Preface

UbiComp 2003, the Fifth International Conference on Ubiquitous Computing, is the premier forum for presentation of research in all areas relating to the design, implementation, deployment and evaluation of ubiquitous computing technologies. The conference brings together leading researchers from a variety of disciplines, perspectives and geographical areas, who are exploring the implications of computing as it moves beyond the desktop and becomes increasingly interwoven into the fabrics of our lives.

The full papers and technical notes for UbiComp 2003 are published in the Springer-Verlag Lecture Notes in Computer Science (LNCS) series, volume 2864. In addition to papers and technotes, UbiComp 2003 is hosting a wide variety of other presentation forums, including demonstrations, interactive posters, a doctoral colloquium, a video program, twelve workshops, and a panel. This broad selection of venues and media within the conference is one of the great strengths of the UbiComp series, and this Adjunct Proceedings volume includes extended abstracts from each of these forums. While the acceptance rates in these categories were higher than for the full papers and technical notes, all submissions were subjected to a peer review process designed to ensure high quality.

Firstly, UbiComp 2003 includes a *Panel* track chaired by Gerd Kortuem. The panel, chaired by Eric Paulos on the final day of the conference, features participants sharing their views on the prospects for new forms of "mobile play" engendered by ubiquitous computing technologies.

The *Demonstrations* program, co-chaired by Eric Paulos and Allison Woodruff, with assistance from Elizabeth Goodman, includes approximately forty examples of ubiquitous computing technology, applications and art, many of which provide opportunities for attendees to directly experience the impacts of ubiquitous computing. The large collection of demonstrations includes a living sculpture, a WiFi game in the streets of Seattle, cardboard boxes for configuring an information network, and new location-tracking systems and extended-sensor 'motes'.

Our *Interactive Posters* track, co-chaired by Marc Langheinrich and Yasuto Nakanishi, offers a venue for the presentation of late-breaking and/or controversial results in an informal and interactive setting. This year, over forty posters were accepted, representing a variety of scientific backgrounds, and including many researchers who are new to the field of ubiquitous computing.

The participants in the *Doctoral Colloquium*, chaired by Tom Rodden, are given the opportunity to present their thesis research plans to a panel of senior researchers representing several areas within ubiquitous computing, and receive focused, constructive feedback. These students may also choose to present their work to the larger conference community as posters.

The *Videos* program, chaired by Jason Brotherton and Peter Ljungstrand, offers another format in which researchers in ubiquitous computing can present their work. Videos offer an opportunity for authors to present their work in a scenario of use, creating aspects of the context that may be difficult to replicate on-site at the conference venue. In addition to the extended abstracts in this volume, the twelve videos this year are also distributed in DVD format.

Finally, twelve *Workshops* precede the main conference this year, offering the chance for small groups of participants to share understandings and experiences, to foster research communities, to learn from each other and to envision future directions. This year's workshop program, chaired by Michael Beigl, covers many emerging topics in ubiquitous computing, including healthcare, commerce, privacy and intimacy.

We are very grateful to the chairs and authors in all of these participation categories for providing attendees with new perspectives on and experiences of ubiquitous computing. We are also want to express our immense gratitude to Khai Truong, our webmaster and design guru, for his outstanding work on the conference web pages and on the visual identity for the conference, which appears on the web site, the student volunteer tee-shirts, the

conference program, the conference DVD cover, and, of course, the cover to this volume.

Several organizations helped provide financial and logistical assistance for the conference, and we gratefully acknowledge their support. The donations by our corporate benefactor, Intel, and by our corporate sponsors, Fuji Xerox Palo Alto Laboratory, Hewlett-Packard Laboratories, IBM Research, Microsoft Research, Nokia Research and Smart Technologies, help us provide a world-class conference experience for all attendees.

Finally, we wish to thank all the people attending the conference, as it is the opportunities to meet and interact with all of you interesting people that makes the planning of such a momentous event a worthwhile endeavor for all involved!

October 2003

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Table of Contents

III Interactive Posters

Interfaces

Ambient Displays

End-User Programming of Smart Objects

Interaction, Collaboration, and Information Sharing

V Videos

VI Workshops

Part I

Panel

Mobile Play: Blogging, Tagging, and Messaging

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You can discover more about a person in an hour of play than in a year of conversation. – Plato 427-347 BC

ABSTRACT
Ubiquitous computing, by its very definition, aspires to weave computing technologies across the fabric of our everyday lives. Many of the successes and failures encountered during the pursuit of ubiquitous computing will be dictated by the manifest integration of play. It is play that helps us cope with the past, understand the present, and prepare for the future. This panel of experts is passionately interested in engaging in a critical dialogue around the applicability, adoption, and consequences of such elements of play in ubiquitous computing research. As motivation, several tremendously popular ubiquitous computing themes with playful elements will be examined: blogging, tagging, and message play.

Keywords
Play, blogging, tagging, messaging, digital graffiti, SMS, IM, ambiguity, toys, GameBoy, mobile computing, context aware play.

INTRODUCTION
It is during play that we make use of learning devices, treat toys, people, and objects in novel ways, experiment with new skills, and adopt different social roles [1]. As children we clearly don't play to learn, but we certainly learn from play [2, 3]. Play helps us as children (and adults) to answer the questions: What can I do in this world? What am I good at? What might I become [4]? Many of us attribute our abilities, interests, and even our careers, to childhood toys, games, and play [5-7]. Play unquestionably resonates with the very essence of human behavior and our role in society and will play a vital role in the adoption of ubiquitous computing.

While gaming is a popular and important part of human play, this panel is focused more specifically on the fundamental activity of mobile, situated human play and its role in ubiquitous computing.

CAN UBICOMP COME OUT AND PLAY?
Current ubiquitous computing research has provided marked milestones of systems, tools, and techniques along the path of situated, focused problem solving. While crediting the achievements of this area, we explicitly draw emphasis to the portion of everyday life made up of non-goal directed activities and play.

We make two important observations about play: (1) humans seamlessly move in and out of the context of play (sometimes on a minute by minute basis) and (2) when at play, humans employ a separate mental cognition. The scope of their current activity is more ambiguous [8], and their expectations about people, artifacts, interfaces, tools, *etc* are increasingly relaxed. The mind is open up to wildly fanciful interpretations, connections, and metaphors. The rules of human engagement are completely altered. It is often during this unique "play time" that we serendipitously establish important intellectual connections, leap to improved views of our world and society at large, and resolve conflicting paradigms. In essence, it is often through play that we advance our own substantial, novel contributions in life.

This fundamentally important human phenomenon clearly deserves a forum as a legitimate theme within the context of ubiquitous computing. In fact as ubiquitous computing researchers, we must not only be aware of this human tendency to play, but perhaps more importantly use it to our advantage. When does play occur? How does it begin and end? When is it appropriate or inappropriate? What elements give rise to play? Quell play?

MOBILITY
Play by its very nature is an active event, promoting co-ordination, flexibility, and fine motor skills [9]. Often toys, the tools of play, respond to movement and hold our attention. From an early age toys encourage physical play: activity centers for babies, push-pull toys for toddlers, and blocks, balls and climbing frames for older children.

Throughout our lifetime, we draw upon these innate skills and experiences to provide a safe and comfortable means of interfacing with others and the world around us through play.

There is no doubt that the current commercial adoption of wireless, mobile ubiquitous computing devices is indirectly spawning novel practices of social, mobile play. The research buzzwords of context awareness, always on, body worn, multi-medial, community awareness, and social networks are in fluid use across diverse non-research communities. Today's personal mobile devices have already been repurposed by independent, passionate users and groups for various forms of mobile play. As ubiquitous computing researchers, we have a primary interest in understanding the methods of such adoption and, more importantly, the evolution of its re-appropriation.

While we are interested in exploring new trends in mobile play, there are numerous currently deployed systems that have been re-appropriated from the context of work to play. The documented evolution of these systems and their current usage models help drive many of the research questions for future mobile play. We use these systems as a starting point for debate of mobile play.

BLOGGING

A blog (derived from "*web-log"*) is a web page made up of usually short, frequently updated posts that are arranged chronologically – similar to a "what's new" page or journal. There is no limit to the content or topic of available blogs: links and commentary about other web sites, political issues, news about companies/people/ideas, diaries, photos, poetry, mini-essays, project updates, fiction, journalism, and even personal messages by embedded reporters on today's modern battlefield [10]. Blogs are almost always personal, imbued with the temper of their writers. Perhaps more importantly, to invoke Marx, blogs seize the means of production, bypassing the ancient rituals of traditional publication houses. In some sense blog posts are instant messages to the web.

The technologies to support blogging have been in place since the dawn of the web, yet it has not been until recently that this technique has self organized itself into a playful social pursuit. With modern wireless mobile PDA's and phones, the urge to share and play with text, images, and sound in real time across vast distances and within a social network of friends (and enemies) is overwhelmingly compelling.

Several of the panelists have extensive experience playing in such worlds as well as building and evaluating tools that use and extend the blogging metaphor of social empowerment.

TAGGING

Tagging is often used within groups and communities to mark ownership or control over an object or territory. Tagging and graffiti are typically viewed as an anathema by the community. However, graffiti is simply defined as an inscription or drawing made on some public surface. Graffiti is an extremely important medium through which we engage into dialog across and within our community. Not just "gang tags" but political stickers, city produced marks indicating gas lines, discarded receipts, cigarette butts, broken benches, covered parking meters, and scrawled messages are all examples of public place community message play.

How will ubiquitous computing contribute to play within the space of tagging? What motivates the human passion of marking objects? How do we communicate by, through and with objects and artifacts? Why and how do objects exhibit an aura [11]?

Not surprisingly, nearly every manufactured item already contains a unique "tag". Better recognized as a barcode, this form of tagging has been socially re-purposed by digital, wireless tools to generated independent dialogs about these objects, empowering communities. Similarly, where will radio frequency identification tags (RFID) situate themselves within this space of social community dialogue? How will we tag wireless 802.11 access points? Where will such technologies and techniques give rise to play?

MESSAGE PLAY

From childhood note passing to adult flirtations couched in amusing metaphors, we find humans engaged in message play. We elucidate this continuing motivation for message play by example: the wireless pager. The initial usage model for pagers was that a person would send their phone number to another individual's pager; the recipient would dial the received number on a phone and establish a voice connection. What evolved was an entirely different usage model. In fact a new cultural vocabulary of numerical messages arose. For example, users defined new encodings such as, "When I send '1-2-3', that means 'thinking of you', '4-5-6' means 'feed the dog'."

Similar playful re-appropriate occurs with our current personal messaging tools such as cell phones and SMS text messaging. One teen expressed, "I carry my mobile phone around all the time, even in the house.…It's like my little baby, I couldn't live without my mobile, I bring it into the bathroom with me." Similarly, another couple on separate continents (and hence time zones) used SMS to send playful awareness messages to each other with no intention of engaging in dialogue. "When I get up in the morning I send her an SMS message that I'm 'Now making coffee' just to let her know what I'm doing….I guess I want her to be able to imagine me in the kitchen making coffee."

This urge to send playful messages is evident in almost every personal messaging tool in current use: instant messaging (IM), SMS text messaging, mobile phones, and wireless PDA's. For example, corporations created the service of "Caller ID", but its appropriation as an awareness messaging tool through "one ring calls" became a preferred form of message play between users. Fundamentally, humans engage in play and will certainly continue to socially repurpose mobile technology to satisfy this necessary human urge.

This leaves numerous open questions for debate: How will other forms of ubiquitous mobile message play be created? Engaged? Deigned for? Encouraged? Diverted? How will mobile play affect human relationships in terms of trust, persuasion, and conflict? How will we map current messaging techniques onto and across such systems? What direct and side effects will result?

PANELISTS (Alphabetically)

The following is an alphabetical listing of each of the panelists that will participate in this panel along with their position statement on this topic and a brief biography.

Barry Brown

Biography

Barry Brown is a research fellow and ethnographer at Glasgow University where he explores social issues surrounding human leisure and technology. Recently his focus has been on various leisure enabling technologies such as music listening, museum visiting, and tourism. He has edited a highly respected book that deconstructs many aspects of mobile phone usage [12]. Barry has also investigated the parallels of video game interfaces and its relationship to ubiquitous computing [13].

Position Statement

Designing technologies for leisure presents a number of challenges for technology designers. It is not just that the goals in leisure are more diffuse, or that there are a more diverse set of requirements. In leisure the aim is enjoyment, rather than productivity. *How* something is done is often more important than the end result. For the tourists we have studied, using a guidebook was enjoyable *in itself* as well as contributing to their visit [14]. For music enthusiasts finding new music is not just a goal but enjoyable process *in itself* [15].

The importance of enjoyment as part of the experience of using a technology is something we, as ubiquitous computing researchers, can learn from gaming software. For example, gaming software often develops a user's skills in a particular technique, and when that technique is perfected *discards* that technique to encourage the development of new forms of competency. In this way games maintain an interest in learning new and more advanced skills.

Games are also very much social activities (both co-present and online), and much can be learned from how these social experiences are pleasurable and shared. In our current work we are studying groups at play – in situations such as go-kart racing. We are interested in observing how discussion and socializing around an event becomes a powerful component of the enjoyment of the event itself. By designing social support for reflection and follow-up discussion directly into the interface of such systems, the overall experience of the technology can become a more enjoyable one.

Bill Gaver

Biography

Bill Gaver is a Senior Research Fellow at the Royal College of Art. He has pursued research on innovative technologies for over 15 years, working with and for companies such as Apple, Hewlett Packard, IBM and Xerox. Recent projects have included electronic furniture for public areas, information appliances that emphasize the emotions and spirituality, and the creation of compelling public experiences from urban pollution sensing and data from Antarctic lakes. He is a principle investigator on Equator IRC, in which his group is exploring digital devices that offer ludic opportunities for the home.

Position Statement: Designing Ubiquitous Play

Play is ubiquitous. Not only do we play when we're supposed to play – when we're gaming, or blogging, or flirting – but we play when we're doing other things as well. We play with ideas, with interpretations, with our own identities. We're curious, we explore, we fiddle, and doodle. From this point of view, play is not an activity so much as an attitude, one in which we're relatively free from external constraints and defined tasks.

In my research I am trying to understand how to support playful attitudes without defining systems as being 'for play.' For instance, in the ongoing Equator IRC, we are looking at technologies for the home that encourage people to reflect on their own activities, to try on new roles, to day-dream and speculate. None of the things we are designing could be considered 'for play,' yet they all depend on a playful frame of mind. They are intended to sit in a middle ground between work, consumption and entertainment, encouraging people to wander and wonder, rather than focus on clear tasks.

How do we design to allow play without dictating it? A couple of factors seem important. First, we need to embrace subjectivity – our own and others' – in our designs. Rather than seeking to create experiences based on our knowledge about typical desires and activities, it is often more compelling to design for the idiosyncratic and unusual. Second, ambiguity and openness are important factors in creating systems that people can appropriate into their own lives. Rather than dictating what a system is for, or even what it means, it is often more effective to design systems that are suggestive and open to interpretation. For it is in the act of making meaning from ambiguous situations that we are often at our most playful.

Marc Smith

Biography

Marc Smith is a research sociologist leading the Community Technologies Group at Microsoft Research.

The focus of the group is to explore and build tools to support association and collective action through networked media.

Position Statement

Play, in the form of exploration, direct manipulation, and collaborative interaction is a critical component of social life. Information technologies, despite their extensive uses in the forms of "games" often lack a playful quality and impose instrumental usage patterns. This often leads to significant underutilization of technical capacities as users avoid exploration for fear of stepping beyond the scope of their instrumental skills. The emerging capacities of ubiquitous computing suggest new opportunities for encouraging playful exploration of technical systems by supporting the primary sensory channels of feedback, direct manipulation, inscription, and mutual awareness. At question is how the playful uses of information technologies will be domesticated or will potentially rupture existing social institutions.

Nina Wakeford

Biography

Nina Wakeford is Director of the INCITE research centre at the University of Surrey, UK. Trained in anthropology and sociology she studied for her PhD at Oxford University where her thesis focused on the sociology of risk. For the past ten years she has been working on sociological approaches to new technology production and consumption, including studies of email discussion lists, web pages, mobile phone use, web logs and public internet access points, including wireless. One of her current projects uses the route of the number 73 bus in London as a way to sample usage of digital content in the city, including web pages, text messaging and blogging. She is also studying the way in which ethnographers work with interface designers, artists and engineers, and what they learn from each other.

Position Statement

A sociology of ubiquitous computing necessarily involves thinking about the linkages between space and social practice. One way of engaging with digital content in the city of London, for example, is to create mundane light content which might be characterized as playful in nature. Teasing, joking, shaming, and pranking are all routine activities of the set of young people in the UK who characterize themselves as heavy users of mobile phones.

Creating a sociology framework around the concept of mobile play involves thinking about the many wider social and structural processes in which these activities are embedded. For example to characterize an activity as 'playful' draws on wider cultural assumptions of risk, trust and blame. It may also involve notions of intimacy and power. The contemporary sociology of childhood can aid here: young people are no longer seen as invisible and inconsequential subjects, but active actors with agency. This explains the kinds of digital play which we have observed amongst young people both on the 73 bus route study and which they have reported in in-depth interviews.

PANEL PLAYTIME

Clearly, the focus of this panel is to use the synergy of the panelists and audience participation to elucidate the grand research challenges in the area of mobile play. As expected, individual panelists will present positions and relevant work to support their arguments at the panel. The inevitable insuring discussions across panelists and audience will hopefully reveal the foremost research questions associate with mobile play.

However, we are also interested in consciously creating scenarios during the course of the panel that allow the audience to freely enter into a playful state of mind. Not literal game play, but play as a vital part of brainstorming, self-discovery, identity, and creativity.

Come out and play!

