The Disappearing Computer

European Commission -

US National Science Foundation

Strategic Research Workshop

The Disappearing Computer

Vienna, Austria, 23-24 April 2004

Workshop Report and Recommendation

1. TABLE OF CONTENTS

CONTRIBUTORS

Representatives from funding organizations

Thomas Skordas	EU, IST–FET, Belgium	Thomas.Skordas@cec.eu.int
Panagiotis Tsarchopoulos	EU, IST, Belgium	Panagiotis.Tsarchopoulos@cec.eu.int
Remi Ronchaud	ERCIM, France	Remi.Ronchaud@ercim.org

Organizers

Norbert Streitz	Fraunhofer IPSI, Germany	streitz@ipsi.fraunhofer.de
Paddy Nixon	University of Strathclyde, UK	Paddy.Nixon@cis.strath.ac.uk

EU Participants

Liam Bannon	University of Limerick, Ireland	liam.bannon@ul.ie
Joelle Coutaz	CLIPS-IMAG, Grenoble, France	Joelle.Coutaz@imag.fr
Hans Gellersen	Lancaster University, UK	hwg@comp.lancs.ac.uk
Achilles Kameas	CTI, Patras, Greece	kameas@cti.gr
Morten Kyng	University of Aarhus, Denmark	mkyng@daimi.au.dk
Spyros Lalis	University of Thessaly, Greece	lalis@inf.uth.gr
Allan Maclean	Image Semantics, UK	Allan.Maclean@imagesemantics.com
Friedemann Mattern	ETH Zürich, Switzerland	mattern@inf.ethz.ch

US Participants

Gaetano Borriello	University of Washington, Seattle	gaetano@cs.washington.edu
Roy Campbell	University of Illinois at Urbana-Champaign	roy@cs.uiuc.edu
Anind Dey	Intel Research Lab, Berkeley	anind@intel-research.net
Anatole Gershman	Accenture Technology Labs, Chicago	anatole.v.gershman@accenture.com
James Landay	Intel Research Lab, Seattle, & University of Washington	james.a.landay@intel.com
Joseph Paradiso	MIT Media Lab, Cambridge	joep@media.mit.edu
Daniel Russell	IBM Almaden Research Center, San Jose	daniel2@us.ibm.com
Terry Winograd	Stanford University	winograd@cs.stanford.edu

2. INTRODUCTION AND BACKGROUND

This workshop is part of the EU-NSF strategic research workshops organised by ERCIM under the auspices of the European Commission (IST-FET activity) and the US National Science Foundation (NSF/CISE division) to identify key research challenges and opportunities in Information and Communication Technologies. These workshops are intended to facilitate brainstorming and awareness around potential breakthroughs in innovative domains, stimulating scientific discussions and research activities of mutual interest.

This particular workshop focused on the topic of "The Disappearing Computer" (DC). The idea originates in the activities of the IST-FET proactive initiative "The Disappearing Computer" [3], a cluster of 17 projects most of them funded during the period of January 2001 and December 2003.

Work in this area is also characterized by the terms ubiquitous and pervasive computing. The term "ubiquitous computing" was coined by Mark Weiser (former chief scientist at Xerox PARC):

"Inspired by the social scientists, philosophers, and anthropologists at PARC, we have been trying to take a radical look at what computing and networking ought to be like. We believe that people live through their practices and tacit knowledge so that the most powerful things are those that are effectively invisible in use. This is a challenge that affects all of computer science. Our preliminary approach: Activate the world. Provide hundreds of wireless computing devices per person per office, of all scales (from 1" displays to wall sized). ***This has required new work in operating systems, user interfaces, networks, wireless, displays, and many other areas****. We call our work "ubiquitous computing". This is different from PDAs, dynabooks, or information at your fingertips. It is invisible; everywhere* ***computing that does not live on a personal device of any sort, but is in the woodwork everywhere****."*
(M. Weiser 1988[15]) (our emphasis)

Another related characterization can be found in another quote from Mark Weiser [14]: *The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.*

Ubiquitous or pervasive computing assumes there will be large numbers of 'invisible' small computers embedded into the environment and interacting with mobile users. Users will experience this world through a wide variety of devices, some they will wear (e.g., medical monitoring systems), some they will carry (e.g., personal communicators that integrate mobile phones and PDAs), some that are implanted in the vehicles or the public spaces they use (e.g., car and public space information systems), and some that are integrated in the architectural environment and furniture (e.g., interactive walls and tables). This heterogeneous collection of devices will interact with intelligent sensors and actuators embedded in their homes, offices, public spaces, transportation systems to form a mobile ubiquitous computing environment which aids normal activities related to work, education, entertainment and healthcare. There is a need for wireless communication to support mobile interaction but the environment will also provide access to wired backbone computing resources that are connected to the Internet.

Although these intelligent communicators will be far more sophisticated than current mobile phones, they will always have reduced storage, processing and display capabilities and battery power compared to fixed PCs. Thus, there is a need to adapt information and applications so that they are compatible with the limited capabilities of the devices but also to provide information or adapt services that are relevant to the current context of the user. Sensors in the environment, possibly in collaboration with personal devices, would determine user's current activity – driving a car, walking down a street, in the cinema, in a meeting, running for a bus, about to watch television. The ubiquitous computing environment would thus support users in common day-to-day activities by adjusting lights, switching on the television for favourite programmes, recording the programme when unable to watch it, monitoring health and alerting emergency services in case of problems, warning drivers about potential component failures in their car etc [1]. It is time to address this multitude of perspectives and their relationships and the challenges of a resulting convergent research domain.

Participation in this workshop was by invitation only. The workshop was attended by a total of 20 international researchers and key actors from both Europe and the US. This report summarises the discussions and highlights some areas of future research. The report also includes position statements from each of the invitees.

3. OBJECTIVE OF THE DC-WORKSHOP

The objective of this IST-FET/NSF workshop was to consolidate research experiences in the domain of the disappearing computer and ubiquitous computing (variously called pervasive computing, proactive computing, ambient intelligence) and to map out the core and fundamental challenges for the next stages in this field. This field of research is central for the many aspects of the IST programme of the EU and to many programmes currently active in the NSF. To highlight the importance the EU and the US give to this area – a very rough estimate of funding across projects indicates in excess of $100 million research expenditure in the broad area. Within this significant and emerging field of research, both groups (from the US and EU) have been developing research agendas that highlight the complex interplay between technology and people that is needed to realise Mark Weiser's original vision of cognitively unobtrusive technology – "calm technology".

Within the EU's IST-FET activity, **The Disappearing Computer initiative** has formulated the following overall goal: *To explore how everyday life can be supported and enhanced through the use of collections of interacting artefacts. Together, these artefacts will form new people-friendly environments in which the "computer-as-we-know-it" has no role. The aim is to arrive at new concepts and techniques out of which future applications can be developed.*

In order to achieve this goal, three specific interlinked objectives are guiding the activities:

- Developing new tools and methods for the embedding of computation in everyday objects so as to create artefacts;
- Research on how new functionality and new use can emerge from collections of interacting artefacts; and
- Ensuring that people's experience of these environments is both coherent and engaging in space and time.

Within the US, a number of NSF funded projects (for example Aura, Pico, and Active Space) have also been tackling similar problems; albeit from different perspectives. This is complemented by other activities in the US and in Europe, e.g., the EQUATOR project [7] in the UK.

Given this background, the workshop aimed to:

- Bring together a mix of senior researchers active in various programmes funded by the EC or the NSF.
- Present reflections from the major projects focusing on their insights, core challenges, and perspectives on the domain to seed the discussion; and
- Develop a view on the future of this domain through panel discussions.

4. RESULTS OF THE DC-WORKSHOP

The workshop was structured around six scene setting presentations followed by group discussions and brainstorming. Below we summarise these discussions through a number of themes. As is to be expected in this multi-disciplinary domain, the discussions were wide ranging; as such the themes below are a synthesis of these discussions.

Programming

To understand the open issue of programming the disappearing computer and its applications, consider the deployment of smart dust sized computation and sensory elements in a given environment; this implies that the numbers of entities and complexity of communication within a single local environment are comparable to the scale of the communications in today's Internet. This is a layered phenomenon in that each such environment is variously connected to other such environments. So for each node in today's Internet there will be a whole new internet of *nodes* providing sensory communications. To compound this scaling problem, the meaningful outputs of these sensory environments are likely to be statistically interpreted and will not have *linear* response or failure characteristics. In short, the current models of communication, interpretation, and adaptation are not appropriate.

Consequently, one core problem for the disappearing computers is how to program them. Each new advance in technology has driven research to provide the appropriate programming primitives. The introduction of parallel, and subsequently distributed, computing technologies stimulated basic research developments such as CSP, CCS, Semaphores, Group Communications, etc that are the main stay of every modern programmers toolkit. Ambient systems research has yet to establish what the appropriate semantics of its systems are and consequently it is still missing the fundamental primitives. The only way for future ambient systems to be economically viable to develop is for there to be coherent toolsets. The only way to develop the toolsets is to discover the fundamental primitives, understand their semantics and develop corresponding implementations. As such, programming approaches (models, languages, and support tools) need to be radically redesigned to address the problem. Indicative issues in this debate are:

- How do the designer, programmer and end-user design an ensemble of sensors, devices and resources when they do not own the various facets of the architecture?
- How do we program these systems, or the components of these systems, when the notion of application is nebulous?
- How do we program in the face of uncertainty and partial knowledge?
- How do we understand and program for update of infrastructure, program or data?
- How do we debug these systems in situ given their potential longevity and wide scale deployment?
- What are the new features that demand new programming models?

- How do we give the non-programmer the required control over the environment?

Information Discovery and Retrieval

One of the key requirements to the provision of any disappeared computing infrastructure is an approach or service capable of assimilating and filtering information from various sources and determining relevance: an approach that enables discovery of the necessary information from the environment to achieve a goal or complete an activity. Information sources include contextual information from the environment, personal preferences, user history etc, relatively static information such as spatial data from GIS, and more general information published on intranets and the Internet. To achieve interoperability and interaction, there has to be some semi-automatic approach that allows users, devices, and applications to extract from their environment the necessary information to operate. Such information will be a synthesis of events and data from the environment. Typically, the events will be higher-level (more semantically meaningful and context-sensitive) than the source input events (sensors) and will draw upon a partial view of a global knowledge base comprising elements such as GIS, web-based systems, databases, semi-structured data, etc.

Given some infrastructure to communicate the information, an approach to matching will be needed that describes a correlation of input events and facts that is relevant to a contextual service. This matching is unlikely to be strictly discrete – it is at least partial stochastic – and it will vary over time and location. The challenge lies in developing approaches that provide matching that is consistent within some acceptable operational envelope; an operational envelope that may be different for every user, environment, or situation.

Privacy, Trust and Security

Disappearing computing, by definition, is designed to exploit rich combinations of invisible (or embedded within everyday objects) sensing/computational entities in order to identify and deliver personalised services to the users when they are interacting and exchanging information with the environment. The vast amounts of personal information collected by such systems, typically without the user being aware of this, has led to growing concerns about the security, privacy and trustworthiness of such systems and the data they hold. This is a core problem as users concerned about their private information are unlikely to participate in such systems; which in turn may slow or stop their deployment. Consequently within such environments there is a high demand on solutions from users to be secure, private and trustworthy.

In this context, security describes the cryptographic techniques used to secure the communication channels and required data. Privacy encompasses reasoning about trust and risk involved in interactions between users and services. Trust, therefore, controls the amount of information that can be revealed, and risk analysis allows us to evaluate the expected benefit that would motivate users to participate in these interactions.

Langheinrich [19] asks the following questions in respect of privacy – *what makes ubiquitous computing any different from other computer science domains.* Langheinrich goes on to identify four key motivators:

1. Ubiquity: The infrastructure will be everywhere consequently affecting every aspect of life.
2. Invisibility: The infrastructure will be cognitively or physically invisible to the user – the user will have no idea when or where they are using the *computer*.

3. Sensing: Input to the ever-present invisible computer will be everything we do or say, rather than everything we type.
4. Memory amplification: Every aspect of these interactions, no matter how personal, has the potential to be stored, queried and replayed.

It is worth noting that these observations are not merely an amplification of the current concerns of Internet users with desktop computers. These observations show the deep societal impact that such technology will have. The workshop identified that these areas of security, privacy and trust are critical components for the next stages of research and deployment of ambient systems. Moreover, the trade-offs required to achieve end-user trust in the infrastructure encompass both technological and societal aspects. One step in providing guidelines in this area is the first version of the "European Disappearing Computer Privacy Design Guidelines" developed in the DC-project Ambient Agoras [20].

One strong theme within the discussion identified that trust, as a core enabling infrastructural, is the next step to balance the complex trade-offs demanded by security and privacy. In particular, each decision about encryption, access control, or information exchange implies a decision process. Trust based infrastructure provide the mechanisms for users and systems to base this decision process on their perspective of the risks and benefits involved.

Another related problem area identified the need to understand, both technologically and socially, the nature of identity within such environments and to provide mechanisms to both communicate and protect identity.

Essential Infrastructure

At the workshop, it was stressed that the next stages of research will require much larger deployments of infrastructure and applications. However, the focus of the debate did not centre on how this infrastructure will manifest itself in the short term; rather it considered the open research issues such infrastructure deployment and evolution will engender. A variety of perspectives were presented on what constituted essential infrastructure and these are summarised as: sensor and device infrastructure; hardware infrastructure for input and output interaction; software infrastructure for manipulating and controlling interaction devices; communication infrastructure from the small to large scale; and core enabling middleware services.

The debate considered issues of managing what is "in" the infrastructure and what is supported at the edge of the infrastructure – at the interaction points.

Any infrastructure deployed to support ambient computing will by definition have to be long lived and robust. Consequently new approaches to the evolution of the infrastructure, *in situ* upgrade and update, will be required. Given the potentially vast collection of devices, sensors and personalised applications this update problem is significantly more complex than previously encountered. Additionally, since the infrastructure is meant to be invisible it will be necessary to develop an understanding of what failure means or can be perceived by a user. Consequently new approaches to developing robust systems and application will be required; ones that are fault tolerant, highly available, and that degrade gracefully.

Knowledge, extracted from or stored in the disappearing computer, results from the fusion and characterisation of primitive sensor data, from "perception" and "interpretation" of the context, or as a result of learning or decision-making. It was argued strongly that such knowledge was part of the infrastructure. And that the evolution over time will change what is perceived as environment knowledge and what is embodied in the application. Understanding the nature of the *knowledge infrastructure* was considered to be a core problem.

Also captured in this discussion was the notion of what these infrastructures should support. In essence, how will such infrastructures support fluent interaction? At a technical level much of the focus to date has been on sensing technologies; it was highlighted that there is also a need for new technologies for output paradigms that can be embedded in the infrastructure. Naturally, the need to situate the technology in the social mechanisms was strongly emphasised. The need to understand the balance of *quality*, from a technological perspective, with the end-user needs for functionality was identified as critical to delivering the appropriate infrastructure.

