. We describe the design of the architecture and a number of applications built with the Context Toolkit.

4 The Context Fabric: Infrastructure Support for Context-Aware Computing

Jason Hong, UC Berkeley

Despite hardware advances in wireless networking and sensors, and software advances in toolkits, it is still quite difficult to build effective and reliable context-aware applications. We propose to build a context infrastructure that provides three things to greatly simplify the task of building robust context-ware applications: a distributed data model representing people, places, and things; a context specification language for declaratively stating context needs; and a distributed context service for fulfilling these needs.

5 Perceptual Context Awareness through Wearable and Distributed Sensors

Bernt Schiele, ETH Zurich, Switzerland

The next generation of computers might be literally wearable. Our vision of such a wearable computing device is an intelligent assistant which is always with you and helps you to solve your every day tasks. Besides size and power, an important challenge is how to interact with wearable computers. An important aspect of a wearable device is that it can perceive the world from a first-person perspective: a wearable camera can see what you see and and a wearable microphone can hear what you hear in order to analyze, model and recognize things and people which are around you. A promising direction for interaction with wearable computers is therefore to make the computers more aware of the situation the user is in and to model the user's context. Sensors, such as cameras, mounted to the user's glasses, can recognize what the user is looking at and might model what the user is doing. More recently we also work on using a large numbers of different sensors distributed in the environment in order to model the context of the environement.

6 Context-Awareness, Disappearing and Distributed User Interfaces - Experience, Open Issues and Research Questions

Albrecht Schmidt, Lancaster University, UK

The talk summarizes experiences, open issues, and research questions in the area of context-awareness, disappearing and distributed user interfaces. The discussion is based on several research projects namely TEA-Phone, TEA-wearable computer, proactive environments, context phone book, and aware goods. The question what context is and how context can be described is raised. The talk shows architectures and distribution concepts for context. Issues related to sensors, sensing, and perception are discussed. How to build context-aware systems that support simulation and debugging is a further question that is illustrated in the talk. The evaluation of Ubicomp systems is a central problem in this research field with many open questions. Finally the problem of cross-field developments and interwoven engineering is addressed.

7 Privacy in Ubiquitous Computing

Marc Langheinrich, ETH Zurich, Switzerland

Privacy in Ubiquitous Computing is like the weather: Everybody's talking about it, but no one is doing anything about it. In this talk I try to give ten (good) reasons why it is a good idea to care about privacy in ubiquitous computing; five reasons why privacy in ubiquitous computing is different from privacy on, say, the Internet; as well as ten things to ask yourself when it comes to building privacy-aware ubiquitous computing systems.

8 Addressing the Location in Spontaneous Networks enabling Privacy and Security

Guenter Mueller, University of Freiburg, Germany

In the initial stages of data processing, protection of the private sphere was guaranteed by data protection based on centralized data processing. Through the creation of the Internet and the increasing networking of the computer, particularly between enterprises, new security problems arose which are solved by copying the old model of the firewall and strengthening authentification (PKI). These mechanisms, i.e. firewalls and PKI, are reaching their limits through the trend of spontaneous networking and the miniaturizing of intelligent end devices, together with the mobility of the user and end devices.
Increasingly smaller mobile and stationary devices are spontaneously networking with one another. With each transaction, data tracks are left which ultimately enable a linkage of a clearly identified device to a place and time and the relating to an individual. In such an environment, security, particularly the privacy of the user, is up for consideration: data accumulates on a massive scale over which the user has hardly any more control with regard to collection, access, alteration and distribution.

As a result, many experts proclaim the end of privacy through ubiquitous computing. They prophecy the omnipresence of computers, similar to the invisible presence of everyday electric motors.
The following problems arise:

- Which models and abstraction processes can enable security in an environment in which devices network spontaneously with one another, i.e. without direct administrative intervention?
- Mechanisms (like cryptography) are often no longer possible, as there is no more room on the chip for these functions due to miniaturization of the devices. Can privacy still be nevertheless protected? If yes, with which mechanisms?

We propose a new device addressing which keeps the data track to a minimum: merely the location is used for addressing a device in spontaneous networking (e.g. in a radio-based network). For the analysis of this new way of addressing, we have produced the concept for a prototype as proof of feasibility. The theoretical analysis is based on a hybrid process which contains the element of qualitative and quantitive argumentation.

9 Personal Server

Roy Want, Intel Research

A new paradigm for mobile computing is described. The concept is centered around a small portable device, called a "Personal Server," incorporating a high performance but low-power processor, large amounts of data storage and standardized short-range, wireless communication (e.g., Bluetooth). The device is used to carry personal data and applications. A key differentiator from a standard computer is that the device does not have a display; instead the Personal Server interacts with nearby devices and exploits their resources for data display, user input and additional processing needs. The presentation describes the motivation for this design approach, a prototype implementation, applications and challenges for the future.

10 Interaction in UbiComp: Pirates! and Informative Art

Lars Erik Holmquist, PLAY, Sweden

In this talk, I describe two applications that implement novel interaction techniques for ubiquitous computing. "Pirates!" is a mobile context-aware game developed jointly by the PLAY research group and Nokia Research. The game is played on hand-held computers with proximity sensing. To play the game, users must walk around in the physical play area, in order to engage in combat with other players, find islands with treasure, etc. "Informative Art" uses the visual language of modern art, in particular non-figurative painting, to create dynamic information displays. For instance, a projection display reminiscent of the dutch painter Mondrian's work is in fact a weather display, showing the current weather conditions in six different cities around the world. Together, these projects indicate new ways of using space, mobility and visual media in ubiquitous computing.

11 Resource-Adaptive Navigation Systems

Antonio Krueger, University of Saarland, Germany

Pedestrian navigation systems have to take into account not only the cognitive resources of the user, but also the differing technical constraints of the devices that are used to access navigational way descriptions. The presented work describes the REAL-System that is a hybrid navigation system, consisting of two parts: the indoor-navigation system IRREAL and the outdoor version ARREAL. Both systems try to adept their (especially graphical) presentations to the user's speed, spatial familiarity and goals. Whereas IRREAL works with an infrastructure of custom-made infrared senders, the ARREAL system relies on GPS and an electronic compass to determine its position. Experiences and Results of both approaches are discussed.

12 Active Environments: Sensing and Responding to Groups of People

Joseph F. McCarthy, Center for Strategic Technology Research, Accenture

Most environments are passive deaf, dumb and blind, unaware of their inhabitants and unable to assist them in a meaningful way. However, with the advent of ubiquitous computing ever smaller, cheaper and faster computational devices embedded in a growing variety of "smart" objects it is becoming increasingly possible to create active environments: physical spaces that can sense and respond appropriately to the people and activities taking place within them. Most of the early UbiComp applications focus on how individuals interact with their environments as they work on foreground tasks. In contrast, this paper focuses on how groups of people affect and are affected by background aspects of their environments.

13 Intrabody Communication

Kurt Partridge, University of Washington

Intrabody communication is a way for electronic devices to communicate by sending low-power electrical signals through the body. We have constructed prototypes of these transceivers and measured their performance under various circumstances, including location of coupling on the body, size of touched transceiver plates, etc. A simple application taxonomy is presented that distinguishes applications according to data transfer direction and complexity of information use.