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Part II

Demonstrations

Context Nuggets: A Smart-Its Game

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ABSTRACT

Small, embedded, sensing and communicating computer systems continue to show their applicability in various settings. The Smart-Its platform, which we present, testifies to this. We have developed a game called "Context-Nuggets", in order to test and demonstrate the extremities of this platform when subjected to a setting with multiple, ad-hoc users, discovering each other and exchanging context data. Attendees simply attach a Smart-It to their body and they can join in. The gaming strategy entails collecting as much "context" as possible, through altering interactive behavior with other players. Context sources include light, audio and movement sensors. Context is traded via short-range wireless communications.

A tool that manages the on-site gaming statistics is also used for analyzing run-time behavior and system status of the Smart-Its.

Keywords

Ubicomp Platform, Games, (usability, technology) tests

INTRODUCTION

In-Situ context generation, processing and communication has advantages in many application areas. This demo shows a platform for application scenarios, consisting of tiny computing devices that are embedded into everyday objects, on people or clothing, or in the environment. Further demonstrated are development libraries and tools for building applications and services for supervising applications and experiments. The demonstration presents this technology platform through one example application. The central component of such a platform is a tiny device called the Smart-Its, which is used to retrieve context information from the environment, run applications and communicate via a wireless network. The first part of the demonstration is a Ubicomp game application, secondly we give more details on the technology involved. Attendees are invited to take part or observe the game, and subsequently have a closer look at the enabling software and hardware design of Smart-Its.

Ubicomp games [1] stimulate use of Ubicomp technology, as has been shown in previous Ubicomp conferences - e.g. Pirates [2]. In our game, "Context Nuggets", attendees of the conference are invited to be players by configuring and using a small device. The device can be worn on the waist or adhered to the shirt (figure 1). Analysis tools can be used to actively retrieve the status of the game and hardware, such that the attributes displayed are either game related or retrieved from monitoring the technology.

THE PLATFORM: SMART-ITS

The basic idea behind the Smart-Its platform is a move towards simplifying the embedding of computing, perception and wireless communication into the physical world, along with an integrated toolset to make use of the information collected. The Smart-Its platform enables the development of Ubicomp environments, applications and tests.

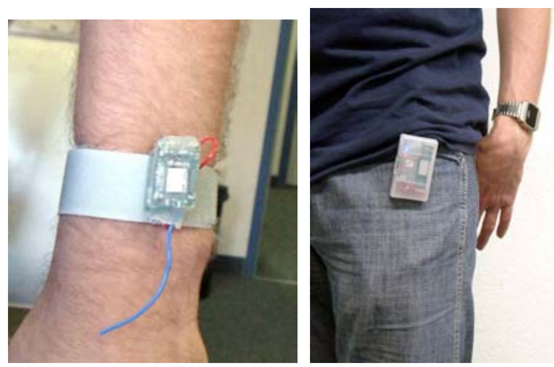

Figure 1: Small Smart-It with sensors attached to body or clothing

A major part of the Smart-Its platform [3] is the hardware device, which comes in various forms (e.g. figure 1). It builds the embedded hardware toolset and contains RF based wireless communication, on-board processing, memory, sensors and actuators. It can produce sensor information from up to 12 sensors, process context information within a local processor, provide adequate storage of context and general information, and host applications such as the game described below. It works independently of any external infrastructure and allows spontaneous, short-range peer-to-peer and ad-hoc exchange of processed data. Smart-Its are tiny, lightweight and have low energy consumption, such that the extent of objects to which they can be embedded ranges from very small or the human body (figure 1). The Smart-Its software can be rapidly developed based on a simple-to-use library providing a high-level access to communication, sensing and actuating functionality. Furthermore, generic programs are available for certain application areas as usability tests.

While infrastructure is optional, as Smart-Its communicate ad-hoc, PC based services such as wireless development and maintenance of Smart-Its applications require such integration. Infrastructure equipment enables access to Smart-Its over the Internet and vice versa. Infrastructure – based services may also be a source of additional context information, such as location or a history database. Figure 2 shows a setting with several Smart-Its distributed in a flat or office environment.

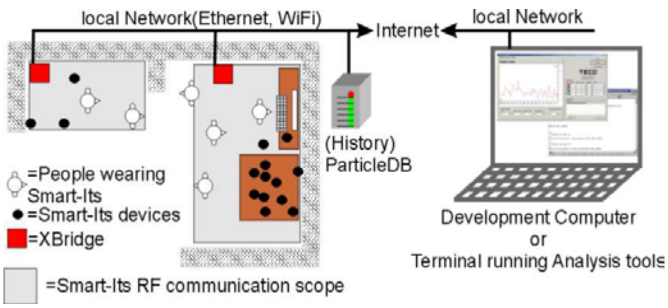

Figure 2: Smart-Its environment

The development toolset is a collection of programs that support programming, configuration and debugging of Smart-Its. With these software tools programming can be done on any PC based computer and over the Internet.

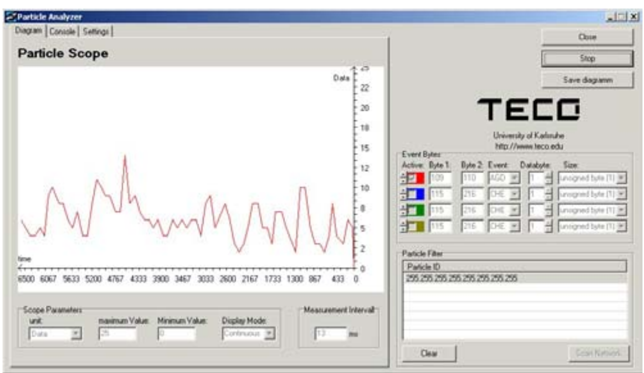

Figure 3: Graphical Visualization via Particle Analyzer

The text-based Smartspy tool and the graphical based Particle Analyzer tool allow the supervision and interpretation of output data from a running Smart-It application (figure 3). The graphical representation of data via the Particle Analyzer provides a quick overview of fast changing context, sensor or network data. This feature is often used for informal verification of Smart-Its behavior or analyzing performance parameters from the network or application. The tool's ability to display raw sensor data is also useful in the application design and debugging phases.

For maintenance or for recording data for test runs, a history database was implemented. This history, stored in the Particle database (ParticleDB), is accessible through a Web-frontend. The tool allows us to export selected data to standard formats for further statistical analysis.

THE GAME: CONTEXT NUGGETS

Imagine being an alchemist in the middle ages trying to produce gold out of mystic ingredients: Lux, spells and magic motions. These ingredients are then used to produce nuggets through a secret formula known only by you. But unfortunately, you cannot use the ingredients you produce yourself. Instead, you have to trade ingredients with other alchemists - one of your lux for one of their magical motions, one of your spells for one of their spells etc.

Based on your formula, "context nuggets" are created and at the end of the day the alchemist with the most nuggets is the winner. Players influence the progress of the game by entering the secret formula to make context nuggets. The secret formula describes how many of the ingredients are needed for creating a nugget and therefore determines the strategy for the player. A total of 10 units from the 3 ingredients are required, and at least one lux, one magic motion and one spell. The 7 remaining units can be allocated arbitrarily by the user, based on a calculated guess of the most available ingredients (figure 4).

Figure 4: Entry page for the Context Nugget game

Producing ingredients, trading and processing the nuggets appear to be "magical" as no explicit user intervention is required. After entering the formula Smart-It devices are distributed to the players and the game starts. At this point, players can influence the game by generating ingredients and meeting other players for trading. Ingredients are produced through a sensor perception on the Smart-it device. Sensing light level results - after a certain time - in producing a lux unit; likewise, sensing movement (acceleration sensor) and sound (microphone) result in magic movements and spells respectively. Following the rules of the game and the secret formula, the device also calculates and stores the nuggets for the player. It is not the intention of the game to encourage players to adapt their behavior to win the game by creating more ingredients etc. - which is also very difficult to perform during the game. In spite of this, creation of nuggets, trading and generation of ingredients can be perceived by the users through short flashes of light in different colors on the Smart-Its device.

The game ends after some hours at a fixed time where all devices have to be given back for final download of buffered data. The "alchemist" with the device containing the most nuggets is the winner.

Technical Setting

To run the game, players are required to wear a tiny electronic Smart-It device and to attach this device to their clothing (figure 1). The device works independently of other computers and networks, holds the game rules and all information concerning the devices' player. The device constantly detects physical attributes such as light, sound and movement.

The device is able to communicate wirelessly and spontaneously in order to exchange ingredients information between participants of the game. Game communication is uses the Smart-Its ad-hoc and infrastructure-less networking. Collection of physical data, semantic aggregation and the ad-hoc communication is done implicitly without any user interaction. Any internal processing like trading and generation of ingredients or nuggets is stored together with a time stamp in the Smart-Its memory buffer. When the device enters a special marked area with connection to the Internet, buffered data is transferred to the Particle DataBase for immediate or later use. Conference attendees are able to monitor the current game status using either their own WiFi enabled device or using a Game Terminal during the game.

Game rules

1) The goal of the game is to create more nuggets than other players

2) You create nuggets by collecting ingredients and processing them to nuggets according to the formula you entered at the start of the game. Converting ingredients to nuggets is done automatically when the necessary type and amount of ingredients are available. Only traded materials can be used to produce nuggets, so you can't use your own ingredients.

3) You are able to generate 3 ingredients: Lux (created from a light level sensor), magic motions (created from movement sensor) and spells (created from an audio sensor) through wearing a tiny magic device. Ingredients are produced automatically without any user interaction.

4) Ingredients that are not traded are perishable - their maximum usability period is about 2 minutes.

5) To create nuggets, you consume 10 ingredients from others alchemists. The ingredients you need are part of the secret formula you enter at the start of the game.

6) You can trade with other participants on a 1-to-1 basis by standing within 5 meters of them or even passing by. The longer you stand next to other wizards the more you trade.

7) Trading and creating can be done everywhere as no extra infrastructure is needed. Simply wear your device correctly at the belt or shirt, not inside a bag etc. Otherwise your ingredient production stops and you are not able to trade.

What it Demonstrates

The Game shows some specific strengths of the Smart-Its platform. First of all, it shows that the Smart-Its are complete self-contained and independent devices. They do not need infrastructure and are able to generate higher-level information, represented here by the context (nuggets) and ingredients, from physical sensors.

The second strength is the ability of a Smart-It to work unobtrusively as factor of its small dimensions and long time operation. Furthermore, the device does not require any administration, maintenance or other explicit interaction to fulfill its task.

The third strength is the de-centralized communication. No master device or access point is necessary. Nevertheless, when connected to a backbone network, additional data analysis and statistic functionality is enabled.

GAME EVALUATION

The evaluation part of the demonstration uses information generated by the "Context Nuggets" game and shows one application of the infrastructure toolset and services. These toolset and services can be used for a variety of application areas including supervision of field tests or living lab [4] tests. In our demo setting, it monitors the progress of the game application, computes game data (e.g. the score) and observes technical parameters.

Observation with Smart-Its

In the Smart-Its set-up, simple sensors are the basis for the supervision in contrast to complex video surveillance often used in controlled laboratory user studies. An advantage of the use of directly attached simple sensor systems is that they can collect data automatically, with fine granularity and independent of the location, e.g. while on the move. Additionally, they are able to measure data constantly without being disturbed by occlusion. For many situations, ad-hoc embedding of the proposed technology is easy to handle and cheap, making the Smart-Its based evaluation suitable for small ad-hoc tests. Due to the lack of video surveillance cameras, the entire user behavior is not supervised. This suggests a move towards privacy-sensitive user monitoring.

There are also some disadvantages. Firstly, only specific parameters can be supervised and have to be known beforehand. Secondly, in the absence of additional surveillance of the user, users may fool the system by not or inappropriately using the devices and so adulterate collected data.

Example scenario: Game supervision

The "Context nuggets" game builds the application scenario for collecting user related data. The behavior of players gives hints to how good the game performs in a given environment. From this data, valuable analyses about the overall performance of the game can be carried out, but also individual player performance data can be shown.

For the proposed game several parameters are of interest:

- How often and when do players generate ingredients

- How often do players meet in general
- How often do players exchange ingredients (combines generation and meeting)

Additionally, for the progress of the game the information about the average "nugget" production per time is of interest.

Technically, the above parameters are retrieved by querying the Particle DB through a Web-Server based script. The ParticleDB holds all events that took place during the game with the correlating timestamp. Using this detailed data, the statistic applications generate graphs and reports. These can then be accessed by a Web-Browser either from the Terminal on the demonstration place or from any other computer connected to the network.

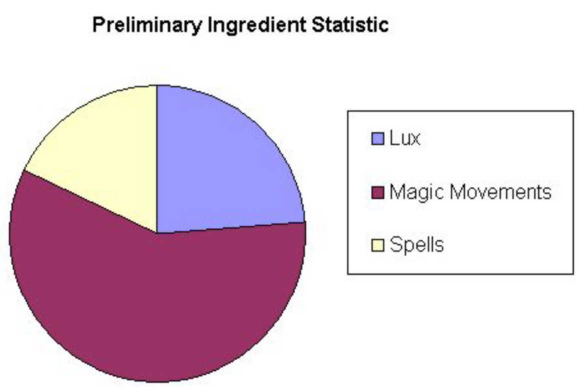

Figure 5: Example Statistic

Example scenario: Technical (network and sensor) set-up evaluation

For technical evaluation the ad-hoc and statistical analysis are also of interest. For the "Context Nuggets" game, network coverage or general network problems could be critical. The percentage and the average time of backbone access of every player and the load distribution among access points are of interest. A low access to one of the access points may indicate the need for a relocation of this access point.

Additionally, the context aggregation behavior of Smart-Its is noteworthy in order to optimize the rule-set of the game. The threshold and generating algorithms for units of ingredients can be adjusted according to the measured movements, noise and light.

All these measured parameters can be graphically displayed through the Particle Analyzer program from one of the terminal PCs on the demonstration site.

ACKNOWLEDGMENTS

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Eos Pods: Wireless Devices for Interactive Musical Performance

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ABSTRACT
In this paper, we describe a hardware and software system for an orchestral performance in which the audience members are the performers, led by the orchestra's conductor. The system is designed such that audience members are not required to have previous musical knowledge. Audience members are seated at banquet tables throughout the performance space. By tapping on a lighted dome at the center of the table when prompted by the conductor, the audience members trigger musical sequences in the composition. Coordination is managed through a central software controller. Like all good centerpieces, the domes are not tethered in any way, easily moved, and unobtrusive when the performance is not in progress.

Keywords
New Interfaces for Musical Expression, ubiquitous computing, interaction design, embedded networking, wireless sensor networks.

INTRODUCTION
New York's Eos Orchestra works to test the limits of orchestral performance, through a regular repertoire of experimental works, and through the commissioning of new works for orchestra. For the orchestra's 2003 benefit banquet, Artistic Director Jonathan Sheffer sought to conduct a performance in which the audience at the banquet performed the piece. Terry Riley's minimalist work "In C" was selected for this experiment, due to its significance as a groundbreaking work in non-traditional composition and its algorithmic applicability [1]. The specifics of the performance were kept at a minimum: the audience was to "play" the work, the result should be a musically acceptable performance of Riley's composition, and the audience members should have an engaging experience in playing the piece. All other details were left to the implementation team's discretion.

The design team members have extensive interest in and experience with performance augmented and mediated by digital technology. Eric and David are both central members of LEMUR (league of electronic musical urban robots), a group of musicians, robotics experts, artists and designers dedicated to creating musical robots. Both have a background in musical composition and entertainment system design, and an interest in electronically mediated musical performance. Tom's background is in theatre lighting and design, and is currently the area head for physical computing at the Interactive Telecommunications Program at NYU. His research focuses on the design and use of networked embedded systems.

The parameters that attracted us to the project were as follows: first, it involved a large number of participants, and a need for tight coordination and performance-level response times, drawing from and expanding on team members' prior experience in multi-participant interactive musical environments [2]. Second, as in any musical performance, the physical operation of the instruments must not take the performer's whole focus, so that the performers can focus on the music, not the operation of the instrument; a derivative of one of several of Perry Cook's observations and principles relating to musical controllers [3]. Any user feedback from the device would have to be in the periphery of the audience/performer's attention, not at the center of it. Third, though a significant amount of technology was involved, it would have to be transparent. The interfaces would have to appear aesthetically to be part of the decor, not an alien piece of control technology. In this sense, it let us put into practice many ideas from Weiser & Brown's manifesto of ubiquitous computing [4], specifically their notions of the synergistic effects of networks of microcontrollers and of technology at the periphery of an experience rather than the center. Though heavily reliant on computing and networking power, this project would center on shared musical environment rather than a computing environment.

SYSTEM DESCRIPTION

The performance was held in a banquet hall at which Eos Orchestra would be performing for invited supporters. The tables in the hall were arranged according to an instrument layout for an orchestra, with each table representing one instrument. Each of the thirty tables at the banquet featured an interactive centerpiece consisting of a 12” diameter translucent acrylic dome approximately 8” tall. Electronics housed within the dome allowed the guests to tap the dome and trigger a phrase of music, as long as they had received a cue from the conductor. In a manner similar to MIT Media Lab’s “Tribble”s [5], LED lights within the dome were used to signal status to the guest players. Three states were communicated: Inactive, Enabled (cued by the conductor), and Playing. Domes were “served” to the tables by the technical staff to replace the banquet centerpieces after dinner was over, so no wires could be permitted for power or communications. User input sensors in the domes communicated via a microcontroller back to a master computer, sending data on how hard the dome was tapped. The master computer used this data to trigger a musical phrase played by that table’s instrument with a MIDI velocity relative to the force applied to the dome.