Appropriate Intelligence and Interactivity

Much of the existing work in this domain focuses on the collection of every facet of the sensed world, storage of every bit of information, and predicting the behaviour of users. These assumptions are often underpinned by, simplistic mental models of interaction and perception. These principles were questioned within the workshop. Although, alternatives were not proposed a number of questions were presented to challenge these assumptions. These are summarised as follows.

How much should we (or the infrastructure) remember? The human mind does not have instant recollection of every event, fact, or piece of information. Mental augmentation, although possible, may not provide the appropriate model for developing a disappearing computer. Investigations into the appropriate models of *recollection* need to be developed.

When do we try to predict the user and when do we let the user choose? The application and development of techniques for predicting user behaviour invariably do not work 100% of the time; not least because the user is prone to atypical behaviour in the midst of predictable behaviour. There is currently no clear understanding of when the user is willing to allow the infrastructure to operate on their behalf and when they are not willing. We need to understand this trade-off and how to support it in a natural manner.

How do we convey the system boundaries to the user? If the infrastructure is truly invisible, how does the user know what constitutes *their* environment, or whether it is working correctly? This raises two open questions of: how do you convey to the user, or give the user clues, about their environment and what they have control of; secondly, how does a user actually use these facilities without having to *program* or specify them from scratch. The first requires experimental investigations into the perception and communication within ambient systems. The second needs to discover and correctly interpret the recurring patterns of interaction within these environments and how best to provide support for these patterns.

Related issues and questions that were discussed at the workshop are:

- How can people interact with “invisible” devices?
- How do people migrate from explicit interfaces and interactions to implicit interfaces and interactions?
- How can we design for transparency and make people “understand” the interface?
- How can we design for a coherent experience?
- How can we design feedback to users in case of errors and malfunctioning which are not explicitly perceived?

Influential New Technologies

It is clear that this research domain is heavily influenced by the continued development and introduction of new technologies. The introductions of such technologies can radically effect not only what is achievable from Weiser's goal, but also how we interpret and envision that goal. A classic example is the location based services facet of this domain which is continually being influenced by the improved accuracy of GPS; the increased use of deployed wireless infrastructure whether it be Bluetooth, 802.11, GSM, or GPRS; and the introduction of new approaches such as Ultra Wide Band RF.

As part of the discussions within this workshop, a number of technologies of varying levels of maturity with potential to have significant impact on this research domain were mentioned. They are listed within this report to draw the attention of researchers. These technologies are:

- Photonics – both from a communications and a sensing perspective;
- Nano-technology – as an enabler for new devices and sensors;
- Quantum Computing – particularly in the context of security and cryptography;
- Autonomic Computing and Communications;

How can we assess success 5 years out?

Every mature domain of science and engineering has to critically reflect on its development and evolution; and quantify its successes and failures. Within the domain of ubiquitous technology we need to consider what constitutes the benchmarks of success and failure. There are two distinct elements to this discussion; firstly the issue of approaches to the evaluation of ubiquitous systems such as specific models, methods or techniques; and secondly, the issue of community consensus on approaches to comparative evaluation.

An emerging theme from this workshop highlighted the need to understand the interplay between technology and people, deployment and societal context. With this in mind, it was identified that new models of evaluation are needed with the community and that these models would have to take account of the wide variety of component elements. In doing so these new models of evaluation would build upon, and perhaps integrate, the existing approaches in each of component disciplines; drawing from social, cognitive, and systems sciences. This results in the request for a mix of evaluation paradigms, ranging from quantitative experimental to more qualitative approaches and comprehensive studies using, e.g., Living Lab scenarios.

Both the European [1, 16] and American communities [17] have elaborated scenarios and grand challenges that are specific to ubiquitous computing. However, although there are many complimentary and overlapping elements within these challenges there are currently no agreed reference points. As Dourish points out, "*General evaluation of new applications is important for purposes of usability but to generate further knowledge of the deeper use structures, for the purpose of future design, analyses of real implemented technologies are fundamental.*" The concluding remark of this report is a call for community activity to develop the benchmark assessment criteria and real-world scenarios that will enable us to answer the question - how can we assess success of our research 5, 10 or 15 years out?

Dissemination

Finally, it should be mentioned that the discussion at the workshop will result also in a journal publication. There will be special issue on "The Disappearing Computer" in the

Communications of the ACM (CACM) planned to be published in March 2005. The guest editors are the organizers of this workshop (Norbert Streitz and Paddy Nixon) and most of the contributions are provided by attendees of this workshop.

5. REFERENCES

[1] ISTAG Report on Scenarios for Ambient Intelligence in 2010 ftp://ftp.cordis.lu/pub/ist/docs/istagscenarios2010.pdf

[2] ERCIM News on Ambient Computing http//www.ercim.org/publication/Ercim_News/enw47/EN47.pdf

[3] EU (IST-FET) funded proactive initiative "The Disappearing Computer" http//www.disappearing-computer.net

[4] IEEE Pervasive Computing http://computer.org/pervasive/

[5] Springer Journal Personal and Ubiquitous Computing http://www.personal-ubicomp.com/

[6] Mobile VCE http://www.mobilevce.com/index2.htm

[7] Equator IRC http://www.equator.ac.uk/

[8] DTI Nextwave technologies and markets http://www.nextwave.org.uk/index.htm

[9] ESRC Virtual Society Program http://virtualsociety.sbs.ox.ac.uk/intro.htm

[10] Computer Science Challenges to emerge from eScience http://umbriel.dcs.gla.ac.uk/NeSC/general/news/uk_escience_agenda.html

[11] Project Aura : http : http://www-2.cs.cmu.edu/~aura/

[12] Project Active Spaces : http://www.cs.uiuc.edu/news/archives/resactsp.html

[13] Project PICO : http://www.cse.uta.edu/pico@cse/

[14] Mark Weiser. The Computer for the 21st Century. *Scientific American*, 265(3):94-104, September 1991.

[15] Mark Weiser "Ubiquitous Computing" site http://www.ubiq.com/hypertext/weiser/UbiHome.html

[16] Information Society Technologies Advisory Group, Working Group Grand Challenges in the Evolution of the Information Society draft report (06 July 2004) ftp://ftp.cordis.lu/pub/ist/docs/istag_draft_report_grand_challenges_wahlster_06_07_04.pdf

[17] Grand Challenges in Computer Science and Engineering, US initiative Computing Research Association (CRA), (http://www.cra.org/reports/gc.systems.pdf)

[18] http://guir.berkeley.edu/projects/patterns/patterns/ubicomp_patterns_test.pdf

[19] Marc Langeheinrich, Privacy by Design – Principles of Privacy Aware Ubiquitous Systems, in UBICOMP 2001, LNCS 2201, pp 273 291.

[20] "European Disappearing Computer privacy Design Guidelines" Deliverable D15.4 of the DC-Project "Ambient Agoras" (IST 2000-25134) available at http://www.ambient-agoras.org

The Disappearing Computer

6. Appendix A: Abstracts and Curriculum Vitae of Attendees (in alphabetical order)

Liam J. Bannon

Director of Interaction Design Centre
Dept. of Computer Science & Information Systems
University of Limerick, Ireland
www.idc.ul.ie

e-mail: liam.bannon@ul.ie

Short CV
Liam Bannon is a Professor in the Department of Computer Science and Information Systems and founder Director of the Interaction Design Centre at the University of Limerick. His research interests range over the gamut of human-technology relations, including cognitive ergonomics, human-computer interaction, computer-supported cooperative work, computer-supported collaborative learning, new media and interaction design, and social dimensions of new technologies. He was a founding editor of *CSCW: The Journal of Collaborative Computing* and is on the editorial boards of*; Journal of Cognition, Technology, and Work*; *Requirements Engineering Journal, Universal Access in the Information Society Journal*; *International Journal of Cognitive Technology*, and the forthcoming *Co-Design Journal*. He was formerly on the editorial boards of *Behaviour and Information Technology Journal, and Journal of Computer Assisted Learning*. Recent research funding include EU FET DC SHAPE & Sob projects, and Science Foundation Ireland Shared Worlds project.

Key words
Human-centred computing, interaction design, socio-cultural theory, place, human experience

Abstract
Even as we develop ground-breaking technologies within a ubiquitous computing paradigm, and open up new design spaces involving the meshing of physical and computational objects and media, we come up against the perennial problem of understanding people's lifeworlds and the nature of human, social and cultural life – within which our technologies must operate. I believe we need a rich understanding of the human, social and cultural world in order to design technological artefacts and environments that people find useful and usable, as well as engaging and playful. There is a need for interdisciplinary research in a number of areas and at a number of levels to explore the possibilities of technical advances in specific domains, as well as investigating new paradigms for how people can interact with and through the new technologies. I believe that there is a felt need, both in Ireland, the EU, and at a global level, for new ideas, concepts and demonstrations concerning how to think about, develop, and trial for human use, the new technological innovations. A key feature of these developments is the increased possibilities for interaction between people with and through the media with which they are engaged. We need to consider the relation between technology and the individual, the community, and the environment. As we enter a new century, issues of sustainability, aesthetics and quality of life all need to be integrated into our research on technological developments. It is this emphasis on human concerns and activity in relation to technology development and use that characterizes a perspective I label "human-centred"

interaction design.. This approach builds on a variety of human and social science traditions that focus on understanding human activity, all of which seek to provide useful and pertinent observations on human action in the world. Novel technologies may play an important role in these human activities, but more likely as a mediating influence, rather than as a conversational partner. I believe that we should learn from the failures of certain kinds of pro-active, technology-push, applications. People do not want to be inundated with "information". Their needs change depending on the situation they are in, so it is difficult to satisfy their needs simply by means of personal profiles or adaptive systems. Again, playing devil's advocate, I would strongly urge that developers explore design spaces that do not necessarily assume advances in machine intelligence, nor more detailed user models. Computers can work on behavioural data, and reflect this back to people, without needing to "interpret" its meaning. The relevance of this approach to technology development is that it provides a distinct perspective that encompasses many of the key issues being faced by (ubiquitous) technology designers today – issues such as awareness, context, interaction, engagement, emotion.

Gaetano Borriello

University of Washington
Dept. of Computer Science & Engineering Campus
Box 352350, Seattle, WA 98195, USA
www.cs.washington.edu/homes/gaetano
e-mail: gaetano@cs.washington.edu

Short CV

Gaetano Borriello is a professor of computer science and engineering at the University of Washington. His research interests are in ubiquitous computing and principally in new hardware devices that integrate seamlessly into the user's environment with particular focus on location and identification systems. He was the founding director of the Intel Research Seattle laboratory from 2001 to 2003. He served on the committee that wrote the National Research Council's recent report "Embedded, Everywhere" outlining a research agenda for embedded sensor networks. Currently, he serves on the editorial board of IEEE Pervasive Computing Magazine and the program committees for the conferences on Mobile Systems, Applications, and Services (Mobisys), Ubiquitous Computing (Ubicomp), and Embedded Networked Sensor Systems (Sensys).

Key words
Ubiquitous and pervasive computing, location-aware computing, personal-area networks, sensors and sensor networks, tangible user interfaces.

Abstract

Location-awareness is a critical component of ubiquitous computing systems. We are focusing our research on two aspects of this problem: location estimation, and wide-area mass-scale deployment

We argue for the use of probabilistic methods to perform location estimation. We can demonstrate that these methods can be accurate, flexible, and practical. Probabilistic methods provide the same or better accuracy as deterministic approaches while being inherently more flexible in two important ways: the ability to fuse data from different sensor types and the

ability to present a more valuable interface to applications by providing a probability distribution of the estimate. Moreover, it is practical to run such algorithms on devices ranging from high-end servers to handhelds and consider the computational requirements as well as memory footprint. Based on these analyses and on the successful research, commercial, and community adoption of our approach, we conclude that probabilistic methods enjoy many advantages that make them the best choice for a wide variety of mobile and ubiquitous computing systems.

To be widely adopted, location-aware computing must be as effortless, familiar and rewarding as web search tools like Google. We envisage the global scale Place Lab, consisting of an open software base and a community building activity as a way to bootstrap the broad adoption of location-aware computing. The concept seeks to take advantage of the exponential increase in deployment of wireless access points. We use these APs as beacons that index a database through their MAC addresses. This permits a privacy-friendly client-side computation of location similar to GPS. Early results show tracking in urban areas can be as accurate as 30m without even taking signal-strength into account. We are currently working on methods to also position users on floors of buildings in addition to 2-D coordinates. Further research is ongoing in how to determine "places" from positions and provide higher-level semantically-rich abstractions of locations to users and applications.

Roy H. Campbell

Siebel Center of Computer Science,
University of Illinois at Urbana-Champaign,
201 N. Goodwin Avenue MC-258, Urbana, IL 61801-2302, USA
http://cs.uiuc.edu/~rhc

e-mail: rhc@uiuc.edu
Tel: +1-217-333-0215
Fax: +1-217-244-6869

Short CV

Dr. Campbell received his Ph.D. Degree in Computer Science from the University of Newcastle upon Tyne in 1976. He is a professor of computer science and has supervised the completion of thirty one Ph.D. dissertations, over one hundred M.S. theses and is the author of over one hundred and seventy research papers on security, programming languages, software engineering, operating systems, distributed systems, and networking. His current research interests include the context awareness, security, privacy, networking and infrastructure concerns of ubiquitous computing and active space environments.

Key words
context and location awareness, mobility, security and privacy, ubiquitous applications

Abstract

I believe in a future where people's living spaces are interactive and programmable. Users interact with ubiquitous applications as they move from space to space, taking applications with them, accessing space specific applications, and building new applications interactively as needed. Users interact with offices, homes, cars, malls and airports to request information, benefit from the resources available, and personalize the space's behavior. Except for confidentiality restrictions, data and tasks are always accessible and are mapped dynamically to convenient resources present in the current location. Users may extend the habitat with

personal devices that seamlessly integrate with the environment. When the physical environment of a user contains hundreds of networked computer devices each of which may be used to support one or more user applications, the notion of personal computing becomes inadequate. Further, when a group of users share such a physical environment, new forms of sharing, cooperation and collaboration are possible.

Research must devise appropriate user interfaces, protocols, algorithms, data structures, services and infrastructure to migrate ubiquitous applications, make context available to those applications and secure and offer privacy to the users of ubiquitous computing applications. Since ubiquitous computing must be scalable and inexpensive, engineering ubiquitous applications and their support must become commonplace requiring standards, tools, and common components. Support for ubiquitous computing requires cyber infrastructure that both supports user ubiquitous applications requirements and safeguards the infrastructure. Major breakthroughs can be expected in creating ubiquitous applications that support significant human activities, particularly in the areas of entertainment, business, health care, and education. Creating a commercial environment in which such breakthroughs can impact all society and all nations will require considerable effort. Of particular concern is the problem of developing a trusted cyber infrastructure for ubiquitous computing. Existing computer and network architectures remain vulnerable to errors, sabotage, and theft and a more heavy reliance on ubiquitous computers will make the situation more difficult to solve. Privacy of the individual is also a major concern with the increase of information from ubiquitous computing, location awareness, and video surveillance. Another difficult problem requiring research is predicting the impact of ubiquitous computing on society. Although the understanding of user interfaces has improved, it has proved to be remarkable difficult to develop interfaces that offer accessible information processing to all members of society. Last, as in all engineering endeavors, ubiquitous computing needs a suite of evaluation methods and tools.

