The First Summer School on Ubiquitous and Pervasive Computing

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The 2002 Summer School on Ubiquitous and Pervasive Computing was organized and run by a team of volunteers from the Swiss Federal Institute of Technology (ETH Zurich) between 7 and 14 August. The school took place at the beautiful Dagstuhl Castle in Germany, close to the border of Luxembourg and France, and grew out of the success of the Ubiquitous Computing Seminar held in the same location the previous year. The lecturers were John Barton, Nigel Davies, Anind Dey, Hans-Werner Gellersen, Marc Langheinrich, Friedemann Mattern, and Thad Starner.

The summer school aimed to provide a basic survey of the most relevant subfields, present the perspectives and underlying technologies, identify pertinent issues within the field, and identify important research themes. Furthermore, it provided young researchers with the opportunity to meet distinguished scholars and contemporaries to discuss and formulate ideas.

The school received more than 120 applications for the 60 available places. Participant interests spanned a vast array of disciplines, ranging from industrial design to distributed systems. Most participants were PhD students from various European countries, but participants from the US, Japan, and China also attended.

LECTURES AND PARTICIPANTS' CONTRIBUTIONS

The summer school comprised 18 90-minute lectures (see "The Lectures" sidebar), three participant workshops, and three group work sessions. Lecture topics covered diverse areas, including hardware technology and sensor systems, middleware components, ubiquitous application examples, and relevant theory. Most lecturers stayed for the entire summer school, initiating impromptu discussions on various related topics as well as providing useful and expert advice on individuals' research dissertations.

On arrival, the school gave participants a dossier containing a dozen or so papers, including articles by Vannevar Bush, J.C.R. Licklider, and Mark Weiser. Group work sessions invited participants to use this material and brainstorm in sets of approximately six people on specific ubiquitous computing research issues. Discussion themes included

- Design exercise: augment artifacts of the Dagstuhl environment.
- What was right or wrong with older predictions and scenarios? Why?
- How will we live in 20 years—what can, will, and should happen?

Groups presented their results and discussed with other groups at the session's end. Group work was productive—not just in creating novel ideas, but also letting participants see how those with dif-

Participants attentively listening to a lecture.

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Discussions during the coffee break.

ferent technical backgrounds approached problems.

The presentations in the participants' workshops were particularly excellent. Most participants gave a 10-minute talk about their research area, and as you might expect with such a diverse group, the short presentations varied in both research theme and style.

THE ATMOSPHERE

Summer school participation included more than intellectual discussions: lecturers and attendees alike played music and took part in team games of volleyball, table tennis, and pool. Some cycled in and around the immediate countryside on Dagstuhl's bikes and used the extensive on-site computer science library, which thoughtfully provided a prominent display of relevant texts.

Although the rest of the week contained organized lectures and group sessions, Sunday provided breathing space from the formal seminars with a trip to Château de Malbrouck in France, a cruise on the river Saar, and wine tasting in Riol at the Mosel river. Other social activities included a visit to the Völklingen Ironworks on Friday evening and a barbecue and movie session on Saturday, with short videos showing various ubiquitous computing scenarios and applications.

Dagstuhl Castle's accommodation, facilities, and food—not to mention its well-known wine cellar—were all excellent and provided an ideal setting for the summer school. The atmos-

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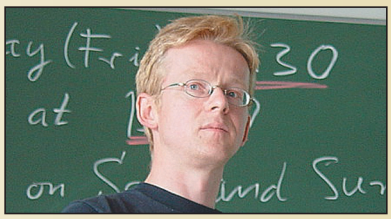

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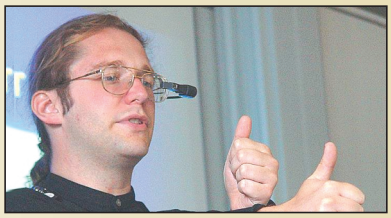

EDUCATION & TRAINING

THE LECTURES

The Summer School on Ubiquitous and Pervasive Computing offered the following lectures:

- *Ubiquitous computing technologies* (Friedemann Mattern). The lecture gave an overview on pertinent technology trends and assessed the long-term trends and future development of relevant ubiquitous computing technologies.
- *Sensing in ubiquitous computing* (Hans-Werner Gellersen). Ubiquitous computing is closely associated with visions of smarter devices and environments that can proactively help their users. Obviously, sensing is a key enabling technology to make this possible. This lecture investigated why sensing is used in ubiquitous computing and how it differs from more traditional sensing applications.
- *Context-aware computing* (Anind Dey). The lecture gave a historical perspective on context-aware computing: what it is and why it is important to ubiquitous computing. The talk discussed novel applications, programming support for context-aware applications, and interesting research issues.
- *Wearable computers as intelligent agents* (Thad Starner). Creating intelligent agents to assist users second by second during their everyday lives is a unique challenge that has few parallels with the past. Research into perception, user modeling, and interface design will be necessary to create compelling assistants that do not interfere with a user's normal work and lifestyle. This lecture concentrated on development platforms, perception techniques, intelligent agents, and evaluation methods.
- *Smart identification* (Friedemann Mattern). The lecture explained how RFIDs (radio frequency identifications—that is, *radio tags* or *smart labels*) work and gave a short overview on smart card technologies. Current and future applications of smart labels were discussed with reference to their suitability, cost, and performance.
- *Distributed systems support for mobile and pervasive computing* (Nigel Davies). The lecture took a broad look at different platforms and paradigms for mobile and pervasive computing. It mentioned historical systems, such as Rover and MOST (Mobile Open Systems Technology), and more recent efforts such as tuple-space-based platforms. This lecture concluded with a look at systems such as Universal Plug and Play and Jini.
- *A brief survey of ubicomp projects* (John Barton). As a new field, ubiquitous computing is still being defined. In part, ubicomp is defined by the projects that choose to be called ubicomp. The lecture gave examples from groups in the US, using a systems viewpoint to relate these projects. Additionally, Barton used these projects as examples to discuss ubiquitous computing research techniques.
- *A Web-based nomadic computing system* (John Barton). The lecture described a project at HP Labs to develop a Web-based nomadic computing system. Physical hyperlinks connect physical entities—people, places, or things—to virtual resources on the Web. Nomadic users of handheld Web browsers can traverse links they encounter, giving them simple context-dependent views of resources around them without tracking the users. Printers, projectors, and picture frames that accept hyperlinks let these users bring bits of the virtual world into their physical environment.
- *Experiences in developing and deploying the archetypal context-aware computing application* (Nigel Davies). The lecture looked at research work in the field of context-aware tour guides. It mentioned past, present, and future research and focused on a context-aware tourist guide project (GUIDE) as a case study of the practical issues in deploying ubicomp systems.
- *Augmentation of environments* (Anind Dey). To aid intuitive interaction with a pervasive computing platform, we often augment people and objects or the environment itself. This lecture discussed when the two augmentation methods are best used alone or combined for supporting novel interaction. Dey gave examples to demonstrate this.
- *Computer-augmented environments: Back to the real world* (Hans-

Participants discussing the future of ubiquitous computing.

phere combined excitement with a liberal mix of trepidation. Many participants left with a desire to tackle and conquer this promising new field. In a brief survey, participants felt the summer school provided high-quality lectures coupled with plenty of opportunities to meet, discuss, and discover other researchers in similar fields. Typical participant comments (see the related sidebar) included "Schloss Dagstuhl was

Werner Gellersen). This talk aimed at conveying a design-driven perspective of ubiquitous computing based on the primacy of the physical world and the ideal of introducing computing technology unobtrusively. It discussed design considerations of physical artifacts and structures, and reviewed research work on augmentation of artifacts for digital interaction (for example, tangible user interfaces and ambient displays).