Two Akai samplers with 16 audio outputs each were fed the MIDI generated by a master computer running a Max patch and output the 30 player parts and a click track. Audio of the triggered chunk would be fed to the main mix and routed wirelessly to the table that triggered it and fed to a local, powered monitor. A click track would also be output from the master computer and mixed to the main audio feed.

In the final implementation, the wireless audio return path was not implemented. Instead, clusters of local speakers were positioned overhead around the room. Three tables were served by each cluster of speakers. Audio for each of the tables served by a local cluster was routed to the cluster, so that the sound appeared to be coming from the table itself.

SOFTWARE

Interaction, playback and communication software was implemented on Macintosh computers in Cycling 74’s Max software. A master Max patch was developed for this application with the following features:

- graphical user interface for operator control of performance parameters
- bidirectional UDP communication with pods
- interactive player subpatch for each pod
- algorithms for MIDI playback, interaction arbitration and

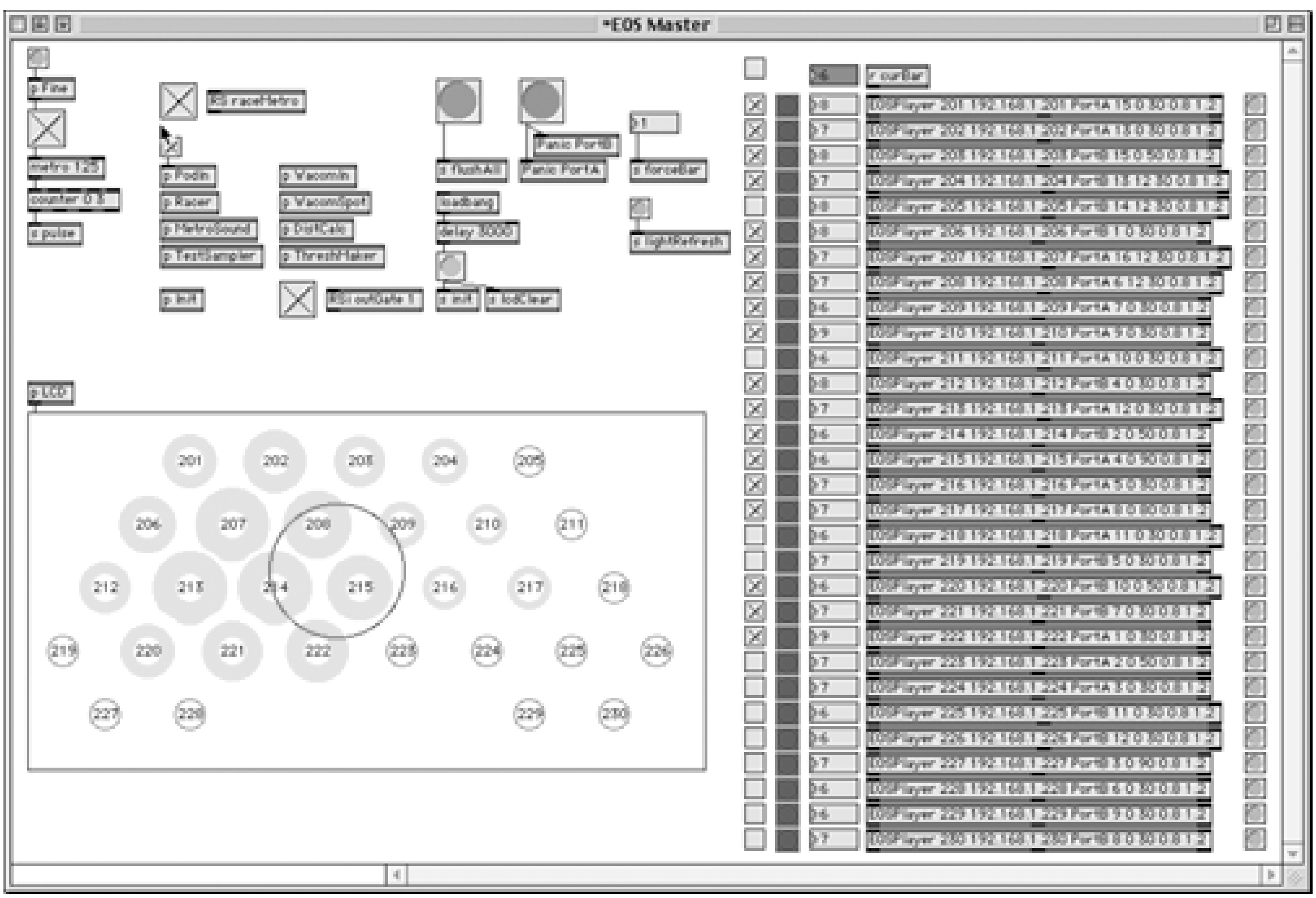

Figure 1. Operator interface in Max

progression through the piece

• control of pod LED's for user feedback

The piece "In C" is composed of 53 individual melodic patterns of varying length to be played in sequence. In the performance instructions, the composer states that each performer must progress through the patterns in order but may make entrances and repeat each pattern numerous times at his or her choosing.

Our patch was designed to simulate these instructions, with entrances determined by the players and progression through the patterns controlled by the patch. A "horse race" algorithm was implemented with a counter progressing through pattern numbers 1 through 53 and each pod racing towards or past this master number but remaining within +/- 4 of its current value. This was done by periodically incrementing each pod's pattern number, with the odds of incrementing being greater if further behind and less if further ahead of the master number.

Players were able to trigger playback of a sequence by tapping on the pod dome. Tap signals were sent via UDP to the host with a message indicating the velocity of the tap and the pod number. If the pod was enabled, a tap triggered playback of the pod's current pattern, with playback volume scaled by both the tap velocity and the pod's level as set in the operator's interface.

Playback of all parts was synchronized to a master eighth-note clock running at a fixed tempo. Entrances occurred on the next eighth note following receipt of a trigger, playing the triggering pod's current pattern synchronized to the master clock.

Players for each pod were implemented as a parameterized subpatch. Parameters to the subpatch allowed setting of IP number, MIDI port and channel for output voice, trigger threshold and voice scaling. The subpatch handled pod communication, triggering arbitration and synchronization, MIDI playback and scaling, LED feedback and UI feedback for each pod.

To give users feedback about playback, the host controlled RGB LED's inside each pod. A red color indicated that the pod was currently disabled, and green indicated enabled. Tapping the pod caused a white flash (all RGB colors on). During pattern playback, blue LED's were flashed on every eighth note beat and every note in the pattern; this was done to ensure ample player feedback, even during rests.

An operator's interface was implemented using the *lcd* object. The interface presented an analog of the layout of the banquet room, with each table represented as a circle with its corresponding pod/table number inside. A thin red circle indicated a disabled pod; a green circle indicated an enabled pod, with the circle's line thickness representing relative volume level. When a pod was triggered, a blue circle within the green flashed on and off to indicate active playback.

The interface enabled the Max operator to follow the conductor's movement among the tables and assist the conductor in controlling the performance. Using a pen and graphics tablet, the operator could move a circular marquee around the interface, with pen pressure controlling the diameter of the marquee and thus the area of influence. The operator could enable, disable and scale volume of each of the pods using keystrokes, with the keystrokes' effects applying only to the pods enclosed by or touched by the marquee.

Bidirectional network communication was accomplished using the *otudp* object [6] to send UDP messages wirelessly between the Max host computer and the pods. Outgoing messages from the host were addressed to each pod on a local IP address and port, with the last byte of the IP number corresponding to the pod's table number. Messages from the pods to the host were sent on a broadcast IP address, enabling both the host and a backup host computer to receive them.

HARDWARE

Hardware for the pods was implemented on a PIC microcontroller, using NetMedia's Siteplayer web coprocessor to manage TCP and UDP connectivity. The entire module was connected wirelessly using an Ethernet-to-WiFi bridge from D-Link. The pods were powered by 12-volt rechargeable motorcycle batteries.

Figure 3. The pods in testing

Sensing was accomplished using a set of four force-sensitive resistors under the rim of the dome. Velocity for the dome was taken as the highest sensor reading on any of the four sensors, provided the value was above a given threshold of sensitivity. Each dome's sensitivity threshold could be set either by sending it via UDP, or by using an HTML forms-based interface on the Siteplayer.

RGB LED output was controlled by the PIC based on UDP messages received from the master control software. The white LED flash on each tap was generated locally by the PIC. All other LED control was received from the master control software. The Siteplayer HTML interface could also be used to set LED intensity levels, and was used during installation for diagnostic purposes, when the master control software was not online.

Message protocol between the pod units and the master control software was kept as light as possible to minimize traffic. Two bytes were sent from each pod to the master control software on each tap: the last octet of the pod's address, and the velocity value. Three bytes were sent from the master control software to each pod: red, green, and blue intensity values for the LED's. Optional fourth and fifth bytes could be sent to adjust the sensitivity of the pod's FSRs, but this was used only during installation.

Because the pods were to be laid out in a specific order in the performance space, fixed IP addresses were used for each pod, to simplify contact with them during installation. Likewise, the wireless bridges were also given fixed addresses in advance. Although it was not strictly necessary to associate IP addresses with instrument numbers, it was convenient, given the time scale of the project.

IMPLEMENTATION FOR UBICOMP 2003

For UbiComp 2003, our implementation of the Eos Pods will be somewhat less extensive than for the initial performance. Between 6 and 12 pods will be used, and only one sampler or synthesizer will be used. Audio will not be routed to local clusters, but will be designed around a central PA system feeding the entire space of the demonstration.

CONCLUSION

The initial performance of the Eos pods at the orchestra's annual supporter's banquet was a successful test run for the system. All technical components performed as specified, with remarkably few technical problems. Communication between conductor, support staff, and audience was somewhat confused as instructions were rushed. For example, the pods were designed to trigger once a player's hand lifted from the pod; not all audience members understood this, and some kept their hand on the pod constantly, wondering why it didn't play. In future performances, we will look for a better solution, allowing for a wider range of playing styles. Overall, however, the audience had an enjoyable experience, and all parties were pleased with the result. Eos has hopes for future and more ambitious performances with the pod system, and we look forward to further refinement of the system as the design team and the orchestra gain more experience with it.

ACKNOWLEDGMENTS

We thank Jonathan Sheffer and the Eos Orchestra for their support and for their openness to experimentation, without which this project would not have been possible. We also thank the staff and students of the Interactive Telecommunications Program at ITP, many of whom were drafted into service in the fabrication of the system; and the staff of Audio, Video, & Controls, whose expertise and enthusiasm made for a more pleasant working experience throughout the process.

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Wishing Well Demonstration

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ABSTRACT
The technology concept described in this paper addresses needs that emerged from ethnographic research on the health needs of tomorrow's elders, specifically the need to envision and plan for the later phase of life. The difficulties of old age are often experienced as sudden shifts which are managed in a reactive, crisis-driven style. The gap between this need for future planning and existing tools motivated the concept of "lifespan mapping" – engaging interfaces to invite reflection about desirable ways to live out the later phases of life. The "wishing well" concept described in this paper is one component of a larger life-span mapping concept that encourages ideation about the future. Users select an image that they find appealing by moving a stone onto that image. Through a sequence of selections, the user develops a collection of images that represent the mood or spirit of particular desires and aspirations.

Keywords
Tangible Interface, Ubiquitous Computing, Calendar, Elderly, Lifespan, prospective cognition

INTRODUCTION
As has been well publicized, the increasing lifespan is sparking a huge demographic shift in U.S. and many other countries, principally in Europe and Asia [1][2]. The needs of the growing elderly population far exceed current medical and social resources. Health issues, from wellness to chronic disease management to support for cognitive decline, will need to be addressed through a variety of innovative approaches that supplement medical offerings. Ubiquitous computing technologies for the home are one such approach that may be particularly well suited to the needs of tomorrow's elders [3][4].

To inform the development of home health computing systems for tomorrow's elders, Intel has conducted extensive ethnographic studies on the lifestyles and concerns of boomers and elders. The initial focus of the study has been cognitive impairment, a health issue that is estimated to be the strongest threat to independent living [5] From analysis of focus groups, household interviews and shadows, a set of key themes emerged as needs and corresponding opportunities for ubiquitous computing.

This paper will address one of these themes: the need for temporal orientation, specifically orientation to the distant future, and the corresponding opportunity area of "lifespan mapping". By lifespan mapping we mean tools that will allow people to reflect on time in very personal and expansive terms – from recollecting the past, to focusing on the present and near future, to envisioning the distant future. We are exploring a host of interfaces that will make all these activities more engaging, textured, and less daunting than they are currently experienced. (** nb: fix grammar at end of sentence)

The particular concept explored in this paper, the wishing well, is a probe to invite reflection and envisioning about the future. Probes are research tools – malleable, low fidelity prototypes – designed to elicit feedback from users [6]. Our intent is to bring probes into the homes of users, and to base our iterations on the way users shape them to meet their needs and desires.

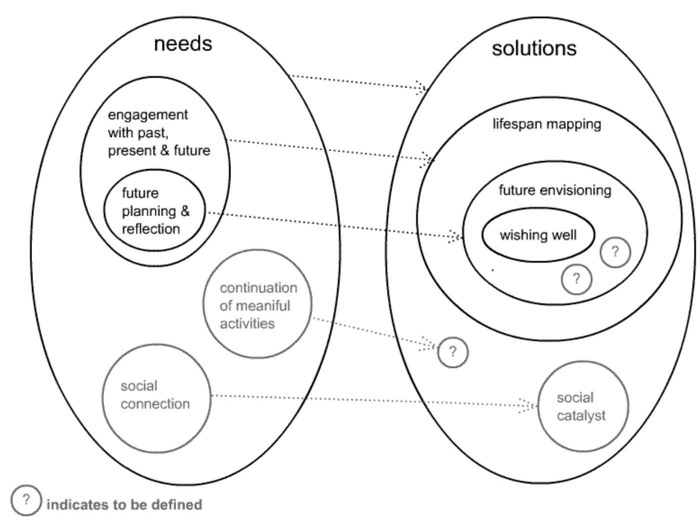

Figure 1. Link between needs and solutions

RESEARCH FINDINGS

Orientation to current time is well recognized as a sign of cognitive lucidity. This immediate temporal orientation is assessed in mental status exams and is relatively well supported through calendaring tools. However, our research indicated the importance of broadening the consideration of temporal orientation to include not only the present, but also the distant past and distant future – realms not addressed in most calendaring tools.

Figure 2. Calendars help with orient people to the present and they are often saved to ease recollection of the past. But they are not so helpful with envisioning and goal setting for the distant future.

It is true that orienting to the present is more challenging in old age: retirement can involve a disconnection from the rhythms, rituals and communities associated with workdays and weekends. Cognitive impairment certainly adds to this challenge. Equally if not more consequential though are the struggles of orienting to the distant future. We found that many people avoid thinking about their and their loved one's old age until forced to do so as a result of health crises. In some of these cases, more planful, proactive decision making may well have pre-empted a number of crises and consequently prolonged periods of independence. In other less dire situations, envisioning the future may have influenced households' choices about where to live, and what social relationships to build in ways that would have improved quality of life later on.

Following are a range of some examples from ethnographic fieldwork that illustrate the tendency to avoid thinking about the future:

- Joe and Lucinda cared for Lucinda's mother when she developed dementia. This was a rocky couple of years. They moved her mother to new facility every three months until finding a sufficiently assistive environment. Each move was precipitated by a crisis: a fall, an incident of aggression, wandering. Lucinda's mother was miserably unhappy in everyplace but the last one. They now wish they had known her mother's probable trajectory: they think this knowledge would have allowed them to avoid some of the crises by moving to a place that was offered graduated levels of assistance.
- Paul and Jenna, who love their urban third floor flat, expressed determination to live there forever. Arthritis in Jenna's knee already makes the stairs a challenge though. When asked about their plans for the future her response was "I suppose we'll cross that bridge when we get to it."
- Sue, a former teacher and successful real estate broker, now suffers from severe vision deterioration that prevents her from driving and a host of other activities. She recently moved to an upscale assisted care environment that she finds stifling. Even though she hasn't driven for ten years, she keeps her car as a symbol for the freedom that she misses.
- "I didn't want to believe this was happening to her" said a young woman about her grandmother who has Alzheimer's. In retrospect, she sees that she and her parents overlooked signs of deterioration for years. She feels that they may have an opportunity where medication could have made a big difference in slowing the course of the disease.

So why don't people think about old age?

There are a variety of obstacles to envisioning the future that emerged from our ethnographic research. First is the very daunting prospect of losing health, freedom, and independence. Imagining these changes for oneself or a loved one is so painful that many simply avoid thinking about them. Another is optimism and the accompanying denial about the prospect of negative future events. This is a delicate issue since an optimistic explanatory style has been associated with better mental and physical health [7][8]. So to some degree, denial about the prospect of illness may actually help ward it off. Denying evidence of existing illness, however, is certainly problematic. Almost every household in our study reported overlooking early signs of dementia and subsequent regret about missing opportunities for treatment, education, and lifestyle planning. Another obstacle is the uncertainty about the future: in particular the resources one will have and the health issues one will have to contend with in old age. Even if these uncertainties weren't there, goal setting and planning can be intimidating. Some worry about not living up to goals: they would prefer to have low or no expectations than to disappoint themselves. Most however, lack the preliminary ideas and vision to start concrete planning. They sometimes only have an inkling of what they want. They lack tools to explore these preliminary desires and wishes in a way that is speculative and even playful. Existing planning tools, which tend to be business oriented, are overly specified for loose ideation about the future.