Joëlle Coutaz

Université Joseph Fourier
Laboratory CLIPS-IMAG
Grenoble, France
http://iihm.imag.fr/coutaz/

e-mail: Joelle.Coutaz@imag.fr
Tel: +33-4 76 51 48 54
Fax: +33-4 76 44 66 75

Short CV

I have studied computer science at University Joseph Fourier (Grenoble, France) where I obtained my doctorate in 1970 and Thèse d'Etat in 1988 in which I set the foundations of software engineering for HCI. I am the founder in 1990, and head of the HCI Group at laboratory CLIPS. I am the author of the PAC model, a conceptual software architecture model for interactive systems. I am a member of the editorial board of Interacting With Computer and formerly of the ACM TOCHI. I have been involved in the ACM CHI conference as paper and panel chair, and as member of the program committee of Mobile HCI, Ubiquitous Computing, and Ambient Intelligence. I was vice chair of the Working Group 2.7 of IFIP. I have been involved in the ESPRIT BRA/LTR project AMODEUS (1989-1995) which promoted a multidisciplinary approach to HCI. My current core research interests include context modeling as well as the concept of plasticity for distributed and migratory multimodal user interfaces. My participation in three European projects (GLOSS, FAME, CAMELEON) as well as the Dagstuhl seminar illustrates these interests.

Key words
Software aspects of HCI, software architecture modelling for interactive systems, migratory user interfaces, distributed user interfaces, plastic user interfaces.

Abstract
With the concept of ubiquitous computing, a new paradigm is emerging bringing together a wide range of disciplines. From the perspective of Human Computer Interaction, this paradigm entails a radical change in terms of design methods and development tools. In this position paper, I will stress the necessity for new tools to support the development of user interfaces (UI). I will also argue for the importance of machine perception.

User interfaces are currently designed for a known context of use based on the GUI paradigm. This paradigm supposes a fixed set of interaction resources (1 screen, a text and a pointing device). In ubiquitous computing, this stability does not hold anymore. UIs will go from stationary to migratory as well as from centralized to distributed. Distribution will happen over a dynamic set of heterogeneous interaction resources that will be borrowed and lent opportunistically. These multi-scale resources, which will range from walls to private eyes, will require that UI's go beyond the classic zoomable model. If we want to go beyond concept demonstrations, we must dare to question the current WIMP technology and to devise new UI-centered models and infrastructures. This technology will sit at the edge of the global computing fabric to form a dynamic cohesive whole.

In addition to UI development tools, we currently need significant progress in machine perception. Too often, machine perception has been developed for its own sake, without concern for the requirements of the real world. If we want services and their UIs to dynamically accommodate the diversity of situations and contexts, we need machine perception to set the foundations for modelling context.

Beyond tools and techniques, we, as responsible researchers, must not forget Ethics. Privacy and trust are core issues. As a researcher in HCI, I am also concerned by the right balance between the anthropomorphic 'machine' envisioned as an equal partner, and the instrumentalist perspective where the 'machine' is a controllable tool.

Anind K. Dey

Senior Researcher
Intel Research Berkeley
http://www.cs.berkeley.edu/~dey

e-mail: anind@intel-research.net
Tel: +1-510-495-3012
Fax: +1-510-495-3049

Short CV
Anind Dey is a Senior Researcher at Intel Research Berkeley and an Adjunct Assistant Professor in Electrical Engineering and Computer Science at the University of California and Berkeley. He received a PhD in 2000 in Computer Science from Georgia Tech, performing his dissertation research on the topic of software architectures to support the building of

context-aware computing, namely the Context Toolkit. Anind performs research at the intersection of ubiquitous computing (ubicomp) and human-computer interaction, looking at techniques for improving users' experiences in ubiquitous computing environments and tools that make it easier for programmers to design and implement compelling ubicomp applications for users. Over the past few years, Anind has been focusing on the issues of end-user programming, privacy and ambient/peripheral displays.

Key words
Context-aware computing, human-computer interaction, end-user programming, software architectures

Abstract
One of the most important challenges in ubiquitous computing is determining how to give end users control of their smart environments. Most of the visions of ubiquitous computing include autonomous agents or programs acting autonomously on the behalf of users. It is unrealistic to expect that these agents will be able to accurately predict what users want to occur in all situations. Instead, it is imperative that end users have the ability to *control* what occurs in these environments. Specifically there are at least three important problems that need addressing: 1) how to support non-programmers/end users in building applications that support delegation of tasks to the environment (*e.g.*, context-aware computing); 2) how to protect end users' privacy in a world of ubiquitous sensing, data synthesis and dissemination; and, 3) how to alleviate issues of information overload. End users know more about their environments than anyone else and are in a better position to specify what their applications should do than any programmer. In addition, as these environments change and evolve, end users will be the only ones available to make changes and evolve their applications. It is imperative that end users be empowered to build and evolve applications to control their ubicomp environments. On the issue of privacy, ubicomp environments are filled with sensors collecting information about users and their actions, processing this information, disseminating this information to others and taking action on it. Users must be able to take control of this information and this process of information collection and dissemination. They must be able to specify who is able to gain access to what information in what circumstances, in a tractable, non-overwhelming way. Finally, on the issue of information overload, with a greater number of sensors collecting information and a greater number of devices that can display information, there are greater opportunities for being overloaded with information. Ubicomp researchers should provide ways of presenting information that minimize information overload but maximize usefulness and timeliness of information.

Hans Gellersen

Professor for Interactive Systems
Department of Computing
Lancaster University
UK

e-mail: hwg@comp.lancs.ac.uk
Tel: +44-1524-593823
Fax: +44-1524-593608

Short CV

Hans Gellersen is Full Professor for Interactive Systems at the Department of Computing at Lancaster, U.K. His research interest is in ubiquitous computing and embedded interactive systems. This spans work on enabling technologies such as position and context sensing, on user interfaces beyond the desktop, and on embedding of interaction and intelligence in everyday artefacts. Recent work includes Smart-Its, a framework for artefact-based applications and platform for rapid prototyping of artefacts with embedded computing.
Hans initiated the HUC/Ubicomp conference series on Ubiquitous Computing and serves as editor of the Journal on Personal and Ubiquitous Computing. He is involved with major research programmes related to Ubiquitous Computing, including the Disappearing Computer initiative and the Equator project in the UK. Hans has been in his current position since 2001 and previously was affiliated with the University of Karlsruhe, Germany. He holds an MSc and a PhD in Computer Science, both from University of Karlsruhe.

Key words

Ubiquitous computing, embedded interactive systems, context-awareness

Abstract

Recent research programmes related to Ubiquitous Computing have begun to embrace embedded technologies to engage more deeply with the vision of 'activating the world'. The Disappearing Computer projects specifically have emphasized augmentation of places and artefacts in people's lives, to literally push computing into the background of what people care about. There has been some inspiring work on 'smart artefacts' as future versions of familiar things in our lives, however on a very limited scale. It is clear that interactive and intelligent behaviour can be embedded in practically everything but it is not yet understood at all how this would give rise to emergent applications, what the implications would be, and how this can be designed to be human-centred in the spirit of Weiser's vision.
In order to work toward a better understanding, it is necessary to build experimental test-beds that push the vision, integrating not only a few artefacts in selected and relatively controlled settings, but thousands of artefacts used across largely varying settings. Among the core challenges is the development of architectures for embedded and decentralized intelligence and interaction, to allow ad hoc collections of artefacts to become more autonomous of surrounding infrastructure. This is in contrast to most current ubiquitous computing experiments which tend to be constructed around richly instrumented locations with centralized systems services – such environments can not be assumed to become ubiquitously deployed. In conjunction with a shift from environment-centric systems to decentralized systems of computational artefacts, it will also be a key challenge how to expose and explain system behaviour, and how to make artefacts and emerging applications reconfigurable/programmable by their owners/users.

Anatole Gershman

Director of Research
Accenture Technology Labs
Chicago, USA

e-mail: Anatole.v.gershman@accenture.com
Tel: +1-312 693 6613
Fax: +1-312 652 6613

Short CV

Anatole Gershman is Director of Research at Accenture Technology Labs. Under his leadership, research at the laboratories is focusing on early identification of potential business opportunities and the design of innovative applications for the home, commerce and work place of the future. The technology laboratories are conducting research in the areas of ubiquitous computing, interactive multimedia, information access and visualization, intelligent agents, and simulation and modeling. Prior to joining Accenture in 1989, Anatole spent over 15 years conducting research and building commercial systems based on Artificial Intelligence and Natural Language processing technology. He held R&D positions at Coopers & Lybrand, Cognitive Systems, Inc., Schlumberger, and Bell Laboratories. Anatole studied Mathematics and Computer Science at Moscow State Pedagogical University and received his Ph.D. in Computer Science from Yale University in 1979.

Key words

Sensors, Artificial Intelligence, Intelligent Sensor Networks, Data Mining, Visualization

Abstract

Ubiquitous computing holds enormous promise for radically transforming the way we interact with our environment. At work, in public areas and at home invisible intelligent computers will understand what we need in our specific context and bring the power of all locally available resources to satisfy those needs. They may even anticipate our needs and protect us from potential hazards. These services will help individuals as well as groups such as families and work teams. Large-scale applications of invisible ubiquitous computing will range from supply chain management and transportation to public safety and the care for the elderly. To bring these benefits to life, significant advances will have to be made in several areas of technology. First, we'll need better, more intelligent and inexpensive sensors capable of collecting all kinds of data from the environment. These sensors will range from temperature and acceleration meters to medical monitoring devices. Of special importance are exact positioning sensors that work indoors. Sensors even at the edge of the network will have to be intelligent and provide some level of information processing in order not to flood the network with raw data. Secondly, we need intelligent sensor networks that will direct the right information to the right recipients. These networks will range from wired to mobile and from fixed to ad-hoc and self-organizing. The network intelligence will be necessary to decide where the information is going, how it should be aggregated and how it will get to its destination, which itself may be dynamic and changing. Thirdly, we need powerful and intelligent analytical tools to decide what to do when information about a person or an object reaches a decision point. Most likely, these tools will have to combine statistical observation with artificial intelligence techniques such as machine learning and case-based reasoning. Critical to the success of these tools will be their ability to handle enormous amounts of data coming from the sensor networks, much of it in real time. Finally, the people controlling such systems will need powerful visualization, knowledge discovery and collaboration tools to make invisible computing not only visible but usable and intelligible.

Achilles Kameas

Research Academic Computer Technology Institute
R&D Unit 3 / DAISy group,
Patras, Greece

e-mail: Kameas@cti.gr
Tel: +30-2610-273496
Fax: +30-2610-222086

Short CV

Achilles D. Kameas received his Engineering Diploma (in 1989) and his Ph.D. (in 1995, in Human-Computer Interaction), both from the Department of Computer Engineering and Informatics, Univ. of Patras, Hellas. He is an Assistant Professor with the Hellenic Open University, where he teaches software engineering. He is also a senior researcher with Research Academic Computer Technology Institute (CTI), where he is the head of Research Unit 3 (Applied Information Systems) and the founder of the Design of Ambient Intelligent Systems (DAISy) group (daisy.cti.gr). His research activities are currently focused in ubiquitous computing (component-based architectures, design and analysis of middleware, ontology-based service discovery and composition, end-user models and tools, application development methodologies), interfacing with biological systems (semantic characterization of biological signals) and swarm intelligence applications (formal specification and analysis, synthesis and emergence of behavior, communication protocols).

Key words

ubiquitous computing, architecture, middleware, ontology, tools

Abstract

In order for ubicomp technology to become acceptable by society, we think that a breakthrough in scale will be required: apart from designing smaller, more robust, friendlier systems, its "face" and the "interfaces" it offers must become non-intrusive cognitively. This will involve the large-scale deployment of ubicomp applications, first in specialized areas (i.e. buildings, health, office environments, games) and then across all environments. To reach this point, we also need to produce results in infrastructures (so that ubicomp applications are supported) and tools (so that they are developed and used).

- Infrastructures: this translates to standardization of procedures to access and use computer-enabled services, ubiquitous interfaces, "natural" and safe interaction with ubiquitous services/applications. To achieve these we need to design appropriately generic layered architectures, design for adaptability (with emphasis in context awareness and evolution through learning), achieve real-time performance, design scalable models to manage the complexity of interactions, accommodate heterogeneity of concepts and implementations, support mobility by creating task representations, incorporate privacy and safety preserving mechanisms that are acceptable from society into systems.
- Tools: developers need processes to design, develop, deploy and evaluate ubicomp systems; these could result from combining and evolving existing ones in distributed systems, component-based systems, hardware design and complex systems. End-users need tools to help them create, adapt, use and generally manage these applications, without bothering with details about network, device compatibility, service location, etc.

Moreover, they need to feel increasingly safe with this technology, so the way data and content are used must be visible and subject to user control.

A critical asset that appears in many different forms in the above is "knowledge", which in this context is considered as information resulting from fusion of raw sensor data, descriptions of context and situations, accumulated or learned experience, decision making procedures and rules, social rules, etc. Significant research efforts should be applied into describing, collecting and coding this knowledge, as well as into providing mechanisms and tools to manage, use and extend it.

Morten Kyng

Department of Computer Science
University of Aarhus
Denmark

e-mail: mkyng@daimi.au.dk
Tel: +45-89 42 57 15
Fax: +45-89 42 56 24

Short CV

Morten Kyng's main research areas are participatory design, computer supported cooperative work, pervasive computing, and human-computer interaction. His main focus is currently participatory design of new paradigms for 'palpable' pervasive computing systems. That is pervasive systems that are capable of being noticed and that the users may investigate and apprehend mentally. Morten Kyng is professor of pervasive computing and coordinator for the EC project Palcom. The professorship is sponsored by Systematic Software Engineering - www.systematic.dk. Morten received his Doctor of Science from the University of Aarhus in 1996. He currently directs the Centre for Pervasive Computing - www.pervasive.dk, a national research centre with headquarters at Katrinebjerg in Aarhus. In 2001 he was, as the only European, appointed to the ACM CHI Academy for leadership in the field of computer-human interaction. From 1996 to 2002 Morten directed the Danish National Centre for IT Research.

Projects sponsored by the European Commission

Coordinator (project manager) for the project Palcom: Palpable computing – a new perspective on ambient computing. Palcom is an integrated project in the 6th Framework Programme, palcom.dk

Project manager for the project OCTOPUS (1995) on multimedia support for globally distributed cooperation.

Project manager for the ESPRIT III project EuroCODE (1993) on an open CSCW development shell.