- *Design exercise on computer-augmented environments* (Hans-Werner Gellersen). Participants broke up into small groups, and each group received an assignment to augment a set of artifacts or a place at Dagstuhl.
- *Ubiquitous exercise* (John Barton). This exercise tried to illustrate some of the potential in pervasive computing and experience some of the challenges. Participants broke into teams, and Barton assigned each team two fantasy venues, such as a school, home, office, train, museum, or shopping area. The exercise's goal was to imagine a useful or pleasant experience using any of this future technology.
- *Simulation as a tool for research in ubiquitous computing* (John Barton). Ubiwise is an open-source simulator for ubiquitous computing. The simulator concentrates on computation and communications devices, either integrated with physical environments or carried by people. It maintains a 3D model of a physical environment that users view on a desktop computer through two windows.
- *Physical-virtual integration, ubicomp applications, ubicomp implications* (Friedemann Mattern). The lecture described how smart labels, wireless sensors, and embedded processors—together with the Internet backend infrastructure—contribute to the integration of the physical and virtual worlds. Smart, everyday objects enable many new applications and business ideas and create unique opportunities and challenges. Living in a smart environment has interesting consequences, however.
- *Power and heat in ubiquitous computing* (Thad Starner). RAM size, CPU speed, and hard disk storage size have increased exponentially over the past 10 years; mobile device battery energy density has increased by less than a factor of 3. So, energy must be a primary design issue when discussing devices for mobility or for distribution into an unpowered environment. Additionally, the heat generated from using this energy can be a limiting factor in computation speed. The lecture explored alternative ways of powering and cooling ubiquitous computing devices, discussed a basic overview of the physics involved, and provided the basic mathematical tools needed to analyze a system. Starner emphasized wearable systems and designing computing infrastructure for developing nations.
- *Evaluation of ubicomp applications and systems* (Anind Dey). This lecture discussed the traditional systems and HCI-based methods for evaluating desktop applications and discussed which approaches are or are not appropriate for ubiquitous computing and why.
- *The case for ubicomp privacy* (Marc Langheinrich). The lecture explored the nature of privacy, its history and driving factors, and how these will influence the way we perceive and value our privacy in a world full of smart, communicating objects that monitor our every move.
- *Tools for ubicomp privacy* (Marc Langheinrich). This lecture looked at some privacy-enhancing technologies and examined if and how these present a viable option for guarding privacy in a future of ubiquitous computing. Many experts agree that technology alone does not suffice and that legal means must complement any technical solution. The lecture gave a brief overview on what laws exist worldwide and what use they could be in the future.
- *Collaborative augmented reality* (Mark Billinghurst). Augmented reality interfaces typically involve the overlay of virtual imagery over the real world. This presentation described how you can use AR techniques to enhance face-to-face and remote collaboration. You can use AR to restore spatial cues normally missing in remote collaboration and provide an intuitive way of interacting with virtual models in a face-to-face setting.

Participants presenting their group work.

very relaxing and inspiring" or "Great mix of lectures, discussions, and social activities!"

The biggest win from the summer school is probably yet to come: the summer school provided a meeting ground for budding ubiquitous and pervasive computing researchers. This will undoubtedly provide greater awareness

EDUCATION & TRAINING

PARTICIPANT COMMENTS

Overall, participants felt active involvement through group sessions, and the workshops were particularly useful. We list here a few of our thoughts as participants.

- *Location awareness* (Csaba Kiss Kalló). Many considered location awareness to be a key enabling technology in context-aware computing. Participants mentioned the Bat ultrasonic indoor location system (AT&T Laboratories, Cambridge) and the HP Cooltown project several times in lectures and workshop presentations. Research that involved ranging estimates from radio technology (particularly IEEE 802.11b wireless LAN) appeared to be important in several fields, and several projects used RFID (radio frequency identification) tags. Many applications discussed used location information to establish multihop communication links in an ad hoc network environment.
- *User privacy* (Alastair Beresford). Marc Langheinrich gave an excellent series of talks on the "Case for Ubicomp Privacy." Marc described the historical legal basis for privacy in both the US and Europe, and promoted a moral and ethical discussion on the need for user privacy in a pervasive computing environment. He described privacy-enhancing technologies such as the W3C Platform for Privacy Preferences (P3P) and analyzed them for their effectiveness in maintaining user privacy in a ubiquitous computing world. This lecture series provided researchers with reminders on the dangers of ignoring privacy problems when designing and building pervasive computing systems.
- *Sharing advice* (Ursula Kretschmer). The participants' workshop gave good insight into different technologies and application areas. Similarities between projects were discussed, and attendees could exchange experiences. Many participants—even those from different backgrounds—face similar problems, so cooperation between different disciplines is very important. Participants used various small mobile devices, including Philips Research's remote-controlled environment and Software Competence Center Hagenberg's temperature-sensing PDA. Sharing mobile device experiences and design decisions in this way will help others avoid the common pitfalls.
- *Research challenges* (Martin Muehlenbrock). The summer school provided an interesting overview of ubiquitous computing's history and state of the art. The presenters not only described their own work, but they also set it in a broader perspective. Currently, many approaches focus on simple applications and the construction of the necessary hardware. Truly complex problems have not yet been tackled, and a great need exists for developing theoretical models and creating simulation and evaluation tools and methodologies. Overall, the summer school was a great opportunity to meet scholars and enthusiastic young researchers.

of work at other universities and a wealth of contacts to draw on in future years to further their own research.

Will a similar summer school convene in the future? From the success of this year's school, it seems likely. Although it's not yet clear where such a school could take place in 2003, it might return to Dagstuhl Castle in 2004 or 2005. You can access more information on the 2002 summer school, including the detailed schedule and most presentations, at www.inf.ethz.ch/vs/events/dag2002. P

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Dagstuhl Castle.