The needs and obstacles that we observed suggest a host of requirements for future envisioning tools that not part current calendaring and planning tools. Specifically, the tools should allow people to:

- Carve out periods of time that are personally salient, while remaining oriented to universally accepted metrics of time.
- Ponder difficult decisions about old age in a nonstressful way
- Conjecture, "feel out", play with, imagine possibilities
- Examine values and let those guide life decisions
- Work through obstacles that may impede wishes or goals
- Plan the way one wants to live, not just milestones
- Evaluate the kind of community and relationships that are important for one's late phase of life and how to achieve the desired quality of social connectedness
- Plant wishes and goals without worrying about whether or not they are achievable
- Reflect and build on previously set goals and wishes

Next is a description of a research probe that is designed to invite ideation about the future. As mentioned above, this is one component of a set of tools to help with what we are calling "life compassing."

CONCEPT: WISHING WELL

A wishing well scenario:

Bob is nearing retirement and contemplating what how he will live in the future. He's been putting it off thinking about it. He's not sure how to begin. Recently he bought a "Wishing Well" toolkit. It seems more like a board game than retirement planning tool and a fun way to consider the future. The pieces of the toolkit lie in front of him on his desk. He starts to play around with a stone that forms part of the toolkit. Using the stone Bob starts to select some images that are displayed on a table top display panel. Later when the Bob is with Sue(his wife) they look at the pictures of new houses and neighbourhoods and activities Bob has selected. Discussing his selections they add new images and remove some from the stone. Sue removes photographs of houses with stairs . Her arthritic knee is giving her trouble. Several months later Bob takes his stone to a realtor. The images stored on the stone help the realtor select houses that Bob and Sue would be interested in buying. The images also form a journal of past thoughts and imaginings of Bob and Sue and aid them in making decisions and planning out how they might live their retirement.

The inspiration for a tool to aid future ideation, comes from the experiences of making wishes, such as blowing out candles on a birthday cake or throwing a coin into a wishing well. These experiences are generative, imaginative, playful and hopeful regarding the future. Wishes are fun to make, can be ambiguous, romantic and emotionally driven. This whimsical spirit of wishing is in contrast to many existing computerized tools; for instance a travel website might demand an airport (preferably a 3 letter code), departure and return date when the user only has a vague idea of when and where travel would be desirable. The Wishing Well interface would invite self-reflection and projection of ambiguous future plans (e.g. "I want to feel like I've been far away" or "I want to travel to Europe") rather than demanding specifics (e.g. date, time and airports.) The intention is to use ambiguity as a resource for design enabling intriguing and delightful user experiences[9].

The Wishing Well helps users reflect on their futures by presenting sets of images that represent a sense of mood, spirit, or atmosphere of a future ideation. These images work like swatches of fabric, samples of wallpaper. or the mood boards used in design studios. They express and communicate direction, feel, and style of wish rather than specifics of a plan. Since these attributes are sometimes harder to articulate and less accessible to people, this tool facilitates communication with family members or someone supplying a service (be it a spiritual counselor or a realtor). The images serve as a record of dreams, desires, and wishes that users can reflect back upon as well as inspiration or kick off points for more ideation about the future.

The hardware consists of a number of stones and a flat horizontal touch screen onto which the main interface is displayed. The main digital interface is an image browser that allows the user to navigate through a series of images related to a future ideation. For instance if the user is planning a new home then images related to homes, architecture, community and neighbourhood will be displayed. The stones are used to hold moods which are defined by a collection of images. Images become associated with a stone by placing the stone over an image. The image is then "absorbed" into the stone.

The Wishing Well is intended to be operated by one user at a time. However by orientating the screen to a horizontal position the interface becomes like a table or board game around which many people can sit, take turns, observe and share ideas. Through our probe research, we will learn how important this social element is to this concept. The reference to board games is reinforced by the use of stone "pieces" to collect images.

Tangibility is an important aspect of the Wishing Well. The stones' physical characteristics of texture, colour, shape, and weight may emotionally engage the users and help them overcome some of fears and inhibitions about envisioning the future.

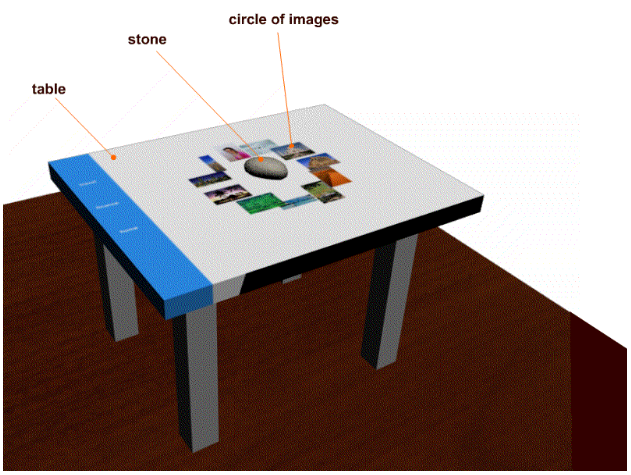

figure 3. table and user interface components

Next/Future Steps

The "Wishing Well" is intentionally unfinished as a concept. We are planning to iteratively shape the interface through cycles of user review and development . Our probe research will address an array of questions including ones such as:

- Are photographs a suitable means of capturing the mood and spirit underlying wishes for the future,?
- Do people want to wish alone or with others?
- Is it more helpful to use ambiguous or literal stimuli to help with preliminary planning
- Do people want their wishes recorded?

Eventually, the Wishing Well and other Lifespan Mapping interfaces will become integrated with the array of proactive health technologies that we are currently prototyping. Our goal is to test these technologies as a home system through clinical trials in 2004.

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Extended Sensor Mote Interfaces for Ubiquitous Computing

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ABSTRACT

Although traditionally used for routing and ad hoc networking research, wireless sensor nodes can also be used to create personal area networks of interactive devices. Our work focuses on leveraging these low power wireless sensor nodes as a communication and control mechanism to create a variety of programmable I/O devices. In this demonstration we showcase: a handheld RFID reader, a DisplayMote with an integrated graphical LCD and accelerometer, and motes with USB and PCMCIA based interfaces.

Keywords

RFID, I/O devices, PAN, wireless sensors, mote

INTRODUCTION

Personal I/O devices connected through a wireless personal area network enable new interaction methods [1]. We have developed a suite of task-specific interface devices that extend the UC Berkeley motes [2] (now commercialized by Crossbow) to leverage coordination between various I/O devices. It is only through combinations of heterogeneous devices that the ubiquitous computing applications envisioned by Weiser [3] can be fully realized.

All too often, the research community reinvents the wheel by implementing the communication link between units on a per application basis as they try to avoid the complexity and power overhead of 802.11 and/or Bluetooth. This leads to heterogeneous networks that require complex gateways for passing data from one device to another. By leveraging a maturing platform, like the UCB motes, the time and effort required to create new platforms is significantly reduced while the homogeneity of the PAN is preserved. Devices are able to directly communicate with other PAN nodes and the need for a single centralized control point is greatly diminished.

At this conference, we will demonstrate a collection of devices that were built to exploit the motes' low-power communication capability. They include a display mote (DisplayMote) that adds a 64x128 LCD screen and an accelerometer, a RFID reader mote (Mite) that adds an RFID reader antenna and logic, and versions of the mote that use USB and PCMCIA interfaces (USBmote and PCmote) to connect to the laptops, PDAs, and servers that populate ubiquitous computing environments.

DISPLAY MOTE

The driving motivation of the DisplayMote (shown in Figure 1) was to create a fully programmable device that would allow a user to be able to provide input to and receive output from a sensor network. The DisplayMote is a mote with a graphical LCD, an accelerometer, a buzzer and four buttons. We extended the Mica2dot mote design to maintain as much hardware and TinyOS compatibility as possible and to lower the barriers for others looking to create a specialty I/O device. Minimizing the size of the DisplayMote was a key aspect to the design; the final form factor is a single PCB design that is roughly the size of a wrist watch. The integrated 64x128 graphical LCD ensures that real-time, pertinent data from the environment around a user can be displayed to the user without requiring them to carry anything more than a wrist-watch. The buttons and accelerometer can be used in many different ways depending on the application. We have used the buttons and accelerometer to create a tilt-and-click input device that can be used as a remote mouse, keyboard, or menuing system. This input method is derivative of TiltType, an accelerometer based text entry method for very small devices [4]. Outside of the I/O uses already discussed, the DisplayMote is also designed for use as a remote control, a

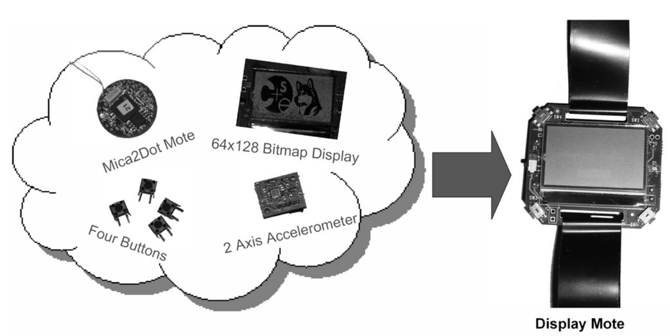

FIGURE 1: Functional Diagram of DisplayMote

FIGURE 2: "Mite" Handheld RFID Reader

reminding device, and as an input device for kiosks and digital public displays. It can also be use as a remote terminal to connect to specialized devices such as the Intel Personal Server [5], that provides personal storage but has no integrated display.

HANDHELD RFID READER

To leverage the growing field of passive RFID technology, we created a small handheld RFID reader that can be used as a personal actuation device. The low-power Mite shown in Figure 2 has a small read range of only a few inches and is based on the Skyetek multi-protocol RFID reader [6]. We enhanced the reader as a sensor node with buttons to create a small, mobile reader with communication and control capabilities. The Mite can read and write information into an assortment of passive RFID tags that have a globally unique ID and storage space for writing additional information. The Mite also has a small rechargeable lithium polymer power source with an accompanying USB charger. Our goal was to create a small, portable handheld reader to allow passive RFID tags to be leveraged in many ubiquitous computing applications.

An envisioned usage model for RFID tags is in smart spaces and location sensing. Tagged objects can contain part history, schematics, or even pointers to product manuals. In addition, tags can moderate physical access control or can contain code that is executed upon a tag read allowing the Mite to be as actuator. Tags can also easily be associated with auxiliary data contained in the infrastructure making the possibilities of configuration almost infinite.

By allowing the user to have a personal reader the privacy model changes so that the user is in control of his or her data and whereabouts. This is in contrast to the fixed readers where the environment is tracking the tag (on a person or object). In this model, a user is tracked by the infrastructure. With the user having the reader under his control, he is able to collect his own data without having to worry about who has access to potentially sensitive location information. Additionally, in this scenario information always flows to the person using the handheld and his devices, eliminating the intervention of outside infrastructure entirely.

MOTE INTERFACES

There has been a general lack of convenient methods to connect motes to standard PCs and handheld devices. We have developed two prototypes to interface motes via common communication ports. The goal is to lower the barriers to entry for new mote users and to provide a means to utilize motes with computing devices that are not equipped with traditional serial ports. We have developed prototypes of a USB and PCMCIA based mote (shown in Figure 3) that exhibit near plug and play functionality. This makes connecting to existing infrastructure more streamlined and less prone to error. In addition, we also use a compact flash mote called a Canby to fill out our toolkit of mote interfaces [7].

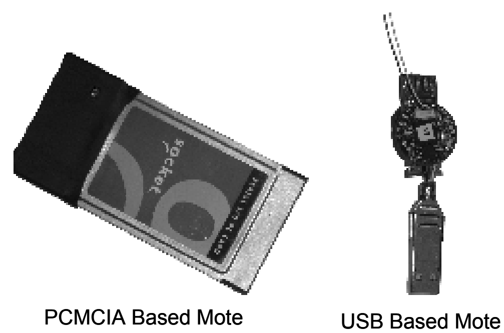

FIGURE 3: Prototypes of Mote Interfaces

APPLICATIONS

While the goal was to develop a set of highly flexible sensors and PAN building blocks, the individual components have been designed around a few core applications sets. These generalized application sets helped guide the design process and provided a checklist for functionalities that we wanted to be maintained throughout the development process. The Mite was designed to be a personal actuation mechanism that would allow the augmentation of objects and spaces with data. The DisplayMote had a simple goal of maximizing the input/output capabilities.

An important application of the Mite is its ability to be used as an actuation mechanism. The Mite can be used to cause actions in the environment based on the information that the reader finds within RFID tags. For example, the Mite can be used as an out-of-band connection mechanism. It can send the laptop, PDA, or any other device enough information to bootstrap itself into a wireless network using the information contained in an RFID tag placed in the environment. A Bluetooth capable device can be augmented with a RFID tag containing its MAC address allowing the discovery process to take less time and giving the user direct control of which devices he chooses to communicate with. Conferences rooms can have RFID tags that contain the necessary data to configure a laptop for that location such as the SSID and WEP key of the wireless network and the name of the printer and/or projector available in the room. Not only does it allow a convenient method of configuration, it also limits people's ability to obtain the information through room access. These actuation events don't have to be limited to computer interactions. RFID tags can be placed anywhere and be used as widgets to trigger events such as virtual switches to turn lights on and off. This allows for extremely dynamic environments where widgets can be reprogrammed and reconfigured.

The Mite was also designed for applications that augment objects and spaces with information. These applications allow users to access and control data that had been associated with a particular item. A prime example of this individual control of data is for associating repair histories with a specific device. Past repairs and scheduled maintenance can be annotated at an elevator itself as well as in a centralized database. This means that the information needed on the worksite would already be at the worksite without relying on a network connection. In addition, individual parts can now store their individual history locally giving more precise and accurate information. Another strong advantage to having inexpensive, lightweight RFID reader/writers is the ability for people to create personalized content. Business cards are imprinted with a variety of static information (e.g. Name, Title, email address, etc) and are given to a variety of people. With writable RFID tags, business cards can contain active content that allows them to become a malleable document full of additional information that can be varied depending on who is the intended recipient. For example, it would be appropriate to embed the URL for a work homepage within the card to give to a work colleague but nice to be able point a friend to a site of pictures from last weeks golf outing using the same business cards. With the reprogrammable memory available with RFID, business cards can now contain sounds, product descriptions, or any other data that can fit on an RFID tag.

The DisplayMote general application set is squarely focused on the lightweight I/O capabilities that the platform offers. The DisplayMote was designed to provide access to systems which has no integrated display like the Intel Personal Server [5]. Our goal was to make a platform the size of a wristwatch to enabled short messages from these devices to be displayed to the user and for the user to give feedback to these devices. Messages might be reminders or lists of surrounding devices that the DisplayMote is able to communicate with. The DisplayMote can be used as a low cost notification system which can be placed outside common spaces (like conference rooms) to dynamically show reservation schedules and the current status of the room. Another application that the DisplayMote was developed to address was the ability to make a "human sensor" a part of the sensor network. By showing messages and giving the user a means of input, a human can interact in real time with a UCB sensor mote on a lightweight platform. This could be useful in the deployment of sensor networks to ensure that each node is properly configured and working.

CONCLUSION

Our goal is to create a toolkit for development of specialized personal-area network devices that utilize a standard wireless communication platform. We leveraged the low-power radio and sensor network protocol work already in progress at UC Berkeley and other research institutions to create general purpose I/O devices. By creating a system of programmable I/O devices that share a common programming language and low power communication protocol, developers should be able utilize these building blocks for application development. Hopefully this approach enables the research community at large to focus on implementing the desired functionality of the device without having to divert their energies to developing the base hardware components.

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Palimpsests on Public View: Annotating Community Content with Personal Devices

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ABSTRACT
This demonstration introduces UbiComp attendees to a system for content annotation and open-air, social blogging on interactive, publicly situated, digital poster boards using public and personal devices. We describe our motivation, a scenario of use, our prototype, and an outline of the demonstration.

Keywords
Annotation; comment; public bulletin boards; community content; social blogging

INTRODUCTION
palimpsest (n). "A manuscript, typically of papyrus or parchment that has been written on more than once, with the earlier writing incompletely erased and often legible."

The system we propose to demonstrate allows people to annotate content on interactive, digital bulletin boards located in public places (Plasma Posters, Figure 1) using PDAs. We envisage this to be a mechanism by which community members can exchange and explore interests and ideas. By publishing such annotations in public places, linked to the content to which they refer, we create a visible "buzz" of "interest clusters".

In this demonstration description, we first describe our digital, community, poster boards, and present user opinions related to commenting and annotating content published on those boards. We then describe our approach to enabling personal and public annotation of digital community content using public and personal devices. We present a scenario, outline our current prototype, and describe our demonstration at UbiComp 2003.

COMMUNITY CONTENT ON PUBLIC DISPLAY
Plasma Posters are large screen, interactive, digital, community bulletin boards that are located in public spaces [1]. Underlying the Plasma Posters is an information storage and distribution infrastructure called the Plasma Poster Network. We have had three Plasma Posters running in our lab for over a year, and two running in sister labs in Japan for 4 months.

Figure 1: Annotating a Plasma Poster posting using a PDA

Unlike digital advertisement boards (e.g. Adspace Network's CoolSign boards), content that is posted to the Plasma Posters is either generated by community members and sent by email, or automatically selected from the company intranet. Content typically consists of URLs, text, images and short movies. A touch-screen overlay on the plasma displays enables interaction with content, including navigation and browsing of posted content and of hyperlinks within that content.

Usage logs, user surveys and interviews have revealed considerable interaction with content at the Plasma Posters, including printing and forwarding of content to oneself and to others from the Plasma Posters themselves [1]. Content authors have also been emailed with comments regarding their postings (e.g. Figure 2). These comments are persistent, conversational threads [3] between readers and authors of posted content. We have also observed the existence of threaded posts (an item that is sent in response to something previously posted). These threads and comments demonstrate the ways by which posted content becomes the nexus of conversation.

Figure 2: A comment on a community posting emailed to the author of that content. The email contains the comment and a URL to the original posting.