Project manager for the University of Aarhus group in the ESPRIT II project EuroCoop (1992)

Key words

Pervasive Computing, Palpable Computing, Participatory design, Computer Support for Cooperative Work, Object-oriented analysis and design.

Abstract

Ambient or ubiquitous computing is an emerging field based on a number of insights and assumptions many of which were described by Mark Weiser in his 1991 Scientific American paper "The Computer for the 21th Century". The promise and the ambitions are high, and several contributions illustrate the potential. This position paper explores a new perspective on ambient computing called Palpable computing. The perspective challenges some of the assumptions taken for granted in the design of ambient computing. Thus *palpable* denotes that systems are capable of being noticed and mentally apprehended. Palpable systems support people in understanding what is going on at the level they choose. Palpable systems support control and choice by people. Often the default mode for a palpable application is to suggest courses of action rather than acting automatically. Palpable computing challenges and complements ambient computing in the following ways:

ambient computing	complemented with	**palpable computing**
invisibility		visibility
construction		de-construction
scalability		understandability
heterogeneity		coherence
change		stability
sense-making and negotiation		user control and deference

Thus palpable computing complements the unobtrusive effectiveness of ambient computing with a focus on making the means of empowering people intelligible. Palpable computing supports users in coping with situations where technology is not doing the (right) job and thus enable us to create technology for a dynamic society where we cannot assume that (all of) our technology has become so natural that we use it without even thinking about it.

Spyros Lalis

Assistant Professor
Computer and Communications Department
University of Thessaly
Greece

e-mail: lalis@inf.uth.gr
Tel: +30 - 2421074978
Fax: +30 - 2421074997

Short CV

Spyros Lalis received a Diploma in Computer Engineering and a doctorate in Technical Sciences from the Swiss Federal Institute of Technology Zurich (ETHZ). Since 2002 he is Assistant Professor at the Computer and Communications Engineering Department of the University of Thessaly. Since 1997 he is Research Associate at the Institute for Computer Science of the Foundation for Research and Technology Hellas (ICS-FORTH), and since 2003 he is Research Associate at the Informatics and Telematics Institute of the Center for Research and Technology Hellas (ITI_CERTH). His interests include Programming Languages and Systems, Software Engineering, Operating Systems, Distributed Systems, Global and Ubiquitous Computing. He has participated in several international research projects. He was coordinator of 2WEAR (http://2wear.ics.forth.gr), a project funded under the FET Disappearing Computer initiative (http://www.disappearing-computer.net).

Key words
Distributed systems, global computing, wearable and ubiquitous computing.

Abstract
The new era of computing is characterized by (a) the heterogeneity of computer elements in terms of processing, storage, sensing, mobility, communication and interaction capability, (b) the increased embedding of such elements into everyday objects or environments, (c) the wide range of possible element combinations that become possible to support applications, and (d) the huge span of applications in terms of lifetime, operational environment, and physical distribution/distance of their elements.

One of the main challenges is to support the flexible combination of these elements, and to perform, maintain and adjust such combinations, at runtime. This must be done in a way that relieves the application programmer from having to implement this functionality (every time from scratch) while providing enough flexibility so that it is possible to specify and control the system's behavior in a simple way.

Context-awareness is important in order to deal with the various operational settings of applications in a flexible and proactive way and with minimal explicit input from the user. However, "low-level" context information should be combined with the user's intention (high-level context). In turn, user intention must be captured as a combination of explicit input (commands), known plans (agendas) and sensing subsystems (monitoring -> inference). Both contextual aspects must be woven into the application and the supporting system infrastructure in an appropriate way.

Last but not least, it is perhaps interesting to challenge the traditional notion of application (a "dump" executable that is started by the user, does something and then terminates), and try to think of different metaphors, e.g. applications are composed of persistent agents that continuously evolve, and which can be suspended when showing no signs of activity and resumed whenever something "interesting" happens.

James A. Landay

Director of Intel Research Seattle
and Associate Professor at the
Dept. of Computer Science & Engineering
University of Washington
Seattle , USA

e-mail: james.a.landay@intel.com
Tel: +1 - 206 - 545-2511
Fax: +1 - 206 - 633-6504

Short CV
James Landay is a Professor of Computer Science at the University of Washington and the Director of Intel Research Seattle. He is also the chief scientist and co-founder of NetRaker Corp. He received his B.S. in electrical engineering and computer science from UC Berkeley in 1990 and his M.S. and Ph.D. from Carnegie Mellon University in 1993 and 1996, respectively. His Ph.D. dissertation was the first to demonstrate the use of sketching in user interface design tools. He has published extensively in the area of human-computer

interaction, including articles on user interface design and evaluation tools, ubiquitous computing, pen-based user interfaces, mobile computing, and visual languages.

Title
Emerging Design Patterns for Ubiquitous Computing

Abstract
Design patterns are a format for capturing and sharing design knowledge. We have recently looked at a new domain for design patterns, namely ubiquitous computing. The overall goal of this work is to aid practice by speeding up the diffusion of new interaction techniques and evaluation results form researchers, presenting the information in a form more palatable and usable to practicing designers. Towards this end, we have developed an initial and emerging pattern language for ubiquitous computing, consisting of 45 pre-patterns describing application genres, physical-virtual spaces, interaction and systems techniques for managing privacy, and techniques for fluid interactions. We evaluated the effectiveness of our pre-patterns with 9 pairs of designers in helping them evaluate and design location-enhanced applications, currently the most common form of ubiquitous computing. We observed that our pre-patterns helped new and experience designers unfamiliar with ubiquitous computing, in generating and communicating ideas, and in avoiding design problems early in the design process. We are currently focusing on developing design patterns in the digital home of the future and exploring whether the emerging pattern language can help designers, as well as become the basis for end-user configuration of the digital environment.

Allan MacLean

Image Semantics Ltd
Cambridge, UK

e-mail: allan.maclean@imagesemantics.com
Tel: +44 7734276000
Fax: +44 1223 422325

Short CV
I am a founder and director of Image Semantics which was set up in 2002 to develop innovative applications and services to take commercial advantage of the mass-market opportunities that are now emerging around latest generation mobile phones. Prior to this, I was with Xerox Research Centre Europe's Cambridge laboratory from its inception as Rank Xerox EuroPARC in 1987. Over the last twenty years I have worked on a wide variety of issues and problems in the broad area of interactive technologies. A common thread has been a strong grounding in use and the user, while also pushing technological and conceptual boundaries. My main research interests have focussed around moving away from the desktop PC since the early 90's, for example, through work on media spaces and mobile computing. I also have a long standing interest in design and the design process as a way of dealing with the increasingly interdisciplinary demands that must be coordinated for the successful development of modern technologies. I worked closely with the ACM (Association for Computing Machinery) to develop relations between the former USSR and the West in the early 90's via the East-West HCI conference series, and in the mid-90's as a founder of the DIS (Designing Interactive Systems) conference series. I have regularly advised on funding

programmes for the UK Research Councils and the European Union and am a member of the Steering Group for the EU 'Disappearing Computer' Programme.

Key words
Mobile applications; Interactive technologies; User perspectives; Consumer market; Design process

Abstract
I would like to explore four directions that I believe will help us work out where we need to focus research effort beyond what we are currently doing. The first two are conceptual – how we think about the core problem we are addressing. The second pair focus on how we carry out research in this area and what disciplines are involved.

Getting to the essence and fighting complexity

From a user perspective, what are the core enabling capabilities that emerge from the wide range of ubicomp applications and services we are currently pursuing? We have a tendency in research to make things too complicated to get a clear message across outside the research community. We need more reflection on work done to date to make sure we understand what is important, can communicate it clearly and have a stronger foundation for future research

Getting to grips with context

We have used the word "context" in far too generic a way over the last 15 years. Devices being aware of what is going on around them will probably be the basis of the next big leap forward in the second decade of the 21st century, but we still haven't reached consensus on what is important here. The initial solution might be as simple as working out how to use location information effectively and in a general and useful way.

Taking the hardware seriously

Too much research is still based on developing software for off-the-shelf devices. We need more emphasis on designing the hardware as an integral part of ubicomp research, incorporating skills ranging from expertise in developing low level circuits to the external form of devices.

Taking the market seriously

We have made good progress in taking people and their needs seriously as part of our research programmes. But we still assume that because we can demonstrate that people SHOULD want the products of our research that they WILL want them. The gap is much wider than we generally appreciate. It is not enough just to involve token companies in research projects and tack on an exploitation plan as part of the proposal. One solution might be to involve people with expertise in the exploitation of technology as part of the research programmes – possibly skills such as business strategy, marketing, channel development, even venture funding.

Friedemann Mattern

Institute for Pervasive Computing
ETH Zürich
Switzerland
http://www.inf.ethz.ch/~mattern/

e-mail: mattern@inf.ethz.ch
Tel: +41 1 632 05 36
Fax: +41 1 632 16 59

Short CV

Friedemann Mattern has been a professor of computer science at ETH Zurich since 1999. He studied computer science and communications at the University of Bonn and received his PhD from the University of Kaiserslautern in 1989. He served as professor of computer science at the University of Saarbrücken from 1991-1994, and at Darmstadt University from 1994-1999. At ETH Zurich, Mattern founded the Institute for Pervasive Computing and heads the computer science department's Distributed Systems Group. His research interests include concepts of distributed computing, ubiquitous computing, and infrastructure mechanisms for dynamic networking of small and mobile devices. Mattern is the co-editor of several scientific journals, and is involved in various research projects (such as M-Lab, NCCR-MICS, Smart-Its), often in cooperation with industrial partners.

Key words

Infrastructures for ubiquitous computing, applications for ubiquitous computing, implications of ubiquitous computing, sensor networks

Title

Social, Economic, and Ethical Implications of the Disappearing Computer

Abstract

The Disappearing Computer is a radical concept: With its orientation towards the public as well as the private, the personal as well as the commercial, it aspires to create technology that will accompany us throughout our entire lives. While developments in information technology never had the explicit goal of changing society, but rather did so as a side effect, the visions associated with the Disappearing Computer expressly propose to transform society by fully computerizing it. It is therefore likely that this development will have long-term consequences for our everyday lives and ethical values that are much more far-reaching than the Internet as we know it today.

However, the repercussions of such extensive integration of computer technology into our everyday lives as propagated by the Ubiquitous Computing paradigm are difficult to predict and one can only speculate. It is certainly not the washing machine querying our dirty clothes for washing instructions that will change the world. But what if parents will never lose track of their children because location sensors and communications modules are sewn into their clothes? And will producers of "smart" goods get a permanent channel to their customers, enabling new pay-per-use business models and having control over the use of their products and services? Would people feel being surrounded by an invisible and comprehensive surveillance network with all the smart objects and wireless sensors that we envision? Also, as more and more objects and environments are being equipped with Ubiquitous Computing technology, the degree of our dependence on the correct functioning of this technology

increases - can we rely on it? And if artifacts become more autonomous and humans move gradually out of the loop - who is responsible if something goes wrong?

Obviously, there are more questions than answers and only the future will tell. But, maybe, we can profit by speculating about the possible consequences of this technology and evaluating it within the framework of established concepts from fields such as sociology or economics. It may thus be possible to steer the development in a direction that has more in common with Weiser's optimistic vision of the 21st century than with the depressing scenarios of some popular but not necessarily unrealistic cyberpunk scenarios.

Other issues:
- How to make sense out of all these data provided by wireless sensors?
- How can we manage all these invisible computers?
- Can we make objects smart without making them intelligent?
- Will we ever get a common and open infrastructure to support smart objects?

Paddy Nixon

Global and Pervasive Systems Group
The University of Strathclyde
Glasgow G1 1XQ, Scotland

e-mail: **paddy.nixon@cis.strath.ac.uk**
Tel: +44-141-548-3588
Fax: +44-141-552-5330

Short CV
Paddy Nixon is Professor of Computer Science at Strathclyde University where he runs the Global and Pervasive Systems Group. He is also research Director of the Kelvin Institute – a company developing and commercialising research in the pervasive systems domain. He holds a B.Sc. from Liverpool University, a Ph.D. from Sheffield University, and an M.A. (in J.O) from Trinity College Dublin. He is a Chartered engineer and a member of the British Computer Society. Professor Nixon's research is focused on the following key aspects distributed systems research: 1. Theoretical and structured approaches to distributed systems construction, 2. Dynamic adaptation and composition of distributed systems, and pervasive computing. He has been co-chair of the EU Disappearing Computer Network and is co-founder of the UK Ubiquitous Computing Network of Excellence. He has been guest editor for special issues of IEEE Internet Computing Journal, The Computer Journal, The Journal of Parallel Algorithms and Architectures, and The Software Quality Journal. He has chaired 6 conferences and 3 workshops in the areas of electronic commerce, parallel and distributed systems, and smart environments. He has published five books, with 2 books under review, and over 100 publications in the areas of pervasive computing, virtual enterprises, software engineering, parallel processing, distributed systems and object orientation.

Keywords: Middleware, Context modelling, Programming Abstractions, Trust and Privacy.

Title: Sentient and Global Scale Ambient Systems

Abstract
The natural progression of research to commercial realisation in Ambient Systems is taking the developments from laboratory examples to real world deployments. However, implicit in

all of these deployments are the limitations of the existing research developments. They are premised on: deployments of hundreds rather than billions of sensors; on local communications at the expense of the global movement of users; on limited representations of context and knowledge; and ad-hoc abstractions and programming primitives. The commercial realisation of such systems still requires significant engineering research expertise. However, to realise truly global and sentient ambient systems requires a fundamentally new set of models and approaches. Our vision is one of the sentient ambient system – one that is both globally aware and responsive, and intimately individual. Below we outline a number of fundamental research challenges that are a consequence of the need to scale up to the levels of sensors and devices implied by the ambient systems vision, and to continue to provide intimate, human control over the information flows within the environment.

Scaling: By this we consider the deployment of smart dust sized computation and sensory elements in a given environment. The numbers of entities and complexity of communication are comparable to scale of the communications in today's internet. In short, the current models of communication, interpretation, and adaptation are not appropriate.

Matching and Discovery: One of the key requirements to the provision of globally aware services is a matching service capable of assimilating and filtering information from various sources and determining relevant matches., we need to provide matching that is consistent within some acceptable operational envelope; an operational envelope that may be different for every user, environment, or situation.

Layering, abstraction, and progra mming: Ambient systems development has yet to establish what the fundamental semantics of its systems are and consequently it is still missing the fundamental primitives. The only way for future ambient systems to be economically viable to develop is for there to be coherent toolsets. The only way to develop the toolsets is to discover the fundamental primitives and understand their semantics and implementation.

The baseline challenge is - how do we develop an active infrastructure that embodies this new extended sensory system and which provides to the user, application or environment an intimate local interface to global dispersed services.