Given people's propensity to interact through and around content in this way, we are developing methods that make content annotation a more prominent feature of the Plasma Poster Network and the Plasma Posters themselves. Inspired by instances of PDA used for sharing comments in focused collaboration, meeting and educational situations (e.g. [5,10]) we have extended the Plasma Poster Network to support capture of posted content to personal devices such as PDAs, creation of annotations for that content on the PDA (with text, graphics, and audio), and reposting of the annotated content to the system, and thus to the Plasma Posters. There are precedents for assuming people will post personal content on situated, public displays from personal devices. Examples include the Progress Bar's Meshboard in London, UK where patrons can send images from cell phones [11], and the Appliance Studio's TxTBoard, where SMS text messages can be sent to public displays [13]. To date, however, these technologies do not support inline annotation of existing content. Further, these technologies so far have focused on what has been called "person-to-place" publishing. We wish to extend this notion to "person-to-place-to-people-to-person" content annotation, augmentation and publication.

ANNOTATION

Annotation involves marking of content where the original remains unchanged. Most examples of digital annotation deal with annotating textual documents, but some do include annotation of audio or video content. Most annotations are text-based or ink-based, although some are audio and pictorial.

We characterize annotation systems as falling broadly into 3 categories: 1. annotations for personal use; 2. collaborative annotations; and 3. public/social annotations. In the first category, the goals are typically to support active reading (e.g. [2,4,9]), to help with content retrieval (including summarization, search and classification), for new document retrieval and for content reuse in composition of new documents. In the second category, collaborative annotation, the goal is usually to point someone else to interesting parts of a document (e.g. including text, video, voicemail, text-chat), as a method of activity coordination, as a method of ongoing note-sharing in a working situation, and for serendipitous sharing. Finally, social or public annotation is less team-directed than collaborative annotation, allowing people to leave comments for others to happen across. In the last case, most are Web–based (e.g. [5,7,10,14]).

Examples of current uses of public annotation can be found in several applications on the World Wide Web. The most common forms include newsgroups and Web-based discussion forums, bulletin-boards or "blogs". Most are designed to be accessed, contributed to and read by lone individuals from PCs. Our design challenges have been to design easy-to-use and appealing methods for such annotation from mobile devices, and to produce interfaces that effectively display those annotations in public fora.

Figure 3: The Plasma Poster Interface, the posting represented on a PDA with the commenting facility visible, and the Plasma Poster display with the created annotation visible. The notes along the right edge of the Plasma Poster are all annotations that have been created by community members from their PCs, PDAs, or the "scribble' interface at the Plasma Poster itself.

ANNOTATING COMMUNITY CONTENT: A Scenario

Before detailing the technical aspects of our demonstration, we present a scenario of the system in use.

While listening to a talk on a new shared note taking application, Jane, a conference attendee overhears someone near her talking about how they have just implanted a tracking device in their dog. She opens her laptop and does a quick Google search on "rfid dogs" and e-mails the first link she finds to the address of a nearby Plasma Poster, giving the posting the title "Is rover going robo?" Another attendee, Jason, passing by the Plasma Poster in the lobby nearby notices the post, and wants to add that such tracking devices are highly controversial as their safety has not been fully proven. He presses the "comment" button on the display and uses the scribble pad to attach an annotation ("not my dog!") to the display, adding a pointer to a URL to a Web site where the tags are discussed more critically. Later, another attendee, Jeffrey, who has just been to a talk on ambient displays sees same posting. He approaches the display with his PDA and presses the "grab posting" button, and downloads the current posting to his PDA using the wifi connection. After he sees that his PDA has opened a web page showing the content from the posting and the comment left by Jason, he wanders off to another talk, sketching a response along the way.

Later, other attendees gather around the display and begin talking about the post. They read the comment left by Jason and look through the site he recommended, and conversation begins to focus on where exactly they implant the tags. After scouring the article, they locate the paragraph that describes where the implants are positioned ("usually in the fleshy area of the neck…"). One of the folks near the display uses a gesture to highlight that paragraph and attaches an annotation to that region ("where they implant it…"). When they are about to leave the lobby area, they notice another annotation posted to the display, added remotely by Jeffrey. They open the annotation and find that it is an animated sketch of an orb getting darker and lighter. They then press the audio play icon next to the sketch and hear the author's description of the animation ("an ambient display that gets brighter as your dog gets farther away"). This spawns a whole new discussion amongst those present, with some arguing that the proposed design is ridiculous while others make the case that while simplistic it may have merit. Later, Jane is passing by the Plasma Poster and sees all the annotations that have been posted over her original content. She is amused to discover her post has caused so much response and debate, forwards the recommended URL to her home email so she can read it later.

System implementation and architecture

The Plasma Poster Network is a client-server system that has been designed to make it easy for content creators to distribute information to their community (Figure 4). Server components provide the collection and hosting infrastructure. The Plasma Poster server consists of a relational database (e.g., MySQL from MySQL AB) and Java servlets and Java Server Pages (JSPs) that run in a standard Web server (e.g., Tomcat from the Apache Software Foundation). Client components provide a variety of content displays and interaction mechanisms. For example, posting of information to the Plasma Poster Network is primarily through e-mail. A PosterShow Visual Basic application provides a cyclic view of posted content suitable for display and navigation on a Plasma Poster client platform (e.g., large plasma display or personal computer).

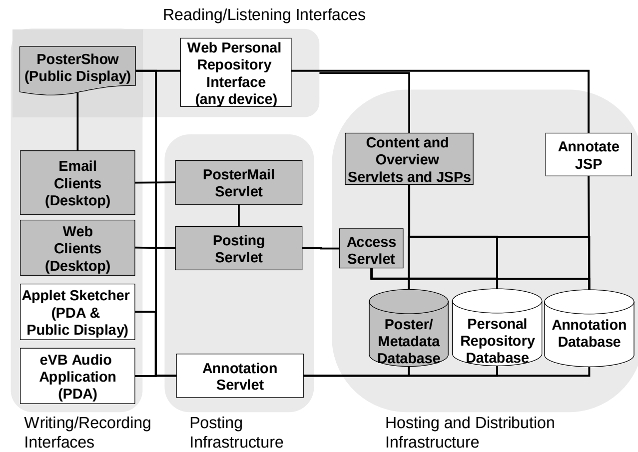

Figure 4. The Plasma Poster Network Architecture, with Annotation components shown in white

Additions to the Plasma Poster Network make it easy for readers of previously posted content to create and distribute annotations on that content. The arrangement of technology we demonstrate here extends previous systems for access to publicly shared content through personal devices [5] by bringing together an infrastructure and range of client applications that support a collage of devices (public and personal), working across multiple media types, and focusing on associating annotations with community posted content, where annotations may be immediately introduced into the system or where sufficient contextual information is stored on a personal device to allow offline annotation to be made and later uploaded into the system. On the server side, the Annotation Servlet accepts annotations on posted content from both sketch-based and audio annotation clients. Upon receiving annotation data, the servlet interacts with system databases to associate annotations to content. A link to the posted content is stored along with the annotation's media type, a link to the posting author (defaulting to "anonymous" when user information is not available), and the onscreen location of the annotation interface at the time the annotation was authored. Furthermore, to support conversation across multiple annotations, the servlet can specify that a particular annotation is a reply to a previously posted one and that a set of annotations are related and should be shown simultaneously, allowing multimodal annotations. The Annotation servlet also interacts with a personal repository database to store postings of interest to individual users for their personal perusal at a later time. Stored content can include a complete posting, parts of a posting, annotations or any combination of these. Also on the server side, the

Annotate JSP allows client applications access to the data in the annotation and personal repository databases. Client side support for annotations on personal devices includes a sketching tool and an audio-recording tool. The sketching tool is implemented as a Java applet and allows users to draw responses to comments. Users first specify a posting to annotate using an interface served by the Annotation JSP. Once a user has selected a posting, the sketch applet allows use of the PDA stylus to input simple annotations. The audio annotation tool is implemented as an embedded Visual Basic application and allows users to record a brief comment using the device's built-in microphone. Comments are uploaded to the Annotation Servlet using the wifi enabled PDA.

The Annotate JSP provides client side interfaces for annotations on public displays. The JSP dynamically displays annotation icons next to postings their associated postings. In this way users may scroll through and open annotations using simple gestures. Users may also sketch annotations on the public display using a version of the sketching tool for that device. Also on the client side, a Web-based interface allows users to manage their personal content repository. Users can review postings and associated annotations that they have collected from public displays or store new content to post at a later time. This interface thus allows users working away from the display a way to see annotations to postings in which they have expressed interest.

DEMONSTRATION FOR UBICOMP

Before the conference, select members of the UbiComp community will be asked to register with our system and to post some content for public display. Four PDAs will be available at the conference itself to enable attendees to interact with posted content.

We will support content posting, capture and annotation from laptops, PDAs, and PCs. We will support, for example, a laptop user in the conference's internet connection area who wishes to post the web site of a nearby restaurant that he enjoys as well as plate suggestions and other comments. Similarly, we will support users who, for example, take and upload photos of a demonstration in-progress. We will support viewing and annotating content both at the public display itself as well as via personal devices. For example, a person using the public display can leave a sketch or audio response to the posted restaurant suggestion. A PDA user, meanwhile, can press a button on her display that captures the content of the posting and all of its annotations to her PDA. She could then walk over to the demo to witness it herself and attach her comments to the posting. We will also support targeted annotation of specific parts of content. For example, a user of a public display may use a gesture to select and attach annotations to a specific region of text.

Instead of posting the annotation directly to the display, the user might want to take another picture and perhaps make comments about both pictures collectively. In this way she has appropriated publicly posted, social content into a novel piece of content that is once again personal. She could then repost this new content to the display to again transfer the content to another domain of ownership. In future work we intend to explore how users conceptualize such transfers of ownership.

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Platypus Amoeba

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ABSTRACT

Platypus Amoeba (Platy) is a reactive sculpture. It knows when someone is petting it and it can indicate how it feels. By petting Platy the user speaks to it. Platy uses lights and sound to speak to the user. This feedback can indicate happiness or sadness or other emotions. Users begin by trying only to initiate a response from the Platy but then quickly change to trying to get a happy response. The user is trying to control Platy by petting it in certain ways but Platy is controlling the user by indicating which way it would like to be petted.

Keywords

virtual pet, interactive sculpture, responsive technology, zoomorphism, human-robot interaction

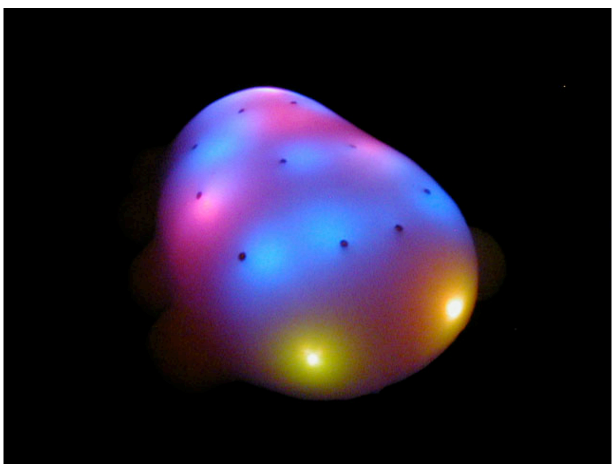

Figure 2: Final *Platypus Amoeba*.

INTRODUCTION

Technology is continually being devised to satisfy people's needs. But how does technology change our needs? How willing are we to change our actions and desires based on technology? *Platypus Amoeba* is an experiment in human/computer interaction. It asks us; what is our relationship to our technology? It is not technology masquerading as a creature but rather a creature born of technology. *Platypus Amoeba* entices with the desire for power as it allows us to cause exciting light patterns and strange noises. But quickly we see the limitations of that power as certain interactions cause negative or unsatisfactory responses. We then change our behavior to get the desired response. Is the user controlling Platy or is Platy controlling the user?

INTERACTION

The ideal interaction with the *Platypus Amoeba* is most effective if there is one person at a time. The user must pet from front to back to get a vocal response. If the user fails to be consistent with their patterns of petting, Platy may stop glowing or emit a harsh squeal. Platy can react with different light formations. For example, Platy can follow your hand with lights that mirror your action. Afterwards, Platy can get tired and its lights start to trail the action of your hand over its body. Like the Public Anemone Robot (2) Platy can choose to not interact with the user.

PHYSICAL FORM

The physical form of the *Platypus Amoeba* morphed from its original concept, a giant caterpillar, to an organic and zoomorphic shape, unidentifiable but familiar. The shape of Platy is round and bulbous. The nubby legs of Plat*y* can be attributed to the original giant caterpillar concept. When one actually touches Plat*y*, its texture is flexible and resilient. There is resistance against your hand when Platy is touched due to the thickness of the silicone material. Platy's exterior is made from soft, translucent silicon rubber. Platy's mass is derived from the resilience of the Dragon Skin Q silicone rubber, which allows for the density and resistance when touched. Based on human interaction with Platy, the natural response is to squeeze Platy's body and hold one of its legs. Users are fascinated with its texture and tactility, usually stroking Platy until the point where they feel comfortable to squeeze its body.

Figure 1: Original concept of *Platypus Amoeba*.

ZOOMORPHISM

The zoomorphic shape of *Platypus Amoeba* is attributed to the giant caterpillar, but also to an inconceivable shape not found in our natural environment. The definition of zoomorphic is having the form of an animal, of, relating to, or being conceived of in animal form or with animal attributes. Platy's shape lends itself to no particular creature, but it's two eyes (See Figure 3) and many feet/nubs make it seem to be some sort of creature. Noises of an unknown creature emanate from it. Users are able to decipher a beckoning purring or sometimes a less friendly or ambivalent response. What social cues determine emotion through sound? How does the user determine if a certain coo or purr emitted from the Platy is a positive or negative response?

Figure 3: *Platypus Amoeba* wakes up.

EMPATHETIC RESPONSE

Platypus Amoeba looks like a small, helpless creature. By touching it's soft skin and it reacting, you are sharing an experience with it. Soon, it is clueing you in to what it wants and you make it sparkling happy or you are depriving it and it is truculent and sad. According to pet behavior studies, cats exhibit signals indicating "Don't Pet Me Anymore" aggression, explaining why cats that seem to enjoy being petted suddenly bite (3). In contrast, cats can emit noises that express a desire for attention that gives humans the desire to pet. With Platy, the user will continue to pet it and receive positive feedback. If the feedback is negative, the user will question, where in their actions did the Platy signal "Don't Pet Me Anymore" aggression.

INTERFACE

Platy experiences the outside world through sixteen phototransistors. These detect the shadow of the users hand as he/she pets the Platy. Phototransistors were chosen primarily for aesthetic reasons (See Figure 4). Many other sensor options were discarded because they would not be pleasing to the eye. Photo resistors would look bad, force-sensing resistors would be expensive and unattractive, QPROX sensors would have been nice as they could be almost completely hidden but we were unable to get consistent results. Platy provides feedback through the sixty-four LEDs, which shine through it's back, through the color of its eyes as well as through various purring and cooing noises from a hidden speaker. The lights can show red, green, and blue like a TV screen as well as white. This gives us a full range of color options to work with. Platys sounds were created by a human voice. They were based on years of living with pets while trying to keep away from identification with any particular animal.

Figure 4: Shell of the *Platypus Amoeba*.

DESIGN AND FABRICATION

Platypus Amoeba is designed to look like a living creature but not like any particular living creature. Users may think of the Platy as alive without identifying its personality with a person or a cat or some other actual creature.

Platy is designed to look cute. People should not feel threatened by Platy or have too much difficulty thinking of Platy as alive. Most electronics are hidden and the over all shape seems harmless. Eyes are low and set far apart in a large head resembling the Japanese super-deformed style of character design (1). The leg/nubs appear underdeveloped. Overall it looks like the baby of a strange alien.

ARCHITECTURE

Platy is self-contained except for the power source. The exterior shape was first sculpted in oil-based plastecine. From this shape we made a three-part plaster mold which we poured the uncured silicon into. The electronic components sit inside this silicon shell with only a wire, for power, protruding. The Software resides on a PIC16F877 microcontroller, which controls four MAX7219 light controllers and an ISD1416 chipcorder sound chip (See Figure 5). Also inside are a small speaker and four arrays of sixteen lights. One array for each color red, blue, green and white for a total of sixty-four lights. Economy was a consideration in design and the total cost of the internal components was under $200US.

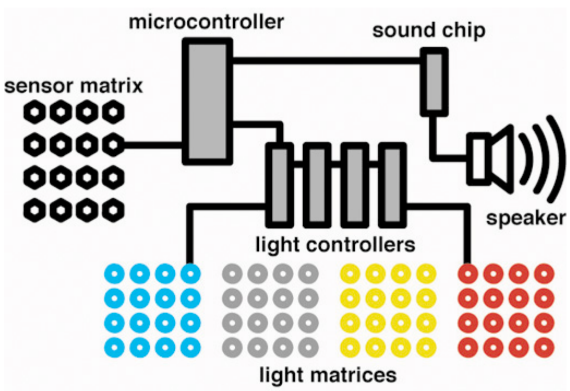

Figure 5: *Platypus Amoeba* block diagram

RESULTS

User testing with general public took place at the ITP Spring Show 2003. In general, users were pleased with the tactility and interactivity of Platy. Many initial responses were to try to pick up Platy and/or squeeze the main body but Platy reacts only to petting. For video of user response and interactions with the Platy please visit our video link: http://stage.itp.tsoa.nyu.edu/~vl336/Spring_2003/SD/platypus.html

CONCLUSION

Perhaps *Platypus Amoeba* can be networked with others to create a small army of responsive creatures. With different personalities formed by how each user treats their Platy, perhaps different Platys could interact with each other and with information from a variety of sources. Ideally, Platy would become completely portable and run on batteries. Platy's accessibility and mobility would become more ubiquitous and part of the household.

ACKNOWLEDGMENTS

Cindy Yang who made the *Platypus Amoeba* silicone body in a three-part plaster mold without ever having attempted such a thing before, Mallory Whitelaw who helped with dynamic coding, Cindy Jeffers, for all her help, Greg Shakar, for his invaluable technical support, and Tom Igoe, our professor.

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M-Views: A System for Location-Based Storytelling

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ABSTRACT

M-Views is a system for creating and participating in context-sensitive, mobile cinematic narratives. A Map Agent detects participant location in 802.11 enabled space and triggers a location appropriate video message which is sent from the server to the participant's "in" box.

Keyword
context-aware systems, participatory media, wireless indoor location awareness, mobile cinema, storytelling

INTRODUCTION

As handheld computing becomes more popular, it will gradually incorporate context-aware features into everyday usage [1] [2]. Information selection will become easier because devices will infer what their users want—even before they pick up a stylus. While location-based marketing and instant messaging seem certain, less attention has been paid to the creative possibilities of context-aware, ubiquitous computing until recently.

Every person creates and receives stories. People talk to others, write in diaries, and send messages by phone, fax or mail. Over the Internet, this flow of information is enhanced by the speed, capacity and flexibility of computer technology. Email and webpages record our "personal narratives." Weblogs can be regarded as an evolving tour through the author's life [3]. This form of storytelling will inevitably migrate to the handheld, context-aware platform. Thus, there will be new possibilities for art and entertainment: interactive media that relates to the user's current environment. We are interested in exploring these possibilities.

Our goal is to build a system for the development and deployment of mobile, context-aware applications—specifically location-based, cinematic stories. This platform, *M-Views*, consists of the following components:

- Client-server architecture, allowing multiple clients to connect to a story server, which analyzes their context/location data and sends each client the next piece of its personalized experience

- Scripting language and authoring software [4], giving authors the tools they need to create and test location-based narratives

- Location awareness engine, which uses wireless network signal strength analysis to estimate the location of each handheld client

Figure 1: A mobile cinematic story

The resulting M-Views experience takes the user on a journey through the physical world, and pieces of the story—in the form of media clips—appear on the handheld at different locations. The selection, order, and timing of these clips are all unique; each person will experience the story in a different way, because with every movement, s/he affects its outcome. We call this interactive experience *Mobile Cinema*.

Mobile Cinema is augmented by physical surroundings and social engagement. As the participant navigates physical space, s/he triggers distinct media elements that often depict events at the location where they appear. The individual media segments are acquired at discrete times and places, with allowances for the serendipitous augmentation of the whole experience through instant messaging (done with the M-Views client). Since any system is only as good as its content, our research has also included the production of three mobile "movies" of this kind, which range from a mystery, to a college drama, to our latest story: an action thriller called *15 Minutes*.

M-Views was designed for Mobile Cinema, but its robust features allow it to have other capabilities as well. The platform can be used to support many types of applications.

TECHNOLOGY

The M-Views client-server architecture consists of multiple handheld clients connecting to a centralized server over a wireless (802.11) network. It makes use of an account/subscription service model, allowing users to subscribe to multiple stories at the same time. The server contains modules and information used for specific behavior, such as particular types of context monitoring or scripting operations and the location awareness engine. Story scripts are also maintained on the server and dictate the content and media to be returned. M-Views applications are defined by these story scripts.

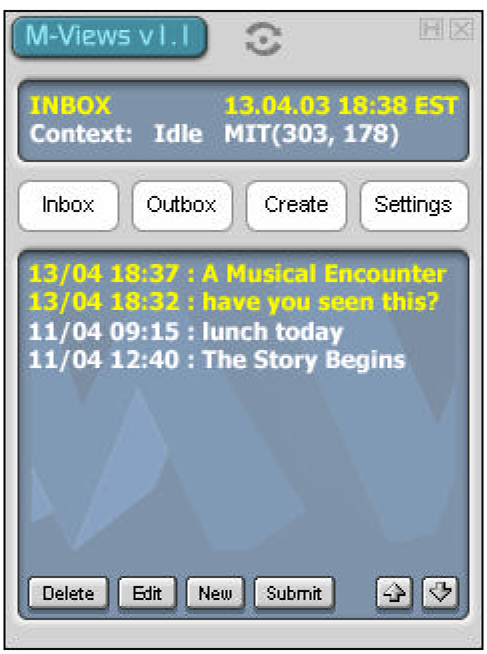

Figure 3: Client Interface on Pocket PC

M-Views Client

The M-Views client operates on the Windows CE operating system (Pocket PC). Each new event is dropped into a message queue, which is visibly represented as the user's inbox. In addition to the message manager interface shown in Figure 3, the client also features a map viewer/editor tool. This permits users to see their server-calculated positions and those of others. It also allows administrators to calibrate map coordinates using only the standard client. The software is modular and can be augmented for new functionality and sensors. It uses third party programs (such as Windows Media Player) to play streaming media over the network. When a message arrives with an associated media URL, the streaming media player is launched. The information flow is diagrammed in Figure 4.

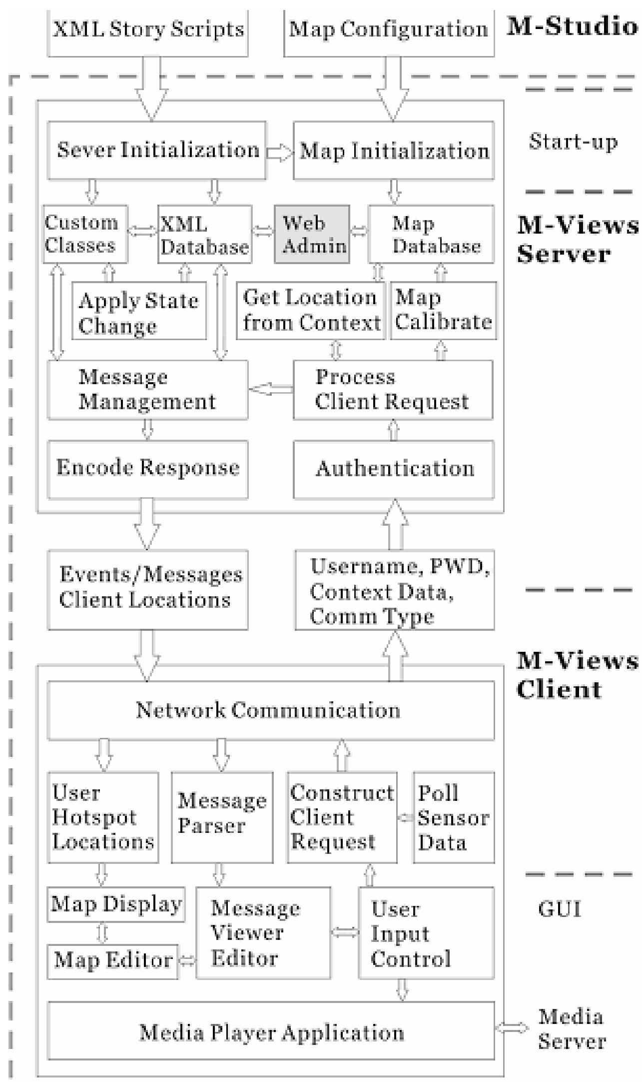

Figure 4: System Information Flow

Communication

Communication between the client and server is carried out via HTTP POST requests. Using this protocol provides both stability and portability. Every update cycle (approximately once per second), the client transmits authentication information, communication settings, and sensor data to the server, which then validates the information and sends back messages, story events, and location estimates. This communication scheme eliminates the need for a logon/logoff mechanism, and it is very fault-tolerant. If the connection is interrupted (perhaps due to losing wireless network coverage), the client will keep trying to send the last request until a connection is made or the program is terminated. To allow for roaming between wireless networks, the client attempts to reinitialize its wireless network card and DHCP address after any connection timeout or interruption. In practice, it takes about 10-30 seconds to reacquire a new network connection after the previous one has been lost.

M-Views Server

The M-Views server is written in Java and runs as a servlet with the appropriate container software, such as Apache Tomcat. After initialization, the server maintains all story, message, and user information as memory-resident XML data. XML management is done using the Apache Xerces 2 package.

The server features a messaging framework that is specifically designed to support narrative structures but flexible enough to be used for a full range of applications. Under this framework, all messages—whether they are client-to-client instant messages or events encountered in a location-based story—are processed using the same mechanism. All messages and events are stored in either a story script or the general message forum (to which all users are subscribed and where client-to-client messages are created). Additionally, all messages, even those sent by clients, can be made context-dependant and can have associated media URLs. These features, coupled with familiar functionality (i.e. message forwarding and group mailing), allow for an intuitive, robust, context-aware messaging experience.

Scripting

Story scripts contain a collection of messages (events). These XML elements include event information, requirements for the client's context and state variables, state change information (applied to a user's profile when he or she receives the message), heuristics that describe the content, and an associated Media URL. The scripting system is used to specify story behavior based on user activity, and each event element contains user variable requirements and results. If current variable values (maintained in the account data of each user) meet event requirements, the event is considered encountered, and the user's variables are changed according to any update rules that may also be defined for that event.

Location Awareness

MapAgent is the default location awareness engine written for M-Views. M-Views clients monitor the Received Signal Strength Indicator (RSSI) for all 802.11 wireless access points in range. These measurements are averaged over a small time window and transmitted to instances of MapAgent running on the server. For each subscribed map, the associated MapAgent compares the RSSI averages to measurements recorded previously by an administrator at known locations, which are called hotspots. Hotspots have a threshold, and they are represented on the map with translucent circles, as in Figure 6. The MapAgent algorithm uses a combination of nearest neighbor matching, triangulation, and trajectory estimation to determine client locations. The average accuracy is between 1 and 5 meters, depending on the environment, map resolution and calibration layout. It functions both indoors and outdoors. MapAgent also keeps track of all clients currently appearing on the map, allowing applications to incorporate a location-based social component.

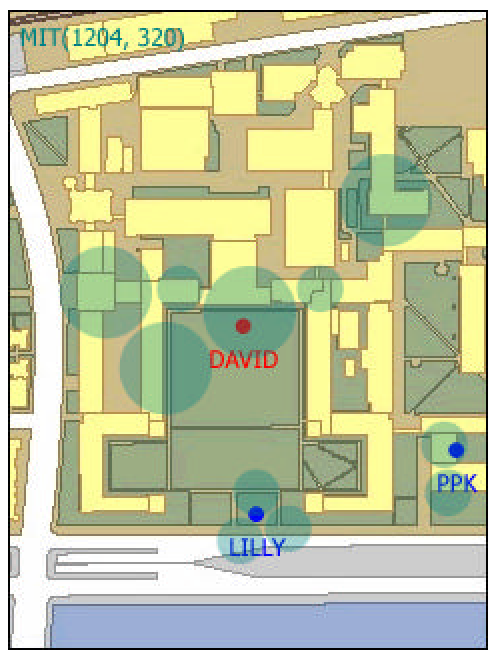

Figure 6: Map Monitor on the Client

STORY DESIGN

The need for good content has prompted the creation of numerous M-Views stories. These have included two large productions by students at the MIT Media Lab: a campus-wide mystery (designed as a time-dependent scavenger hunt) and a dramatic tour through the lives of students at MIT. Each production stressed different aspects of Mobile Cinema—in particular, nonlinearity and the connection with space.

Nonlinearity refers to the modularity of story clips. Authors must accept the possibility that clips will be seen at odd times or in strange orders. Therefore, the story and each clip that composes it must be able to withstand these uncertainties. M-Views authors have discovered that every clip should be entertaining independent of the other story material; each scene must have its own miniature "story arc."

Connecting with space is essential to the mobile experience. The small screen of a handheld device is a disadvantage in this regard. Therefore, it is up to the author to anticipate the interest and curiosity of the user. Carefully planned cinematography is the key here. Authors of Mobile Cinema have learned to give their audience spatial awareness and dramatic focus through use of motion, extreme close-ups, and wide establishing shots.

SIGNIFICANCE

Previous context-aware mobile media systems, such as the Cyberguide system [5], the Guide system [6] and the Hippie project [7], are all aimed at providing location-based experiences for visitors, city travelers, or museum tourists. All these systems adopt client-server architectures similar to M-Views, but differ in that they do not focus on the narrative aspect. In addition, few systems are full development platforms for mobile applications. None of this past research has focused on the development of cinematic narrative and little effort has been made to purposely support multiple kinds of mobile applications using these architectures.

M-Views breaks new ground by giving people the chance to author and experience Mobile Cinema with unlimited freedom—use it to create your desired type of mobile movie or game, or build your own context-aware application. Or simply write about your own life using the space around you as your medium.

ACKNOWLEDGEMENTS

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Stanford Interactive Workspaces Project

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ABSTRACT

"iRooms" (Interactive Workspace rooms) are characterized by the presence of one or more large shared displays plus several users' laptops or handhelds. (See figure.) Key philosophical underpinnings of the iRoom project are *fluid interaction* and *incremental integration.* Fluid interaction refers to the ability of users to focus on the tasks they are doing, not on the technology being used to do them. Incremental integration refers to the ease with which new behaviors or devices can be incorporated into an existing ensemble of components forming a ubicomp environment, in order to augment or modify the behaviors of existing applications in that environment. In a "miniature" iRoom, we will demonstrate how the software design decisions that support incremental integration enable the capabilities of fluid interaction. Attendees will be able to directly interact with the technology themselves, instantly download client software, and view prototypes of "portable" iRooms that can be deployed in environments with little or no existing ubicomp infrastructure.

Keywords

Interactive, large display, collaboration, system software, integration, capture and access

INTERACTIVE WORKSPACES

The Stanford Interactive Workspaces project is exploring new possibilities for people to work together in technology-rich spaces with computing and interaction devices on many different scales. We have chosen to focus on augmenting a dedicated meeting space with technology such as large displays, wireless/multimodal I/O devices, and seamless integration of mobile and wireless "appliances" including handheld PC's. We concentrate on task-oriented work such as brainstorming meetings and design reviews (rather than entertainment, personal communication, or ambient information), and on the ability to rapidly prototype new software as well as integrate and augment legacy software.

This cross-disciplinary project is staffed by faculty and students from the Interactivity Lab, Software Infrastructures Group, and Graphics Lab; our experimental facilities are also used as applications testbeds by the Stanford Learning Lab, Wallenberg Global Learning Network (WGLN), Stanford Center for Integrated Facility Engineering (CIFE), and the Program in Writing and Rhetoric.

Our main experimental research facility, the iRoom, is located in the Gates Information Sciences Building at Stanford. We believe the iRoom is representative of "Weiserian" ubiquitous computing spaces within the task domains we are addressing. We are actively pursuing research on the intersection of HCI and systems problems that arise in deploying, operating and developing applications and human interfaces for an iRoom, including:

- Multi-device, multi-user applications
- Multimodal and fluid interaction
- Reusable, robust, and extensible system software for deploying COTS-based (commercial, off-the-shelf) ubiquitous computing environments like our own
- integration of large (wall-sized) displays with advanced visualization capabilities into an iRoom
- integration of computing "appliances" including PDA's, scanners, digital cameras, etc. into an iRoom

We explicitly focus on reusable system software and the ability to integrate "legacy" off-the-shelf applications and systems, and encourage others to build on our work. iROS, the middleware that powers the iRoom, has been deployed in other research and classroom settings around the world, including KTH (Swedish Royal Institute of Technology) in Kista, Sweden, ETH-Zurich, Hewlett-Packard Laboratories, Wallenberg Hall classrooms at Stanford University, and the Center for Design Research at Stanford

University.

iROS: Interactive Workspace Middleware

The dynamism and heterogeneity in ubiquitous computing environments on both short and long time scales implies that middleware platforms for these environments need to be designed ground up for portability, extensibility and robustness. We have developed the iROS (iRoom Operating System) middleware platform for augmented room-sized ubicomp environments through the use of three guiding principles: economy of mechanism, client simplicity, and use of levels of indirection. Apart from theoretical arguments and experimental results, our experience through several deployments with a variety of applications, in most cases not written by the original designers of the system, provides some validation in practice that the design decisions have in fact resulted in the intended portability, extensibility and robustness [6,4]. An important lesson drawn from our experience so far is that a logically-centralized design and physically-centralized implementation enables the best behavior in terms of extensibility and portability along with ease of administration, and sufficient behavior in terms of scalability and robustness.

The fundamental design stance of iROS is that a major challenge of ubicomp middleware is *design for integration.* We will inevitably continue to encounter situations in which the goal is to "integrate" a new behavior, controller, or service into an existing environment not designed to accommodate it; therefore the design goal of all our middleware is to make the integration task as easy as possible. This is reflected at the lowest layer in the iROS EventHeap [7], at the application/UI integration layer by iStuff [1] and the Patch Panel [2], and at the UI generation layer by Interface Crafter [10].

Interactive Workspace Applications and Technologies

iROS has been the basis of numerous technologies and applications, many in regular use in the Stanford iRoom and other interactive workspaces. Although each is the subject of one or more refereed publications, we try to give a sense of the breadth of work that has been enabled by this platform:

The **Workspace Navigator** is a suite of tools designed to facilitate capture, recall and reuse of information in an interactive environment.

iStuff [1] is a framework for prototyping physical UI's by building inexpensive physical devices and integrating them rapidly with existing iRoom behaviors and applications. The Patch Panel [2] provides a generic and easy-to-use software mechanism to intermediate between iStuff and existing applications, suitable for a range of sophistication from non-programmers to power users.