Joseph A. Paradiso

MIT Media Laboratory
Cambridge, USA
http://www.media.mit.edu/~joep

joep@media.mit.edu
Tel: +1-617-253-8988
Fax: +1-617-253-6285

Short CV

Joseph Paradiso's background ranges from high-energy physics detectors and spacecraft control systems to electronic musical instruments. He now explores the development and application of new sensor architectures and extremely dense sensor/processor networks for human-computer interfaces and intelligent spaces. An expert on sensing technology, he has developed a wide variety of systems that exploit many different sensor modalities to track human activity. A summa cum laude graduate of Tufts University, Paradiso received his PhD in physics from MIT as a Compton Fellow. Before joining the Media Lab, he was at ETH in Zurich working on precision drift chambers and the Draper Laboratory in Cambridge, Massachusetts, working on underwater sonar, precision alignment systems, and aerospace vehicle control. He is an associate professor and directs the Media Lab's Responsive Environments Group, and co-directs the Things That Think Consortium, a collaboration between Media Lab researchers and industrial partners to explore the extreme future of embedded computation.

Key words
Sensor Technology, sensor networks, electronic skins, expressive interfaces, quasi-passive wakeup

Abstract
Sensor networks will provide the means for user interfaces to break out of today's constrained platforms and permeate the environment. This produces a major shift in how sensors are used in user interfaces. Rather than relying on only one or two kinds of sensors designed a priori to measure particular parameters, many sensors will be used that don't necessarily directly measure the quantity of interest, but allow it and several other parameters to be estimated from the wealth of raw data being produced. This is analogous to vision systems in the large amounts of potentially indirect data being produced, but here the different types of sensors produce measurements of different flavors, as they look at an environment from many different perspectives. Fusing this data into dynamic features that reflect a user's state and can infer goals is the major challenge in ubiquitous computing, and indeed incorporates many stubborn problems that have been nagging computer science for decades. As these sensor nodes generally have limited resources (e.g., power, computation capacity, communication bandwidth), they must be optimally and dynamically balanced (i.e., what sensors to look at and which features to calculate and transmit) depending on local and global context. A key challenge in power management is to have these sensor nodes spontaneously activate upon receipt of sensor signals that are passively filtered to select appropriate stimuli (what we term "quasi-passive wakeup") – achieving this with radio (having the sensor nodes activate upon passive reception of a coded signal) is perhaps an even greater challenge. Our ability to intimately blend diverse sensors with local, interconnected processing on nodes spaced mm apart or closer promises to usher in a new generation of intelligent materials or multimodal electronic skins, where the frontiers of electronics fabrication, sensor integration, data fusion, ad hoc networking, and emergent computation intersect to launch a new field of sensing mechanisms with nearly biological complexity. Such work holds the potential for revolutionary applications in areas such as robotics, medicine, and smart materials.

Daniel M. Russell

User Sciences & Experience Research Lab (USER)
IBM Almaden Research Center
San Jose, USA

daniel2@us.ibm.com
Tel: +1-408-927-1907
Fax: +1-408-927-3033

Short CV

The central organizing themes of my research career has been to (1) understand the nature of how people use large & complex collections of information, and (2) to create attractive, comprehensible, and evocative user experiences of that information.

Following this lead, I work to invent new mechanisms that let us know more, perceive more richly, and comprehend the world in new ways. This focus has lead me over the past several years to work in the areas of the design of information experience, sensemaking, intelligent agents, knowledge-based assistance, information visualizations, multimedia documents, advanced design and development environments, design rationale, planning, intelligent tutoring, hypermedia, human/computer interfaces.

Most recently I've turned my attention to how large amounts of information can be worked with in many different settings, which inevitably has led me to work in ubiquitous computing, and understanding how to make the computer disappear into the work.

I am now at IBM's research center at the southern tip of Silicon Valley, the Almaden Research Center, in San José, California, USA. I have previously worked at Xerox PARC and at Apple Computer's research lab.

Key words
large shared displays

Title

Attention Shock: Living in a world of multiple competing information streams

Abstract

How do you know what you can do in a given place? How does the world inform you of possibilities and options?

Perhaps the greatest challenge facing the disappearing computer is that of attention management, or rather, human attention conservation, as we try to live in a world that grows increasingly computational and interactive. As technology increasingly shrinks computers and embeds them into more worldly stuff, many of them will become human-attention seekers. As displays become less expensive and more ubiquitous they will appear on everything and become every surface. Where displays go, advertising will follow. Where advertising goes, human attention will be increasingly diverted, and the competition for attention, or attention conversation, begins.

As a computing culture, we will need to create / design or evolve mechanisms for informing people about what computational opportunities are available (especially in a given space), while simultaneously NOT creating a world where every clock, every wall hanging, every thermostat cries out for attention. Weiser and Brown called for a world of "calm computing."

We need to take that concern seriously and understand what our attentional limits are, and how to best design entire environments that are composed of many pieces from multiple makers —yet are still comfortable, workable, serene environments for humans to inhabit.

Norbert A. Streitz

Head of Research Division
AMBIENTE – Smart Environments of the Future
Fraunhofer IPSI
Dolivostr. 15, D-64293 Darmstadt, Germany
http://www.ipsi.fhg.de/ambiente , http://www.ipsi.fhg.de/~streitz

mailto: streitz@ipsi.fraunhofer.de
Tel: +49-6151-869-919
Fax: +49-6151-869-966

Short CV

Dr. Dr. Norbert A. Streitz (Ph.D. in physics, Ph.D. in psychology) is the head of the research division "AMBIENTE – Smart Environments of the Future" at the Fraunhofer institute IPSI in Darmstadt, Germany, where he also teaches at the Department of Computer Science of the Technical University Darmstadt He studied mathematics, physics, chemistry, and psychology at the University of Kiel, Germany, and psychology, education, and philosophy of science at the Technical University (RWTH) of Aachen, Germany. He was a post-doc research fellow at the University of California, Berkeley, a visiting scholar at Xerox PARC and at the Intelligent Systems Lab of MITI, Tsukuba Science City, Japan. His research interests range from Cognitive Science, Human-Computer Interaction, over Hypertext/Hypermedia and Computer-Supported Cooperative Work to Interaction Design for Ambient/ Pervasive/ Ubiquitous Computing in the context of an integrated design of real and virtual worlds. He and his team are known, e.g., for the development of Roomware®, the integration of room elements (walls, furniture) with information technology. Since 2001, he is the Chair of the Steering Group of the EU-funded proactive initiative "The Disappearing Computer (DC)", a cluster of 17 projects, and also the coordinator of the DC-project “Ambient Agoras”. Since 2003, he is the Co-Chair of CONVIVIO, the EU-funded Network of Excellence on People-Centred Design of Interactive Systems. He has published/edited 15 books and more than 90 papers presented at the relevant international conferences or in journals in his areas of interest. He serves regularly on the programme committees of these conferences and on several editorial boards (e.g., ACM TOIS - Transactions on Information Systems, Personal and Ubiquitous Computing). He is often invited to present keynote speeches to scientific as well as commercial events in Europe, USA, South America, Asia, especially in Japan.

Keywords

Interaction design, social architectural space, ambient displays, context and awareness, privacy.

Abstract

There is no doubt that the field of ubiquitous and pervasive computing is facing major problems and challenges caused by the very nature of the field, especially if it is approached in a serious way going beyond limited lab settings. Real-life applications require a huge number of sensors (challenges for mass production, integration, operability) creating an even larger amount of sensor data that have to be communicated (challenges for sensor networks), processed (challenges for pre-/post processing, aggregation), utilized by applications (challenges for inferencing, reasoning on the basis of often incomplete data), used in causing

effects in the environment (challenges for actuators) as well as facilitating the information processing and decision making of humans. These are impressive technical challenges that deserve a lot of attention and effort.
On the other hand, this technology should serve a purpose – after all. This constitutes another set of challenges. It includes identifying the why and what for, the personal, social, organisational, spatial and application context. The theme of this workshop ("The Disappearing Computer") illustrates nicely that the computer/the technology should be in the background or as the goal of the DC initiative stated: "to explore how everyday life can be supported and enhanced through the use of collections of interacting smart artefacts. Together, these artefacts will form new people-friendly environments in which the 'computer-as-we-know-it' has no role". The associated objectives include: "to ensure that people's experience of these environments is both coherent and engaging in space and time". This is the dimension I like to address and where I still see substantial deficits in research, development and exploitation deserving corresponding attention. The DC initiative made a foray into this emerging field but we still do not know enough about, e.g., what constitutes an augmented social architectural space that provides awareness and a feeling of the place and communicates its (service) potential to people and enriches their experiences. We also need to look much more at what are the issues when going beyond one person addressing groups of people and organisations and their interaction with multiple artefacts populating local and distributed spaces. Another important area is control and privacy in sensor-enriched or should I say sensor-flooded or polluted environments. Finally, I like to predict that ubiquitous computing will become a base technology that is part of our infrastructure. It will merge with other fields and will be - as hypertext functionality is now via the web – available everywhere.

Terry Winograd

Dept. of Computer Science
Stanford University
USA

e-mail: Winograd@cs.Stanford.edu
Tel: +1 650 723 2780
Fax: +1 650 723 0033

Short CV
Terry Winograd is Professor of Computer Science at Stanford University, where he directs the Interactivity Laboratory and the teaching and research program in Human-Computer Interaction Design. He is one of the principal investigators in the Stanford Digital Libraries project, and the Interactive Workspaces Project, which does research on ubiquitous computing. He recently completed a sabbatical at Google, a search engine company founded by Stanford students from his projects. In collaboration with Armando Fox at Stanford, he has led research on the Stanford Interactive Workspace, a middleware software layer and set of interaction technologies for integrated work in multi-user multi-platform settings. A key focus is in providing users with fluent interactions that provide interactive functionality in a group setting with a minimum of distraction. http://hci.stanford.edu/winograd

Key words
Interactive workspace, fluid interaction

Title
Relating theory and practice in ubiquitous computing

Abstract

There are many research challenges from the technical side, to provide both mobile and environment-based devices that are robust, power-efficient, cost-effective, etc. Without minimizing the importance of these, I will focus on the other side of the challenge, making the ubiquitous environment comprehensible and usable for a wide class of people. As we move away from the desktop, the people who will be the “users” (though at times implicitly) of our technologies will not have either the training, the attention, or the interest in dealing with complex interfaces. On the other hand, they will tend to be more discretionary users (as opposed to productivity applications whose use is necessary for a job), so they will not use the systems unless high expectations are met. Designing appropriate interactions for this context will require new concepts and techniques beyond those that are now standard for desktop and PDA.

Successful technologies and applications are being built in many places, based on designer intuitions, careful observation of users, and devotion to iterative improvement. These will always be required, but are not sufficient to provide for the growth of the expanding world of “invisible computers” and their settings. The challenge for research is to develop generalizations and theories at an appropriate level that can distill what has been learned from experience in a way that provides systematic conceptual support and guidance for design. These will not have the straightforward quantitative nature of current fine-grained theories of motor activity and perception that have been employed in HCI, but they do need to be more generative than the broad theoretical paradigms we borrow from philosophy and conceptual branches of psychology. So the challenge has a meta-level: not just developing specific theories, but a process by which the research community can develop practices and norms that create the context for theories in practice. In doing this, we need to stay grounded in real design settings and needs, including the emerging worlds of mobile computing, network-centric interaction, and place-focused interaction.

7. APPENDIX B: PRESENTATIONS

EU-NSF advanced joint Research Workshop

24. April 2004, Hotel Bristol, Vienna

IST: Future & Emerging technologies

The Disappearing Computer

Norbert Streitz
Fraunhofer IPSI
Darmstadt, Germany

Agenda of DC-Workshop

9:00 – 9:15 Welcome and Organisational Issues

9:15 – 10:30 Session 1: Overview and Intros Part I
- Norbert Streitz : DC initiative (EC-FET)
- Paddy Nixon: plans for new EC-FET initiative
- Hans Gellersen: EQUATOR in the UK
(incl. discussions on presentations)

10:00 – 10:30 Morning Break

11:00 – 13:00 Session 2: Overview and Intros Part II
- Anatole Gershman: Applications Perspective
- James Landay: Proactive Computing at Intel
- Terry Winograd: Theory and Practice
- Discussion and identification of topical clusters

13:00 – 14:00 Lunch

14:00 – 15:30 Session 3: topical clusters and discussion in subgroups

15:30 – 16:00 Afternoon Break

16:00 – 18:00 Session 4:
reports from subgroups, conclusions, next steps

20:00 Social event dinner

Motivation and Background

- Projects of the DC initiative finished (end of 2003)
- International perspective on the DC initiative
- EU-NSF advanced joint Research Workshops are an excellent vehicle for this activity
- Mission
  - Present and discuss future R&D directions, challenges, visions in this emerging area
  - Create opportunities for EU-US collaboration
  - Recommendations to seed calls for proposals (=> see Paddy Nixon's presentation)
  - Visionary view on the Disappearing Computer
  - Dissemination (report, special section CACM)

Ubiquitous Computing and Calm Technology

The most profound technologies are those that disappear.

They weave themselves into the fabric of everyday life until they are indistinguishable from it.

Mark Weiser (Xerox PARC)

„The Disappearing Computer“- Initiative

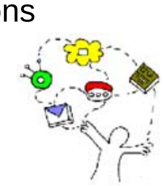
- 5th Framework Programme
- Information Society Technology (IST)
- Future and Emerging Technology (FET)

- This proactive initiative was conceived in 1999
- The call for proposals was issued in February 2000 with closing date in May 2000
- Projects started in January 2001

Goal of “The Disappearing Computer”

To explore how everyday life can
be supported and enhanced through
the use of collections of interacting artefacts.
Together, these artefacts will form new
people-friendly environments in which
the “computer-as-we-know-it” has no role.

The aim is to arrive at new concepts and
techniques out of which future applications
can be developed.



Specific Objectives of the DC-initiative

- Developing new tools and methods for the embedding of computation in everyday objects so as to create artefacts.
- Research on how new functionality and new use can emerge from collections of interacting artefacts.
- Ensuring that people's experience of these environments is both coherent and engaging in space and time.