The **AmbienTable** explores issues involving the use of tables as ambient displays. The table displays several visualizations relevant to iRoom users, including the status of the room's EventHeap , recent activity in the room, and the contents of the iClip-board. For example, the EventHeap Visualization provides awareness of the flow of information between machines within our environment, and has also been used to identify bugs and breakdowns in the system.

iWall (Interactive Wall) is a software framework for easing the development and deployment of multi-display post-desktop applications for ubiquitous computing environments. Multiple general-purpose graphical "views" run on several devices of vary-ing capabilities and platforms and are controlled by applications through a simple but powerful EventHeap-based protocol. iWall interacts smoothly with other iROS-based technologies such as iStuff: for example, a user can play iPong (a table-tennis game spanning multiple displays, using iWall as a substrate) using iStuff and the PatchPanel to select among multiple physical "paddle controllers" as they play.

The **iClipboard, PointRight** [8], and **Multibrowsing** [9] together provide the essential mechanisms necessary to easily move data (Web pages and documents) back and forth between users' personal devices and large shared displays. PointRight allows a single mouse and keyboard to control multiple screens. When the cursor reaches the edge of a screen it seamlessly moves to the adjacent screen, and keyboard control is simulta-neously redirected to that machine. Laptops may also redirect their keyboard and pointing device, and multiple pointers are supported simultaneously. Multibrowsing allows any pointer to direct the movement of content from any display to any other display. The iClipboard allows cutting-and-pasting of content across machines (shared or personal, Windows or Mac), and integrates with PointRight to do the right thing (a user can cut something on one screen, use PointRight to have the same mouse move the pointer onto another screen of a different type of machine, then Paste).

Although most iRooms deployed to date are fixed facilities built into infrastructure-rich rooms, we have also explored encapsulating much of the functionality of the iRoom in an "appliance" that also addresses the needs of roaming/nomadic users. The **MeetingMachine** [5] provides a substantial amount of the functionality of an iRoom in a projector-like appliance, and can be immediately deployed in a facility with no other infrastructure. The MeetingMachine's design decisions reflect important differences that arise when trying to accommodate nomadic as well as "fixed" users in interactive workspaces.

DEMONSTRATION SCHEDULE

We will have three kinds of demonstrations at Ubicomp'03:

"Let us show you" demos will consist of guided demonstrations highlighting Interactive Workspace applications and technologies, including the Workspace Navigator, iStuff for physical UI prototyping, the Patch

Panel for incremental integration and reconfiguration, and the AmbienTable for visualizing interactive workspace activity. Not all applications will be demonstrated during the entire demo session; please visit our booth for the detailed schedule.

"Exploratorium" style demos[1] will provide conference attendees the opportunity to freely interact with iRoom demos as they wish; researchers will be available to explain "what's going on" in each demo, and posters adjacent to the demo booth will give further details.

"Try it, you'll like it" will allow conference attendees with Windows XP laptops to try the MeetingMachine for themselves. Whereas the demo iRoom is intended to simulate the permanent iRoom at Stanford, the MeetingMachine provides a substantial amount of the functionality of an iRoom in a projector-like appliance, a kind of "iRoom-in-a-Box" that can be immediately deployed at a meeting or brainstorming session even if there is no network infrastructure in place. The client-side Windows software for the MeetingMachine will be available on CD-ROMs and USB Flash/CompactFlash drives for attendees to download immediately to their laptops. In addition the MeetingMachine will support media transfer via USB, CompactFlash, and RFID tags.

SUMMARY

iROS and its associated applications have been successfully used in a number of experimental and production scenarios, including design brainstorming sessions by professional designers, construction of class projects built on the iROS system, training sessions for secondary school principals, construction management, collaborative writing in a Stanford English course, and of course, our own weekly group meetings. iROS technology has also been deployed in two classrooms in Stanford's new Wallenberg Hall, and Multibrowse and PointRight have been readily adopted by instructors of courses ranging from engineering to Classics. Overall results have been positive, with many suggestions for further development and improvement; public deployments of iRooms for student use in libraries and dormitories are in the planning stage, using the MeetingMachine appliance [5] for rapid deployment. We have been encouraged by comments from programmers who have appreciated how easy it is to develop applications with our framework. Finally, the adoption and spread of our technology to other research groups also suggests that our system is meeting the needs of the growing community of developers for interactive workspaces.

For more information and publications on the Interactive Workspaces project, to see photos and videos of the iRoom, or to download the iROS software (including easy installers for Windows NT/2000/XP), visit *http://iwork.stanford.edu.*

[1] Inspired by the "do, then read" hands-on exhibits at the Exploratorium museum in San Francisco, for those readers who have visited it.

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Picture of Health: Photography Use in Diabetes Self-Care

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ABSTRACT

Physicians and nutritionists often prescribe behavioral change such as healthy eating and regular exercise to patients with diabetes without an understanding of the reality of the individual's life. As a window into the patient's experience, we propose a new type of health record, photography. Diabetics shoot pictures of their daily actions such as eating, exercising, and socializing. Software tools synchronize the images with concurrent blood sugar data. Diabetics review and critique their health practices by examining these records in diabetes education settings or with health care providers. We present results from a study and demonstrate the use of this method.

Keywords

Explanation, health education, imagery as data, reflection, visual systems

INTRODUCTION

Approximately sixteen million people in the United States live with diabetes. The disease is a major risk factor for heart disease, stroke, and birth defects, and it is the leading cause of kidney failure, amputations, and adult blindness [7]. Very generally, diabetes is a condition in which the individual lacks enough effective insulin to transfer sugar from the blood stream to the cells. Without proper care, sugar remains in the bloodstream leaving the cells starved of energy. Over extended periods, elevated blood sugars damage small blood vessels and nerves leading to the conditions described above.

Physicians treat diabetes in the doctor's office, hospital and laboratory, but people live with this disease in homes, offices and public spaces. Treatment often takes the form of a general prescription of healthy behavior. Diabetes cannot be cured, but it can be controlled with insulin supplements, oral medicines, and most importantly for this work, by modifying one's health practices. Physicians and dieticians tell their patients to increase exercise, decrease fat and carbohydrate consumption, and monitor blood sugar levels with commercial glucose meters. These behaviors greatly reduce the likelihood of diabetic complications [8,12]. Yet, people find it difficult to adhere to new regimented behaviors. Anyone who has attempted a diet or exercise plan is familiar with that frustration.

There are two major difficulties in maintaining such a routine. Firstly, it is often difficult for diabetics to understand that the actions taken now have implications for health status late. They are not motivated to shift behavior. Unlike conditions with immediate biofeedback from unhealthy behaviors such as asthma, in diabetes the damage caused by continued high blood sugar may not manifest for many years. At that point, it is often too late to save deteriorating vision or blood flow in fingers or feet. Without such biofeedback, many diabetics falsely assume they are taking care of themselves adequately. Secondly, physicians and nutritionists generally suggest self-management procedures without knowing about the person's extant routine. These treatments do not necessarily fit into the individual's reality. It is difficult to recommend specific foods to eat and exercises to do without knowing, for example, if the person likes to cook or how much free time he or she has to exercise. General solutions cannot help each specific individual.

However, it may be possible to help diabetics develop better understandings of how daily activities impact fluctuations in their blood sugar and use this method to design personalized interventions. Most diabetics routinely carry portable monitoring devices—glucose meters—to test their physiological condition (e.g., their blood sugars) multiple times a day. These meters sample the amount of sugar contained in a small drop of blood (usually drawn from fingertips or the forearm) and display the result as a number[1]. Glucose meters dramatically increased the lifespan of diabetics by giving them immediate feedback about *how* they are managing their blood sugar [13]. Knowing one's blood sugar and how it fluctuates can assist the development of routines to normalize one's health.

The work we describe in this paper is concerned with augmenting this meter to help diabetics and their physicians understand *why* blood sugar levels are low, elevated, or normal. In a sense, we want to create the behavioral equivalent of the glucose meter, a way to

[1] Blood sugar is measured in milligrams per deciliter (mg/dl) in the United States, in millimoles per liter (mmol/L) in other countries.

capture and examine diet, exercise, and other routines to understand the connection between behavior and blood sugar measurements.

In this project, we outline and test the concept of a behavior meter. This meter includes a novel data format to supplement the blood glucose readings, photographs. These photographs offer literal portraits of events in a person's life. By juxtaposing these images with blood sugar values a diabetic and health care providers can begin to understand the intersection of behavior and blood sugar control for both creating a treatment plan and critiquing its efficacy.

Images in this capacity function as data for reflection and review. Educational researchers have studied how learners can analyze behaviors depicted in still and/or moving images, generate and test hypotheses about how and why these behaviors occur to develop deeper understandings of various concepts [1-3,5,6,10,11,14,15]. In the area of healthcare, asthma patients were asked to videotape their daily routines[9]. These results showed inconsistencies between the amount of allergens patients reported exposure to and those captured on video. This work suggests that people cast their activities in a "healthy" light even while enacting unhealthy practices. We think diabetics may act similarly, explaining a healthy lifestyle to medical professionals while a closer examination of their daily activities might reveal examples of unhealthy routines.

The remainder of the paper describes a series of design studies that introduced photography into diabetes self-monitoring practices. We report on a project done in a class on diabetes self-care, where newly diagnosed diabetics often go to learn how to cope with their disease. We introduced photography into those courses to help students connect lecture materials to their daily lives as captured on film. And, we describe a computer-based visualization tool designed to help diabetics see relationships between their blood sugar measurements and photographs of their daily routines.

CLASSROOM STUDY

Background

We began our inquiry through observing a course on diabetes self-management held in a local hospital to understand class procedure and curricula requirements. The class ran for ten weeks and met once a week for an hour. In this class, diabetics learn about self-care practices such as eating the right number of portions of a particular food group and caring for feet and eyes that often suffer complications. A different specialist teaches each session in his or her own teaching style. Generally, these are hour-long lectures in which attendees passively. About 10 people came to each session with 3 or 4 missing any particular meeting.

Intervention

For the next course, we worked with the nurse practitioner in charge to introduce photography into appropriate sections of the class. We prototyped the project through using disposable cameras distributed to the class attendees. We asked people to take pictures of meals, exercising and social events, anything that people thought might impact blood sugar. People took the cameras home between sessions to take pictures and returned them for processing at a subsequent class.

Results

Diabetics shared these images with other people in the class. These pictures served as focal points of health discussions. Instead of talking about subject in the abstract, the students discussed specific situations from people's experience. For example, people used the language of the classroom such as ideal portion size to discuss meals pictured like the one in Figure 1. In addition, the nutritionists and nurse practitioners were allowed "into" the homes of these patients through these pictures. They saw what their patients regularly ate, what is in the refrigerator, where they walk and generally what their lives are like. This information changed the level of specificity with which health care providers discussed problem solving with patients.

figure 1: A photograph of one student's dinner. This image prompted discussions about portion sizes, food preparation, and balanced nutrition.

Consistent with Rich et al.'s work with asthmatics, diabetics seemed to report their behaviors in a positive light even while engaging in unhealthy behaviors. In Figure 2, the photographer reported taking the picture to show the syringes and healthy foods. Other students asked about the soda with sugar and the beer. Through the social interaction of the class, inconsistencies between the patient's view of a situation and the health conscious outsider's view came to light. These discrepancies fueled discussion.

figure 2: Two photographs from a student's collection. While the student claimed to be photographing his refrigerator, others focused on objects that contribute to poor health (e.g., the soft drinks and beer).

In general, photography inspired a new level of discussion in the classroom. Students became more vocal with both their questions and their critiques. In interviews, patients said they became more aware of the options they have on a day-to-day basis and of the choices they made. Whether this type of awareness could lead to long-term behavioral change has not been established.

SOFTWARE DESIGN

With images we began to capture a record of behaviors over time but these records did not include how behavior impacts blood sugar changes. In order to do so, we experimented with data visualizations of blood sugar and juxtaposing images with these types of visualizations to create a more complete record of health. Figure 3 shows the top-level visualization of blood sugar values for a one-month period. Figure 4 is a detailed view of the images placed on a timeline that depicts blood sugar fluctuations for one day.

We prototyped this project with the help of two diabetics and have used our experience with them to plan subsequent work. One diabetic gave us his logbooks and records and shot pictures informally to give us his reactions to the process. The other person, Dan, uploaded his blood sugar readings, shot pictures for a six-week period and met with us regularly to discuss his experience.

Results

Data visualizations as well as the pictures both provided evidence that patient's theories about health do not always capture the full story about self-care practice. Dan's blood sugar visualization for example, revealed very high readings more often than he thought they occurred. He explained these results as a consequence of not taking enough insulin. Increasing the insulin dosage would be a solution to this predicament, but changing personal particular meals that seemed to drive up blood sugar behaviors would also facilitate good blood sugar control and be healthier. Closer inspection of the data set revealed Instances where very high readings, co-occurred with images such as in Figure 4. Such examples from the data set

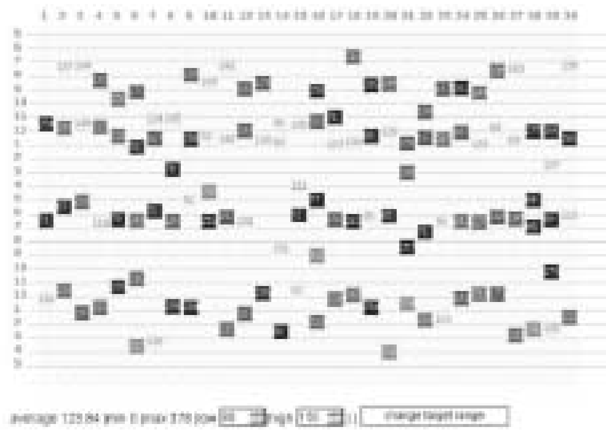

figure 3: A visualization of blood glucose levels over time. Each column represents a day of monitoring; each row is an hour of time. The colored boxes indicate blood sugar measurements, with dark, light, and off white symbolizing low, high, and acceptable glucose levels respectively. The visualization used is color-coded. These data showed that Dan had high readings dispersed throughout the day. The use of color helps patients and physicians get a global overview of glucose levels that could not be seen with simple line graphs.

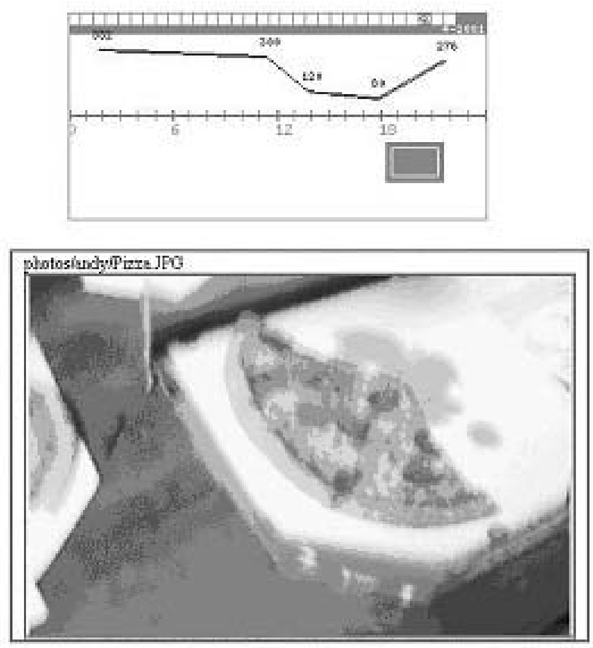

Figure 4 A closer look at one person's blood sugar levels and photographs. The upper image shows a line graph of his glucose for the day with an icon representing the time that the lower photo was taken. His blood sugar elevated to 276 mg/dl after eating the pizza in the photograph.

motivated discussion. Additionally, Dan did experiments using this tool. For example, he "tested" whether dancing would lower his blood sugar by taking pictures during a party. Yet, without social support such as was available in the diabetes classroom, Dan did not seem to question his previously held beliefs about his health. The data visualization with blood sugar data and images did allow for exploration and reflection of personal health. But, while Dan generated explanations for events, he did not change his underlying theories about his own self-care. Meeting with a health care provider or other with diabetics may be critical in utilizing these image technologies for improving self-care.

GENERAL DISCUSSION

Imaging technology is becoming more cheaply available, and increasingly ubiquitous. Generally, health care records are composed of physiological data that reflects the state of an individual's health verses the causes of a particular condition. Image technology allows for new types of health records for personal reflection and sharing with health care providers. In these projects, we have explored how such a visual record of behavior could be made and the utility of such a record in both a classroom setting and on an individual basis.

FUTURE WORK

We are currently testing the value of data collection in implementing behavioral changes. To do so we have enlisted a group of college-aged diabetics at Pennsylvania State University. They have used our software to synchronize blood sugar and image data and have discussed these data with researchers. Currently, we are analyzing results from this study.

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Noderunner

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ABSTRACT
In this paper, we describe Noderunner, a game designed for cities with a thriving wireless telecommunication infrastructure. It explains the game how to play it. Additionally this paper comments on how Noderunner offers the general public an entrance point into the many conflicting social, political, and economic forces that compete to deploy WiFi hotspots in public spaces.

Keywords
Wireless, City, Game Design, Augmented Reality, Art

THE GAME
Noderunner is a game that transforms a city into a playing field. Two teams race against time to access as many wireless Internet nodes as possible. To prove that they have successfully connected to an open node, each team must submit photographic proof to the Noderunner weblog. During game play, the weblog becomes a busy scoreboard tracking the competing teams in real time. After the game, the photos provide visual documentation of the path taken by each team and public spaces that have free wireless connectivity.

Each four-person team was given a WiFi enabled laptop, a digital camera, taxi fare, and two hours to get from Bryant Park in midtown to Bowling Green in Lower Manhattan, both free wireless parks. Teams earned points by taking their portraits in the exact spots where they were able to connect to wireless access points. They also earned points by using scanning software to sniff all the nodes along the way, even those that were password protected or too weak to transfer pictures. The teams collected logs recording hundreds of closed or weak nodes, but scored more points when they were actually able to use a node to upload a picture.