Overview

- 17 projects accepted for funding
- 55 institutions from academia and industry
  21 universities, 16 research institutes,
  18 companies in 15 countries
- start: 1. 1.2001, duration: 2,5 -3 years
  end: 31.12.2003
- total EU funding: 23 million €

Steering group of the DC-Network
- Chair: Norbert Streitz (Fraunhofer-IPSI, Germany)
- Host Organization: University of Strathclyde, UK with Paddy Nixon as co-chair

DC website
- http://www.disappearing-computer.net

List of DC-Projects

2WEAR
A Runtime for Adaptive and Extensible Wireless Wearables

ACCORD
Administering Connected Co-Operative Residential Domains

AMBIENT AGORAS
Dynamic Information Clouds in a Hybrid World

ATELIER
Architecture and Technologies for Inspirational Learning Environments

e-GADGETS
An architectural style for Extrovert Gadgets

FEEL
Non-intrusive Services to Support Focused, Efficient and Enjoyable Local Activities

FICOM
Fiber Computing

GLOSS
Global Smart Spaces

GROCER
Grocery Store Commerce Electronic Resource

INTERLIVING
Designing Interactive, Intergenerational Interfaces for Living Together

MIME
Multiple Intimate Media Environments

ORESTEIA
Modular Hybrid Artefacts with Adaptive Functionality

PAPER++

SMART-ITS
Interconnected Embedded Technology for Smart Artefacts with Collective Awareness

SHAPE
Situating Hybrid Assemblies in Public Environments

SOB
The sounding object

WORKSPACE
Distributed Work Support through Component-based Spatial Computing Environments

PALCOM
Palpable Computing
(DC follow-up)

DC Initiative: Networking Activities - 1

Supporting cross-project collaboration:

- *Disappearing Days/Nights*
  (workshops on selected themes)
- *Research Ateliers*
  (joint activities of people from a range of projects to work together for a week or so)
- *Troubadour Grants*
  (travelling grants for visiting a number of sites)

DC Initiative: Networking Activities - 2

- *Jamborees*
  (major annual events as a focus for the DC community: combination of exhibition, project reviews, workshops)

1. Jamboree took place at the ETH Zürich (Switzerland) in October 2001
2. Jamboree took place in Göteborg (Sweden) on 29. Sept. – 2. Oct. 2002 co-located with the UbiComp 2002 Conference
3. Jamboree took place in Ivrea (Italy) 20.-22. November 2003

Disappearance of the Computer

Computers used to be "primary artefacts", now they become "*secondary*" artefacts and move in the "background" in several ways

- *Physical* Disappearance

vs.

- *Mental* Disappearance

Some Selected Issues

Contexts

- Individual/personal, social, organisational context
- Spatial/architectural envelope
- Application context

Questions

- What constitutes an augmented social architectural space providing awareness and feeling of the place? (=> 'agora')
- How to communicate the (service) potential of the environment for enriching people's experience?
- How to introduce distance-dependent semantics?
- How to address the local vs. distributed situation?

Disappearance and Interaction

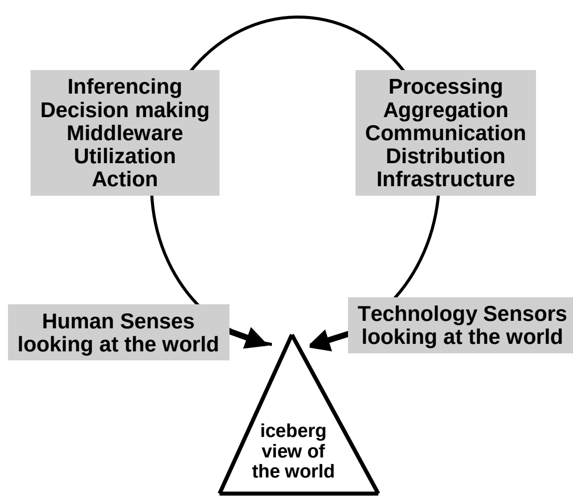
- How can people interact with "invisible" devices ?
- How do people migrate from explicit interfaces/ interactions to implicit interfaces/interaction ?
- How can we design for transparency and make people "understand" the interface ?
- How can we design for a coherent experience ?
- What should happen in case of errors or malfunctioning which are not explicitly perceived ?
- How can we design for user's control and address the resulting privacy issues in sensor-enriched (or -polluted) environments ?

Suggestions for Topical Clusters - 1

Human ⟷ **Technology**

Human Interface | **Services, Functionality** | **Middleware, Infrastructure** | **Sensors, S-Networks**

Suggestions for Topical Clusters - 2



Agenda of DC-Workshop

9:00 – 9:15 Welcome and Organisational Issues

9:15 – 10:30 Session 1: Overview and Intros Part I
- Norbert Streitz : DC initiative (EC-FET)
- Paddy Nixon: plans for new EC-FET initiative
- Hans Gellersen: EQUATOR in the UK
(incl. discussions on presentations)

10:00 – 10:30 Morning Break
11:00 – 13:00 Session 2: Overview and Intros Part II
- Anatole Gershman: Applications Perspective
- James Landay: Proactive Computing at Intel
- Terry Winograd: Theory and Practice
- Discussion and identification of topical clusters

13:00 – 14:00 Lunch
14:00 – 15:30 Session 3: topical clusters and discussion in subgroups
15:30 – 16:00 Afternoon Break
16:00 – 18:00 Session 4:
reports from subgroups, conclusions, next steps

20:00 Social event dinner

Proactive Computing at Intel Research Seattle: *The Where & What*

James A. Landay
Director, Intel Research Seattle
Professor, University of Washington

April 24, 2004
EU-NSF Workshop
Vienna

Intel Research   www.intel.com/research   intel

Intel Research Seattle Overview

- Mission: Develop & evaluate new usage models, applications, & underlying technology for ubiquitous computing
- Work with University of Washington
  - Universities the "Radar" in Intel Research's Open Innovation Paradigm
  - Intel + free flow of university research (e.g., ***interns***)
- Size: 13 researchers, growing to 20 full-time researchers
  - community of 35 (w/ interns, visitors, & campus collaborators)
- Collaborate with labs in Berkeley, Cambridge, & Pittsburgh, all working towards "Proactive Computing" vision

Intel Research   intel

Proactive Computing

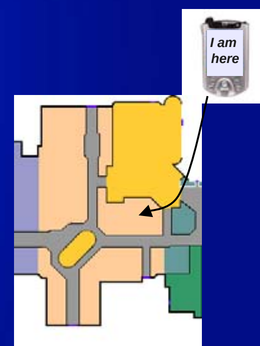
- *Def.* systems acting in anticipation of future problems, needs, or changes of the user
- To be proactive a computer system must understand the user's context & how it changes over time
  - ***Who*** the user is & who they are with
  - ***Where*** they are
  - ***What*** they are doing
- Our current lab focus at Intel Research Seattle is on solving the ***where*** & the ***what***

Overview

- Introduction to Intel Research Seattle
- ***Place Lab Location Infrastructure***
- SHARP Human Activity Recognition & Prediction
- Design Pre-Patterns for Ubicomp

The Goal of Place Lab

- Enable widely available location-enhanced computing
  - allows us to study/build truly ubiquitous systems
- Build a positioning system that is
  - wide-scale, indoor & outdoor
    - can be used *everywhere*
  - privacy observant, low barrier to participation
    - can be used by *everyone*



How Will it Work?

- Exploit wide-scale WiFi deployment
  - WiFi base stations broadcast unique IDs
  - position WiFi devices using database tying base-station-IDs to location
  - could work with any radio beacon (e.g., mobile phone cell sites)

- Build a global user-contributed RF-location mapping service (the DB)
  - leverage “war drivers” & WiFi Clubs
  - collect trace logs of regular users who opt in

Making Location-Enhanced Application Development Easier

Program with *place* rather than *location*

- Coordinates are not meaningful to people
  - *"Hey Joe! Guess who I bumped into at 47.232, -122.454!"*
- Develop techniques for mapping coordinates to meaningful places
  - e.g., *47.232, -122.454* →
    {'bank', 'Wells Fargo', 'private property', 'indoor quiet space'}

Privacy in Place Lab is Different

- Many location-enhanced computing services have a computation trust problem…
  - "Who can figure out where I am?"
- Computation trust in Place Lab eased by client-side computation of location
  - clients listen for beacons using passive monitoring (like GPS)
  - clients cache WiFi AP database data locally
- Explore users' notions of place & privacy with experience sampling method
  - give participants WiFi-enabled PDAs & periodically interrupt them
  - ask questions of the form: where are you? are you with other people? is it ok to reveal your current location?

Place Lab Status

- Have built first version of beacon database infrastructure (23K APs) & cross-platform clients
- Distributed toolkit to early adopters
  - graduate course on location-aware computing at UW
  - Kelvin Institute, UCSD, & Dartmouth
  - distributing to more universities now – get involved!
- Planning out studies for notions of place & privacy

Overview

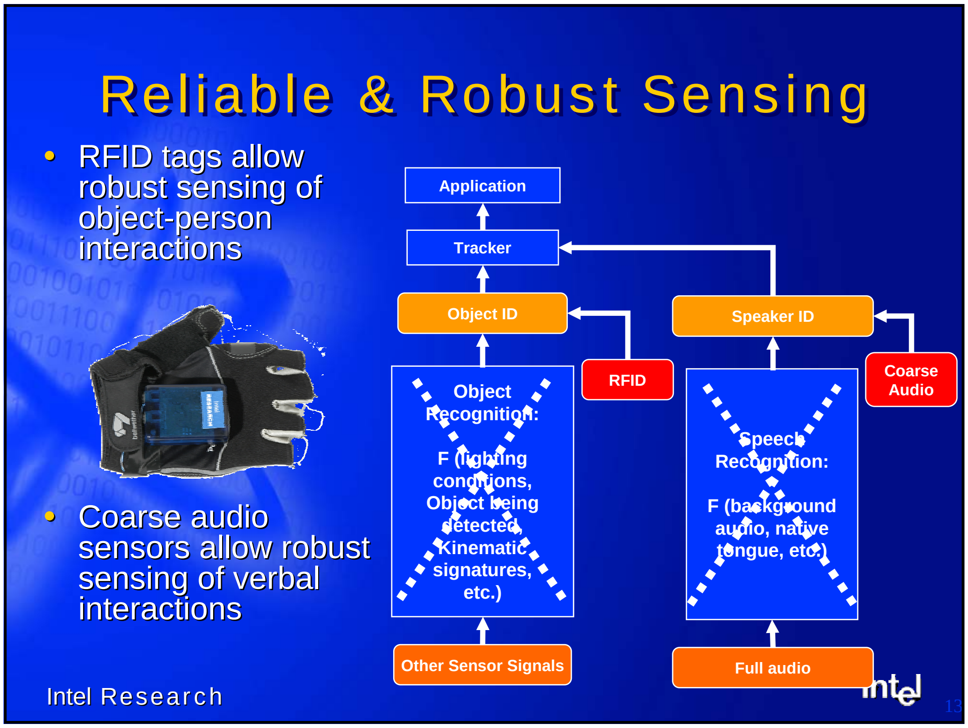
- Introduction to Intel Research Seattle
- Place Lab Location Infrastructure
- ***SHARP Human Activity Recognition & Prediction***
- Design Pre-Patterns for Ubicomp

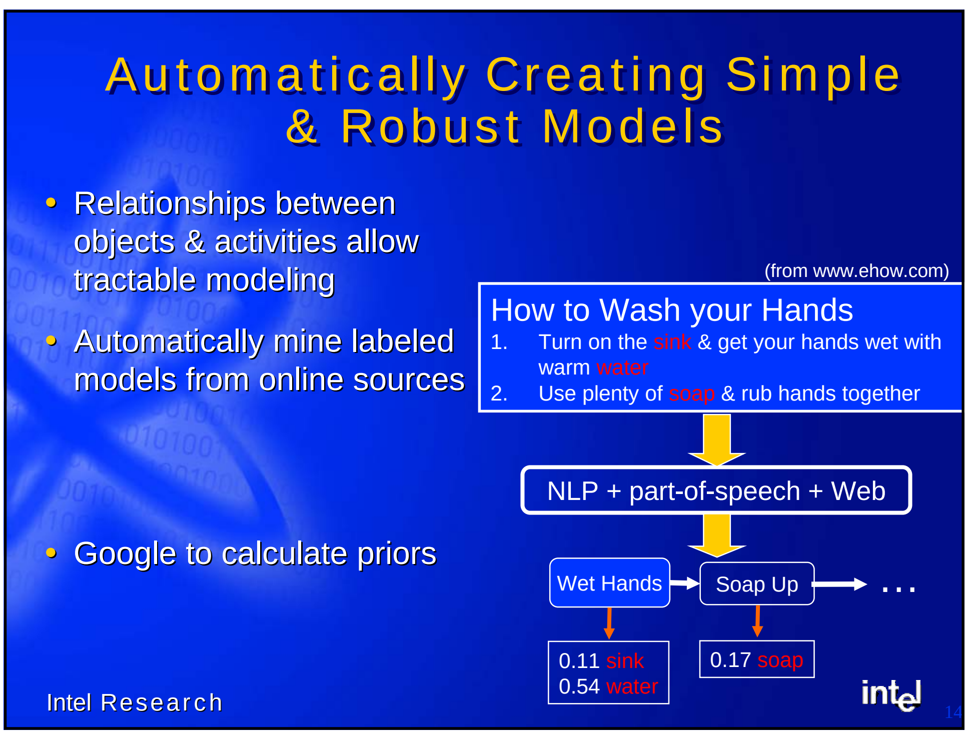
What are the Key Problems in Activity Monitoring?

1. **Sensor processing**: find a sensor stack that can report meaningful features across many activities & scenarios
2. **Representation**: find a tractable model accommodating variations & uncertainties in activities
3. **Creation**: get Machine Learning PhDs out of the loop of hand-creating & understanding models

What New Ideas Let Us Address These Challenges?

- **What people use** is a key way to characterize many activities


Reliable & Robust Sensing
• RFID tags allow robust sensing of object-person interactions
• Coarse audio sensors allow robust sensing of verbal interactions
Application
Tracker
Object ID
Speaker ID
RFID
Coarse Audio
Object Recognition:
F (lighting conditions, Object being detected, Kinematic signatures, etc.)
Speech Recognition:
F (background audio, native tongue, etc.)
Other Sensor Signals
Full audio
Intel Research
intel


Automatically Creating Simple & Robust Models
• Relationships between objects & activities allow tractable modeling
• Automatically mine labeled models from online sources
• Google to calculate priors
(from www.ehow.com)
How to Wash your Hands
1. Turn on the sink & get your hands wet with warm water
2. Use plenty of soap & rub hands together
NLP + part-of-speech + Web
Wet Hands
Soap Up
. . .
0.11 sink
0.54 water
0.17 soap
Intel Research
intel

ADL Application

- **What**: infer activities of daily living (ADLs)
- **Where**: IRS Researcher's house
- **How**:
  - put 108 RFID tags in house
  - people wore "iGlove", performed ADLs
- **Results**: overall 88% precision, 73% recall
- **Limitations**:
  - no longitudinal use
  - only 14 activities in 1 domain
  - inconvenient iGlove required

UW Anesthesiology Training Application

- **Who**: IRS + UWMC + Ind. Design
- **What**: train med school students
- **When**: now
- **Where:** surgical simulation lab
- **Why**:
  - real users & data
  - workplace training domain
  - sensor fusion of iGlove & coarse audio
  - domain expert model interaction

Overview

- Introduction to Intel Research Seattle
- Place Lab Location Infrastructure
- SHARP Human Activity Recognition & Prediction
- ***Design Pre-Patterns for Ubicomp***

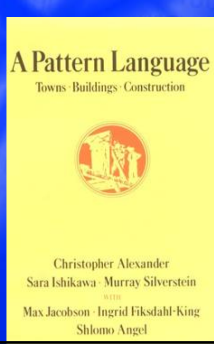
Intel Research

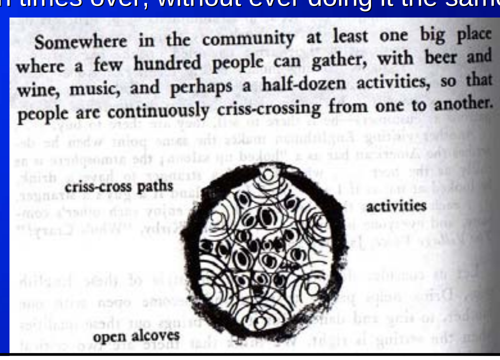
intel

17

Design Patterns

- Design is about finding solutions
  - unfortunately, designers often reinvent
- Patterns communicate common design problems & solutions
  - first used in architecture [Alexander]
- Not too general & not too specific
  - use solution "a million times over, without ever doing it the same way"

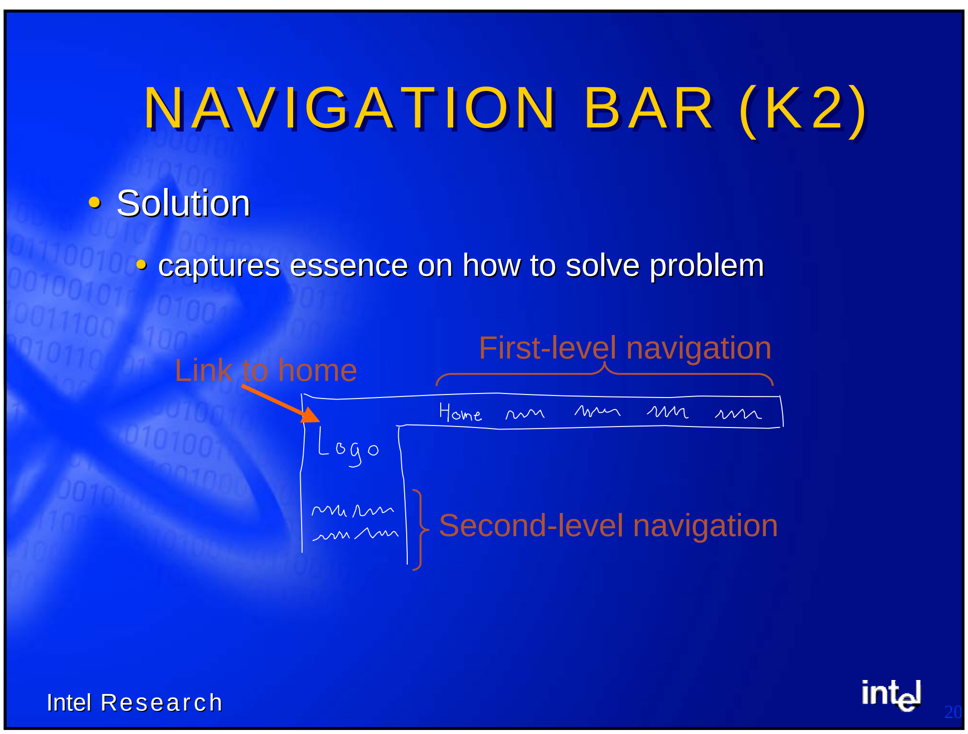



Somewhere in the community at least one big place where a few hundred people can gather, with beer and wine, music, and perhaps a half-dozen activities, so that people are continuously criss-crossing from one to another.

intel

18


NAVIGATION BAR (K2)
• Problem: Customers need a structured, organized way of finding the most important parts of your Web site
Group for User Interface Research
Home
Projects
People
Publications
Links
DENIM and SILK
Download
Documentation
Support
Research
Publications
More Projects
DENIM and SILK
IBM
United States
Search
Home
Products & services
Support & downloads
My account
Select a country
Industries
Home / home office
Small business
Medium business
Government
Education
Buy today, ship today
e-business on demand
IBM Global Financing
Intel Research
intel
19


NAVIGATION BAR (K2)
• Solution
• captures essence on how to solve problem
First-level navigation
Link to home
Home
Logo
Second-level navigation
Intel Research
intel
20

Design Pre-Patterns for Ubicomp

- Can patterns actually lead design?
  - Pattern purists will say no – so let's call 'em pre-patterns
- Can we find patterns from the most popular apps?
  - Mobile communication via cell phone
    - CONTEXT SENSISTIVE I/O (D6) – Use appropriate input & output modalities for current environment
      - e.g., in movie theater don't use sound – use vibration/visual cues
      - e.g., in a car use sound
- Can we find patterns that are found across several different ubicomp (research) applications?

Intel Research

intel

21

45 Ubicomp Pre-Patterns in 4 Groups

A – Ubicomp Genres	B – Physical-Virtual Spaces	C – Successful Privacy	D – Fluid Interactions
Describes broad classes of emerging apps, providing many examples & ideas	Associating physical objects & spaces with information & meaning; location-based services	Policy, systems, & interaction issues in designing privacy-sensitive systems	How to design for dozens/hundreds of sensors & devices while giving users control
Upfront Value Prop. (A1) Personal Ubicomp (A2) Ubicomp for Groups (A3) Ubicomp for Places (A4) Guides for Exploration & Navigation (A5) Emergency Response (A6) Personal Memory Aids (A7) Smart Homes (A8) Enhanced Education (A9) AR Games (A10) Streamlining Business Ops (A11) Enabling Mobile Commerce (A12)	Active Map (B1) Topical Information (B2) Experience Capture (B3) User-Created Content (B4) Find a Place (B5) Find a Friend (B6) Notifier (B7)	Fair Info Practices (C1) Respecting Social Orgs (C2) Building Trust/Credibility (C3) Level of Control (C4) Privacy Feedback (C5) Privacy-Sensitive Architectures (C6) Partial Identification (C7) Pys. Privacy Zones (C8) Blurred Personal Data (C9) Limited Access to Personal Data (C10) Invisible Mode (C11) Limited Retention (C12) Notification on Access (C13) Privacy Mirrors (C14) Keeping Personal Data on Personal Devices (C15)	Scale of Interaction (D1) Sensemaking of Services & Devices (D2) Streamlining Tasks (D3) User Control (D4) Serendipity in Exploration (D5) Context-Sensitive I/O (D6) Active Teaching (D7) Resolving Ambiguity (D8) Ambient Displays (D9) Follow-me Displays (D10) Pick and Drop (D11)

Intel Research

intel

22

A12 • ENABLING MOBILE COMMERCE

Figure 1. Progress in sensors, small devices, and wireless networking is enabling new kinds of mobile commerce. This figure shows a small PDA with a barcode scanner. One could imagine using a system like this to get product reviews while out shopping, as well as recommendations and price comparisons.

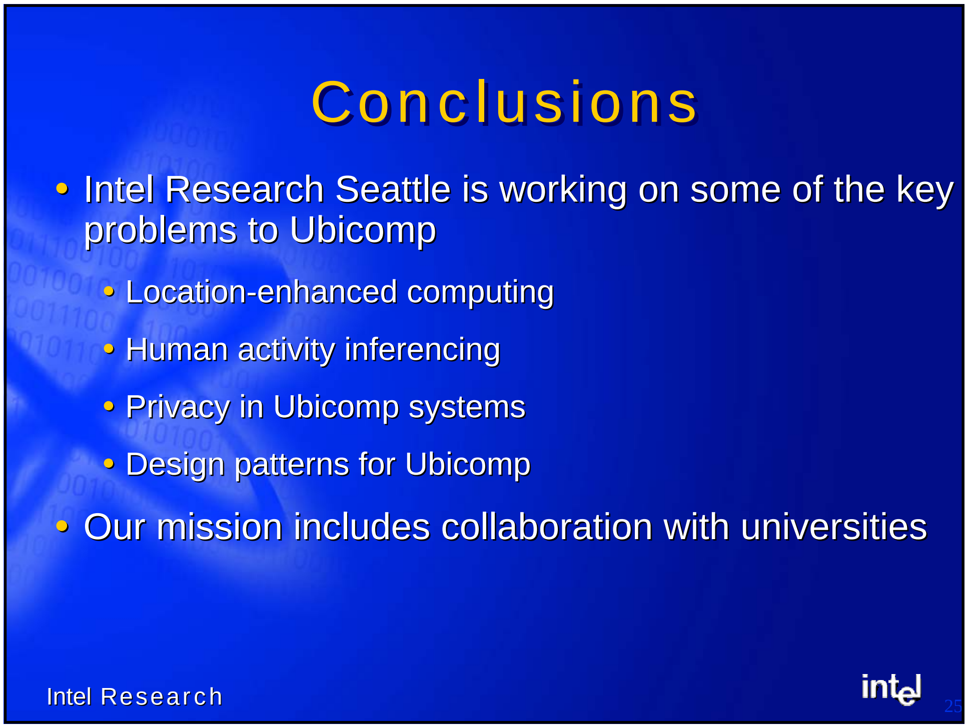
services are slowly emerging. Here, we describe some innovative ideas that are being rolled out.

One idea is to make it easy to find more information about products before you buy them. Figure 1 shows a small wirelessly-networked PDA that also has a barcode scanner. People can scan in barcodes to immediately find reviews, making them more confident about their purchases. Such a service could also provide recommendations (and depending on who offers the service and what their business model is, possibly price comparisons as well).

Figure 2 shows FastFrog, an idea tried out in several metropolitan areas in late 2000. Shoppers could use a small handheld to create wish lists that could be shared with friends and family.

Design Pre-Patterns Status

- Very preliminary work (first paper to appear in DIS 2004)
- Focusing on patterns for the digital home
  - digital home appliances (e.g., Tivo, MP3, etc.) will require end-user specification of state & conditionals -> programming!
  - can we discover the basic Ubicomp interaction language (analogous to point, click, drag, & menus in GUI)?
  - can basic & higher level patterns help designers do better here?
  - can people use patterns to configure their home Ubicomp systems?


Conclusions
• Intel Research Seattle is working on some of the key problems to Ubicomp
• Location-enhanced computing
• Human activity inferencing
• Privacy in Ubicomp systems
• Design patterns for Ubicomp
• Our mission includes collaboration with universities
Intel Research
intel
25

Kelvin

the Kelvin Institute

Creating and Moulding Ambience

Paddy Nixon

Community Driven

- The I-Cubed/Disappearing Computer Experience was a unique and exciting experience.
- A resounding community wish to further and develop the experience.
- Has to take account of new projects (smart-surroundings, AIR, etc.) and emerging proactive initiatives (Communication Paradigms for 2020, Global Computing, Novel Architectures,…) and International context.

Context/Process

- Focused brainstorming meeting produced a view on "Infrastructures and Services for Ambient Systems".
- Support and consultation with FET office
- Production of revised text incorporating need to Foster Collective Creativity
- The process: Focused online consultation currently underway to lead to a revised call.

Terminology

Ambient Systems is the European term for the area variously called Pervasive, Ubiquitous, Proactive, Sentient, Calm…

Kelvin Institute

European focus

"At the core of the European view of infrastructures for ambient systems is the need to enriching and supporting ordinary people in their daily life."

We are challenged to empower the European community – both individually and **collectively**.

Kelvin Institute

Drivers

- Migratory Service View
  - infrastructures for context aware **migratory systems** that are aware of humans and can move with them across mobile devices and fixed infrastructure,
- New levels of Scale
  - From hundreds to billions of sensors. Local interaction in a global infrastructure
- Individual Control
  - Composability and control
- **Collective Creativity**
  - new forms of interaction

Kelvin Institute

Infrastructure

***From an infrastructural perspective we must ask - how do we program ambient systems*:**

We conjecture that this will be achieved by discovering the fundamental programming primitives of ambient systems and by developing an appropriate coherent set of tools to gain understanding of their semantics and implementation.

The Collective View

***From an individual's perspective we must ask - how do we empower the individual and the group to utilise these ambient systems to create and mould their environment*:**

We conjecture that this will be achieved by questioning how we transform the tremendous set of surrounding resources into personal tools for creating customized interactive islands.

Open Challenge

How do we develop an active infrastructure that embodies this new extended sensory system and which provides to the user, application or environment an intimate local interface to global dispersed services.

Kelvin Institute

Envisaged output

- Fundamental contributions to theory and realisation of ambient systems in broad areas:
  - Context awareness
  - Scalability
  - Dynamic Adaptation
  - Creative expression, interaction and communication
- International impact on the NG standards
- Toolkits that will bootstrap the wide scale deployment of ambient services.

Kelvin Institute

Comments and Questions

Kelvin Institute

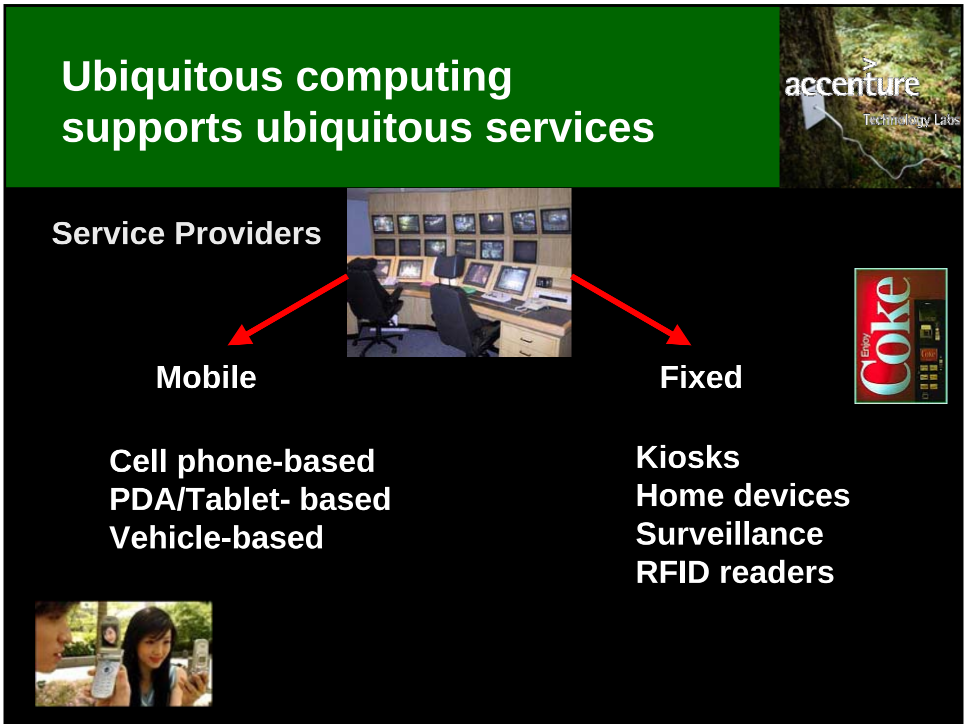
Business perspectives

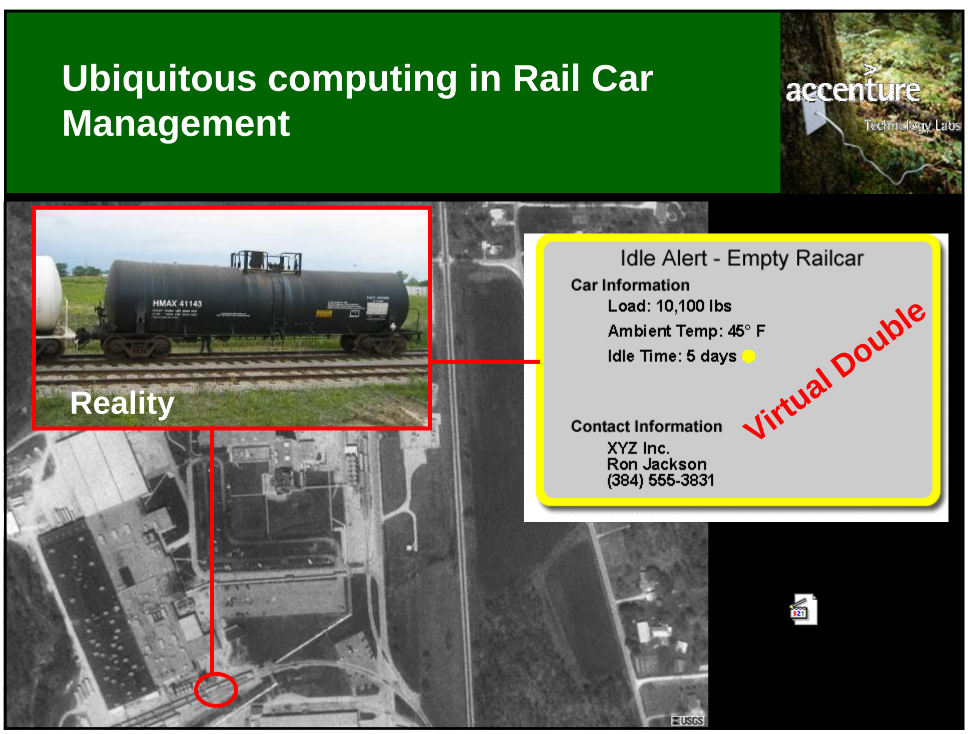
Perspective 1

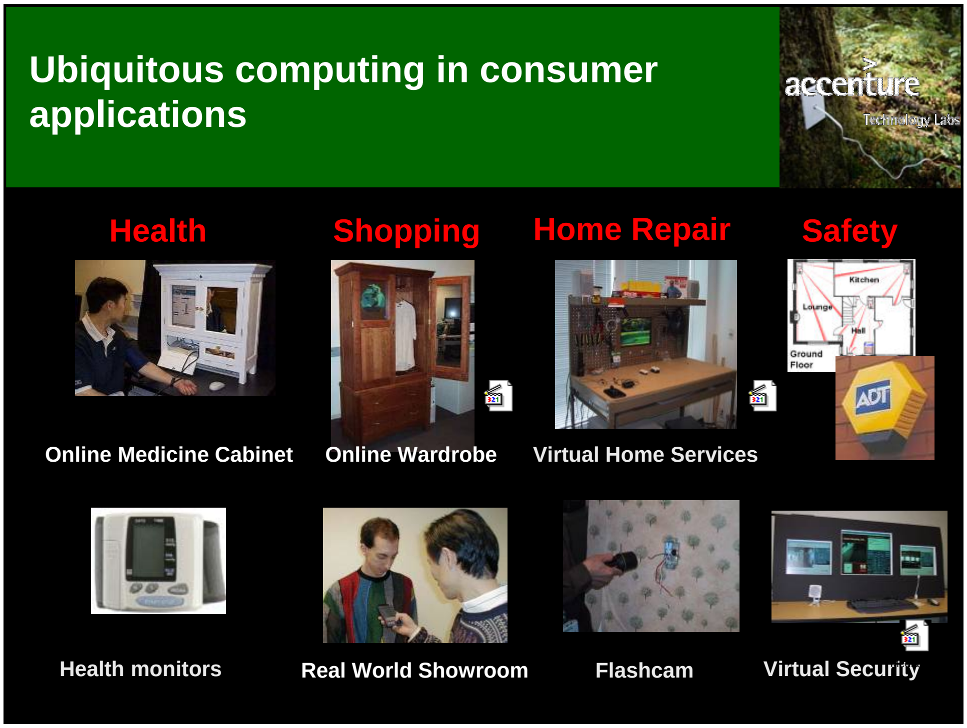
- Receiving faxes on the beach
- Doing your spreadsheet while driving to the airport

Perspective 2:

Using ubiquitous sensors, actuators, displays, and other connected devices to transform business functions from customer service to supply chain management


Ubiquitous computing
supports ubiquitous services
accenture
Technology Labs
Service Providers
Mobile
Fixed
Cell phone-based
PDA/Tablet- based
Vehicle-based
Kiosks
Home devices
Surveillance
RFID readers
Enjoy Coke


Ubiquitous computing in Rail Car
Management
accenture
Technology Labs
Reality
Idle Alert - Empty Railcar
Car Information
Load: 10,100 lbs
Ambient Temp: 45° F
Idle Time: 5 days
Contact Information
XYZ Inc.
Ron Jackson
(384) 555-3831
Virtual Double


Ubiquitous computing in consumer applications
accenture
Technology Labs
Health
Shopping
Home Repair
Safety
Kitchen
Lounge
Hall
Ground Floor
ADT
Online Medicine Cabinet
Online Wardrobe
Virtual Home Services
Health monitors
Real World Showroom
Flashcam
Virtual Security

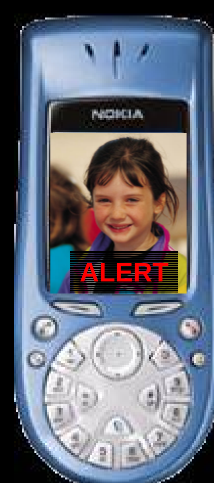

Observation #1:
Disconnect between mobile and fixed services
accenture
Technology Labs
O'hare
Sunglass Hut
SAMSUNG
STARBUCKS COFFEE
DUTY FREE

Observation #2:
There is nobody at the other end of the service

Ubiquitous computing gives businesses unprecedented access to their customers. They are not ready for it.

Observation #3:
Cell phones and camera phones are already the most ubiquitous computing devices

By 2007 there will be approximately 4200 camera phones per square mile in Chicago. Each one is a walking intelligent sensor.



Observation #4:
Ubiquitous computing will create enormous amounts of data which will require large-scale intelligence to process

How do we maintain a consistent picture of the physical world based on massive amounts of incomplete and redundant information from sensors?

We know everything about our customer – what do we say to her in the next three minutes?

Observation #5:
If an object is so smart, why doesn't it talk?

What does it mean for an everyday object to be "smart"?

What will it say to us and how will we communicate with it?

Conclusions

Applications of ubiquitous computing will require scalable intelligence on many levels:

- **Perceptual intelligence in the sensors**
- **Network intelligence**
- **Analysis, integration and planning intelligence**
- **Intelligence for contextualized action**

Relating theory and practice in ubiquitous computing

Terry Winograd
Stanford University

EU/NSF Workshop, April 24, 2004

Interactive Workspaces

Stanford Interactivity Lab

IPSI, Darmstadt

PostBrainstorm

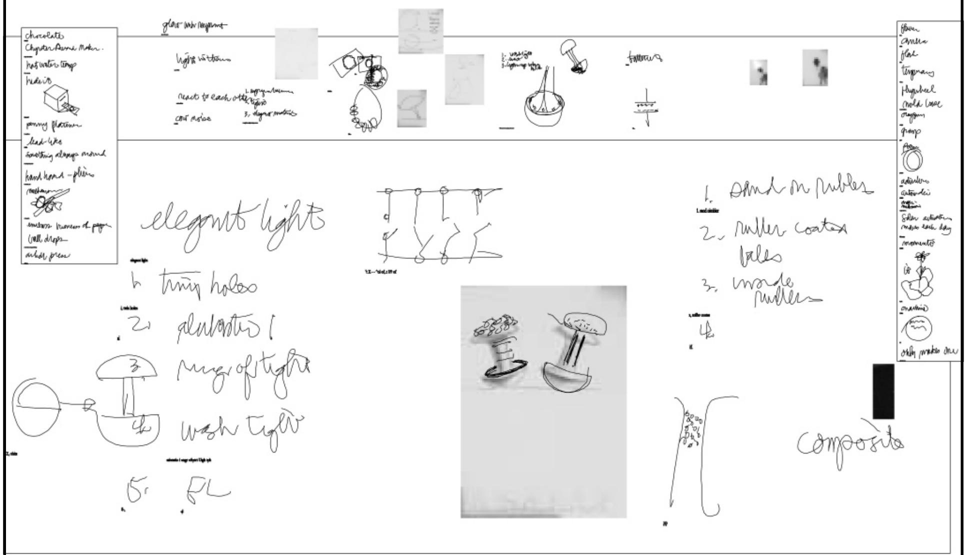
EU/NSF - Terry Winograd – 4/24/04

PostBrainstorm Scenario

- Multiperson environment with joint attention locus on wall screen
- Mix of distributed and centralized activity
- Shared physical space with activity at multiple locations
- Mixture of digital, handwritten, and handsketched materials
- Restructuring and use of materials after the group session

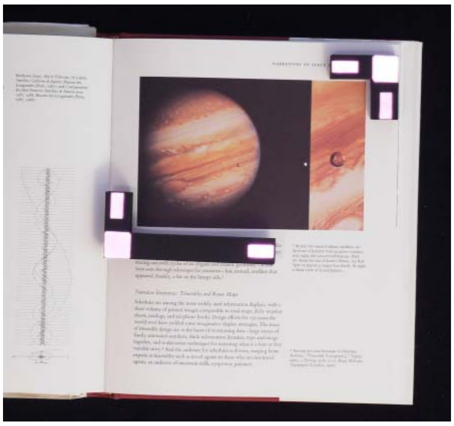
EU/NSF - Terry Winograd – 4/24/04

IDEO: Chrysler Design Award



EU/NSF - Terry Winograd – 4/24/04

FlowScan



EU/NSF - Terry Winograd – 4/24/04

IROS – Ubicomp Middleware

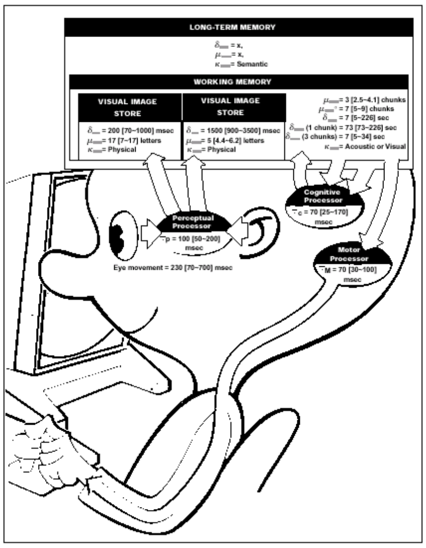
- Pointright
  - Integrated pointing from any device to any device
- Multibrowse
  - Integrated document movement across devices
  - Multiple affordances
    - Menus
    - Drag and drop
- Data heap, Workspace navigator,…

Interactive Workspace Configurations

Moving Information in a Multi-device Environment

- Drag and drop
- MultiBrowse
- Distributed, identity-sensitive cut and paste
- Pick and drop
- Passive tangible carrier
- Throwing and other gestures
- Speech with pointing
- …
- *What is added to GUI considerations in this kind of ubicomp environment?*

Cognitive Theory in Design



•Pointing [Fitt's Law]

•Keystroke level modeling

•Visual search

…

Theory as a Framework for Discourse

- Cognitive dimensions [Green]
  - "…good concepts, not too detailed and not too wooly, that capture enough important aspects of something to make it much easier to talk about that thing"
- they elucidate notions that are vaguely known but unformulated;
- they prompt a higher level of discourse;
- they create goals and aspirations;
- they encourage re-use of ideas in new contexts;
- they give a basis for informed critique;
- they supply standard examples that become common currency;
- they allow the inter-relationships of concepts to be appreciated.

Theory as a Framework for Measurement

- Goal: Turn theoretical concepts that are "not too wooly" into generalizable measurements that can be applied to generating and choosing among design alternatives
- Approach: Design appropriate measurements and compare across a set of design alternatives in a ubicomp setting

Direct Measures

– System
– Human performance
– Use
– Subjective assessments

Value Measures

- Usefulness, Usability, Desirability,…
- Larger context of motivations and concerns

Intermediating Measures

- Measurable characteristics of setting, task, user, artifact, state,…
- Suitable for mapping from direct measures and to value measures

Tradeoffs in Evaluating Candidates for Intermediating Measures

- Feasibility
  - Mapping from direct measures
  - Signal/noise ratio
  - Resources required for measurement in setting
- Importance
  - Mapping to value measures
  - Discriminatory value for alternatives within scenario
  - Generalizability to other scenarios and artifacts

Sources of Candidate Measures

- Constructs from articulated theories
  - (e.g., Cognitive Load)
- Components of cognitive models
  - (e.g., ACT-R)
- Informally developed lists from experience
  - (e.g., Green's Cognitive Dimensions)
- Folk psychology
  - (e.g., Distraction, Frustration, Coolness)
- Systematically collected taxonomies
  - (e.g. Scholtz metrics for Ubicomp Evaluation)

Proposed Metrics for Ubicomp Evaluation [Scholtz]

- Attention: [Focus, Overhead]
- Adoption: [Rate, Value, Availability]
- Trust: [Privacy, Awareness]
- Mental Models: [Vocabulary awareness]
- Interaction: [Distraction, Interaction Transparency, Collaborative interaction]
- Invisibility [Intelligibility, Control, Accuracy, Appropriateness of action, Customization]
- Impact [Behavior changes, Social acceptance, environment change]

Challenges for Applying Theory in Ubicomp Design

- Develop appropriate measures for the multi-device, multi-person, interactive distributed environment
- Characterize the tradeoff space among those measures along with the standard ones (cost, time,…)
- Develop practices, embodied in artifacts such as guidelines and toolkits, reflecting the understanding of this space.

FET - Future and Emerging Technologies

DIMACS — Center for Discrete Mathematics & Theoretical Computer Science

European Research Consortium for Informatics and Mathematics

ERCIM

www.ercim.org

This workshop is part of a series of strategic workshops to identify key research challenges and opportunities in Information Technology. These workshops are organised by ERCIM, the European Research Consortium for Informatics and Mathematics, and DIMACS the Center for Discrete Mathematics & Theoretical Computer Science. This initiative is supported jointly by the European Commission's Information Society Technologies Programme, Future and Emerging Technologies Activity, and the US National Science Foundation, Directorate for Computer and Information Science and Engineering.

More information about this initiative, other workshops, as well as an electronic version of this report are available on the ERCIM website at http://www.ercim.org/EU-NSF/