The simple rule set forced players to develop strategies for planning the most rewarding routes within the city. For example, the East Village was a popular route destination because it offered a large number of open nodes. Participants also needed technical savvy to troubleshoot connection problems and upload pictures despite fragile connections. Spending too much time on a weak node could have been the difference between winning and losing so teams moved quickly through the city with a combination of running on foot and riding by taxi. An additional link was established between the teams and a central 'headquarters' location where the progress of the competitors was plotted on an 80-foot map of Manhattan and where photographs taken by the teams were projected on a large screen. Urban photography gave spectators a new appreciation of the city's open nodes, and the winning team popped Champagne in celebration.

THE FIELD OF PLAY
Noderunner's playing field is the available WiFi spillover in a densely populated area. The density of this spillover is so great that it can be used as a legitimate wireless network. For example, in New York City it is now easier to find an open and free 802.11 hotspot than it is to find a public restroom. New Yorkers with WiFi enabled laptops are becoming accustomed to stumbling on open access points made available by their neighbors, pubic parks, cafes, bars, and not just their work places. These well-traveled cultural spots have never before experienced Internet connectivity, nor has the Internet ever enjoyed such seamless integration into a city's actual architecture and social fabric [1].

Noderunner sessions highlight overlaps between information and the urban environment, encouraging the use of public spaces for creative endearvors. As wireless access becomes more prevalent in our cities, this paradigm offers new opportunities for applications that treat public space as an interface. This work draws on spatially based games like tag, scavenger hunts, and hide-and-go-seek, as well as graffiti art, skateboarding, and urban bicycling that characterize cities like New York. Recently, new technologies have expanded the scope of these activities, spawning a diverse community of artists, entrepreneurs and activists developing location-based models for social movements, advertising, urban services and pervasive gaming [2]. Instead of making our video games look more realistic, we now have the ability to turn our reality into a video game, a city's infrastructure into a play space. Our cities are becoming game engines and software, as citizens collectively program, code, or update the place where they live.

This diverse collective action means that even in the same city, like New York, Noderunner's playing field is in constant flux as WiFi continues to proliferate. At first glance this would appear to make Noderunner easier but as WiFi spreads new legislation, use patterns, and technologies emerge. Will new security measures limit open access despite an increase in nodes and improvements in transmission distance? Played over time, Noderunner games help answer these questions by providing empirical data about our culture's adoption of wireless technology. Noderunner is in itself an exemplar of an emerging culture. A culture where smart and wireless environments are as much an object of play as is a grass field or an open lake.

THE ART AND CULTURE OF OPEN WIRELESS

The open wireless movement is being built by the end-users, one node at a time. Drawing on the original spirit of the Internet, WiFi enthusiasts embrace open standards, peer-to-peer dynamics, and user-centered innovation. As artists, we combined game design with the existing culture of the open wireless movement. Instead of creating an artificial game environment, we tapped into the revolution that was already happening around us. Our goal was not just to contribute to a new genre of public art, but also to actively engage the general public in a vital cultural and technological transformation. Node Runner is continually re-invented by the citizens who build the network and run the streets. The game is an entrance point to the political and social movements behind wireless. We offer Node Runner as celebration of free and open wireless connectivity and as a symbol of the city's cultural flexibility and potency.

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UCSD ActiveCampus - Mobile Wireless Technology for Community-Oriented Ubiquitous Computing*

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ABSTRACT

A university campus is designed to foster a thriving community of learners, but modernity has introduced many stresses. Mobile computing holds the potential to strengthen a campus's traditional institutions of community by creating serendipitous learning opportunities through a process of indirect mediation. This demonstration introduces ActiveCampus Explorer, a suite of personal services for sustaining an educational community based on this idea.

INTRODUCTION

With the arrival of the baby boomers' children, the UC San Diego (UCSD) is quickly growing from an intimate small town into a bustling city full of unfamiliar faces. Building proceeds apace, with dozens of departments and hundreds of labs and institutes finding homes in odd corners of undistinguished buildings, old and new. This rapid growth has brought numerous "big city" stresses. It is hard to keep up with the building on campus and who occupies what building. Unfamiliar faces are everywhere, even obscuring those that you know. With growing diversity and building construction lagging, more students work and live off campus, making them visitors to their own campus and education. One third of undergraduates transfer to UCSD after two years at another college, abbreviating their campus experience.

These changes strike at the heart the campus's mission of learning—research and education. With this mission comes a culture that believes in the power of knowledge to transform people and the world in the most positive way. The university campus, as originally conceived, was a place to nurture those values and pass them on to the next generation, a kind of perpetually rejuvenating cocoon. In becoming a city of towns, and perhaps a city of visitors, UCSD could lose its transformative powers—or it could magnify them. The latter requires new ways for people to stay in touch with old colleagues, meet new ones, and become aware of the exciting opportunities around them.

While the campus administration pursues new policies to sustain our community, the UCSD ActiveCampus project is exploring the use of technology to meet this challenge. With assistance from Hewlett-Packard, we have given HP Jornada PDA's with 802.11b wireless to 800 undergraduates studying computing at UCSD. With UCSD's wide deployment of 802.11b access, we are able to explore research questions in sustaining educational communities via mobile computing.

Sustaining dispersed communities through virtual spaces is well known [12]. Direct support of physical communities is seen in the discourse enabled by E-Graffiti [1] and GeoNotes [4], where users can leave their electronic thoughts in physical space for those who follow (See DISCUSSION). These projects provide a compelling application and warn of the need for a large community and sufficient content to be successful.

Our approach is a variant on a familiar theme[3, 7, 8, 10, 11]: if you and every person on campus carried a mobile, wirelessly connected device, it could be used as a kind of "x-ray glasses" onto your immediate vicinity to let you see through the crowds and buildings to reveal nearby friends, potential colleagues, departments, labs, and interesting events. By making the clutter transparent and highlighting otherwise invisible things, once-unnoticed opportunities are now apparent, creating an environment for serendipitous learning.

A simple realization of this idea for a small wireless device like a PDA is shown in Figure 1. In the top image, the large area is a map of a person's immediate vicinity, as detected through some geolocation method. Overlaid are links showing the location of nearby departments and friends. Department links and the like can be clicked to bring up their web page. A nearby colleague, formerly no more available for lunch than a hundred others, is seen to be in the vicinity and can be instantly messaged or found on foot. Any place or entity can be tagged with digital graffiti, supporting contextual, asynchronous discourse.

ActiveCampus Explorer is a working system available for use by everyone at UCSD [5]. It is in active use by our group and several others (about 50 in number) and was deployed

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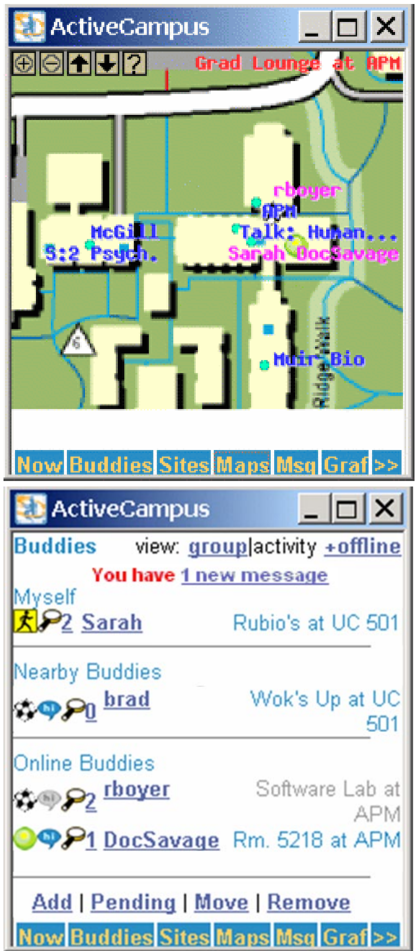

Figure 1: The Map and Buddies services. The Map service shows a map of the user's vicinity, with buddies, sites, and activities overlaid as links at their location. The Buddies service shows colleagues and their locations, organized by their proximity. Icons to the left of a buddy's name are buttons that show the buddy on the map, send the buddy a message, and look at graffiti tagged on the buddy. Other services are reached by the navigation bar or clicking items embedded in the views.

in stages to our base of Jornada users for beta testing and structured events such as games. As part of a broader project using the campus as a living laboratory, researchers in the department of Communication are conducting ethnographies to understand ActiveCampus's impact on campus life.

In the following we first identify a set of sociological issues and places them in a conceptual framework that clarifies how technology can contribute. Second, we define a base set of services necessary to sustain a community through mobile computing. Third, we demonstrate these services with a particular design and implementation suitable for small form-factor wireless devices.

Theory and Requirements

Learning activities, spontaneous and otherwise, are heavily mediated by a university campus through its structural configuration and its institutions.[1] First, the campus organization itself brings people with complementary interests into close proximity, easing communication and increasing the chances of serendipitous interactions. The campus not only brings learners and teachers together, but also concentrates area specialists by organizing the campus into schools and departments of expertise (such as schools of Engineering and departments of Computer Science). A department is not just an aggregation of interest, but is a full-blown institution providing services for its aggregate of people, including working spaces, meeting spaces, seminars, opportunities for chance interaction, equipment, curricula, degree programs, funding, etc., to enable and encourage the processes of learning.

Because these institutions operate through proximity, they function less well when people are not "there" on a full-time or full-attention basis. Moreover, it can take considerable time for someone to internalize the workings—the culture—of an institution. If someone does not know the internal workings of an institution (for example, how talks are scheduled and where they normally occur) its mediating power is lost on them, and indeed possibilities are disguised (when it is possible to drop in for a talk). When such obfuscation is combined with a busy schedule, conflicting priorities, distractions, interruptions (most of UCSD undergraduates possess cell phones), it is not surprising that many opportunities are missed. Further complicating matters is that many campus institutional structures crosscut each other, creating ambiguity, but also richness. For example, UCSD is divided into residential college neighborhoods. Each department sits in a college neighborhood and is nuanced by it, yet it actually belongs to a school, not the college. Each faculty member belongs to a college, however, and of course a department.

We hypothesize that mobile computing applications, by mediating the institutional mediation of learning, can accelerate one's on-going acclimation process, thereby mitigating time and attention deficit. In such a role, ActiveCampus is not a replacement or proxy for extant institutions, but rather a facilitator. Such a role befits mobile devices, given (on the negative side) their limited form factor, interface, and computing power, as well as (on the positive side) their mobility and relative unobtrusiveness.

Building on the idea that a campus organizes institutions for mediating learning, it is natural to consider reifying (displaying) contextual information about (a) you (the learner), (b) mediating institutions, and (c) the sources of learning enabled by those institutions such as a professor, friend, book, event, or another institution like a lab. Since a campus institution is typically a physically aggregated entity, displaying an institution in a *transparent* form and showing its mediated sources of learning "inside" it (or even next to it) is a natural way to convey mediating relationships. Depending on the

[1] Here, we interpret institution broadly, including entities like departments, libraries, seminar series, and even people. The notions of mediated learning described herein are informed by the work of Michael Cole [2].

possible relationships between the learner and the learning source (including role reversal), participants may need the ability to talk—as well as see—through walls. Gradually, then, through experience, a participant learns to parametrically associate the institution with learning sources, imbuing the institution with its full power.

There are many research efforts on augmenting the physical world with information from virtual spaces, albeit without an explicit focus on communities, culture, and learning. At ATT Research Cambridge, users wear goggles which overlay information to enhance their knowledge of what they are already seeing [9]. GUIDE [3], CyberGuide [7], Hippie [10], and a host of other electronic tour guides provide information for the user about the local surroundings using a mapping metaphor to abstract the world, making physical boundaries transparent, and thereby expanding the horizons of the user. These interfaces typically include links to allow the user to drill down for more information. HP's Cooltown creates a web presence for people, places, and things to support users as they go about their everyday tasks [11]. IR beacons, RF ID tags, and bar codes identify entities in the environment.

ACTIVECAMPUS SCENARIO

Sarah, a UCSD computer engineering sophomore who transferred from Mesa Community College last quarter, walks out of her morning Engineering 53 lecture, introduction to electrical engineering. This isn't what I signed up for, she's thinking, wondering where was the engineering her Dad had told her about—building things that improved people's lives? Flipping open her PDA, ActiveCampus shows a map of her vicinity, and she sees a link to a talk with "human" in the title (Figure 1, left).[2] Clicking through, she sees there's a talk just starting in the engineering building on the human-machine interface. Curious, she decides to go. Although the talk gets technical quickly, the introduction has shown her a link between people and computer engineering.

Realizing she's hungry, Sarah heads to the Price Center for lunch. Her usual table of friends is probably gone by now. Really wanting to talk to someone about adjusting to UCSD, she checks ActiveCampus (Figure 1, right) and sees that her "buddy" Brad is nearby and active (both location and message icon highlighted in blue), clicks on him and sends him a "Wanna go eat?" with a couple of clicks. Brad notices the "dome" on his PDA flashing,[3] and flips it open to see that Sarah has sent him a message and is nearby. Now both looking for each other, they see each other through the lines of people and sit down to talk about their day.

After lunch, Sarah decides to go to the library to get a head start on her Engineering 53 homework. Later, leaving the library, she notices that the tree outside the library is not dead, as she'd thought—it's made out of metal and talking quietly. That's so weird. Flipping open her PDA, she clicks over to the digital graffiti page of ActiveCampus, since a friend told her there was lots of arts stuff in there (by default graffiti is not shown on the map since it can clutter). There is a list of graffiti that's been "tagged" in the area, including a "living dead tree" link near the top. Clicking on different parts of the tree leads to different parts of an interactive artwork. Clicking on the tree's roots leads to a story about the tree, pointing her to other talking trees on campus, and gives the lowdown on UCSD's Stuart art collection. Now she begins to understand all the weird stuff she'd been seeing on campus! Clicking on the spray can to the left of the graffiti's subject line, she is taken to a page where she "tags" the interactive tree with a "Thanks tree!" note to be seen by others who view the living dead tree via ActiveCampus. Walking off, she thinks, huh, I wonder if there is a role for art in engineering? She'd have to ask Mark about that.

[2] ActiveCampus uses the PDA's report of all sensed 802.11b access points and their relative signal strengths to infer a location [6].

[3] The flashing dome feature has been prototyped but is not yet deployed. ActiveCampus also uses the second line of each page to convey events like a new message arrival.

DISCUSSION

Sarah's day reveals several crucial properties of ActiveCampus. The most notable is that it helps campus denizens see through the unintended barriers created by institutions. Sarah can see that there is a talk starting nearby, even though it was only officially disseminated to the campus via posters in engineering building hallways. Even if she had seen these posters earlier, it would not have been in the context of her frustrating day and probably long forgotten. Seeing a talk with "human" in the title, and in an engineering building, was her cue that this talk might be especially relevant to her. This is a function of mediation—the particulars in the scope of the general establish a context for interpretation.

ActiveCampus has similar benefits at the Price Center food court and library. In the Price Center, the mere concentration of people is the barrier created by the institution, but the context is eating, which implies relatively unstructured time—a friend of hers at the Price Center is probably free to chat. ActiveCampus merely provided the "final mile" solution, timely and contextualized information about her surroundings.

Colleague Interactions. Sarah's use of the buddy and instant messaging features are indicative of ActiveCampus's facilitator role. After helping her notice that her friend Brad was nearby, she used messaging and his displayed location to purposefully find him. One-click messaging short-cuts are available for typical meeting-directed communications, for example, "Are you free?" If many friends were nearby, she could have messaged all nearby or active buddies in one action to speed the process. In this way, Sarah is using ActiveCampus to maintain and even develop her social network in a chaotic context. Sarah could meet new people by modifying her privacy settings from the default "visible to buddies only" to "visible to buddies and others". Her location can be suppressed independently from her on-line status.

Revealing one's location on ActiveCampus could lead to unwanted interactions. Thus, before Sarah could see Mark on her PDA (or vice versa), both she and Mark had to add each other as buddies—a *mutual acceptance policy*. In an ad hoc community, it might be hard to buddy-up spontaneously with such a method. At UCSD Sarah can use Mark's campus e-mail name to add him to her list. She didn't have to ask him for his ActiveCampus ID or exchange contacts with someone else. In fact, UCSD has a "finger" service that maps names to e-mail names.

Digital Graffiti. Sarah used digital graffiti to answer the question "What is this tree?" because there was no official link for the tree. Consequently, she found out not only what the tree was, but what other people thought about it. This is beneficial to Sarah because she is discovering that this is not just a campus of busy, stuffy professors lecturing to quietly listening undergraduates, but a place where people just a bit "ahead" of her are participating in the campus's academic life. Thus, as with discovering the talk, Sarah has—conceptually—seen through the walls of an art studio to see the campus in action. In actually posting her own graffiti, Sarah has taken an important step from being a passive visitor to a campus citizen involved in community discourse.

Not all of digital graffiti's potential is revealed in Sarah's day. Any ActiveCampus entity can be tagged: a static object such as a restaurant (e.g., "Get the ham sandwich, it's great!"), physical location (e.g., someone's favorite sunset locale), transient object (a buddy), or other graffiti. Through artistic expressions, political debates, and the like, graffiti can become a valued record of campus life. For example, a student might learn what others thought about recent concerts held at a campus venue, find links to band web sites, etc., helping people choose amongst opportunities.

Early Experience. Our own use of ActiveCampus has not been unlike that of our character Sarah. The following are a few typical examples of serendipitous interactions assisted by ActiveCampus.

- Ben drops by Bill's office, but he's not there. Ben checks his PDA and sees that Bill is at the cafeteria across the quad. Ben heads over to the cafeteria and joins Bill and Jens for lunch.
- Bill is stuck in a late meeting and sees that Pat is still in his office. A quick message confirms that Pat will still be there in a half hour for a much-needed meeting.
- Bill is late for a meeting, but has to pick up lunch first. The group waiting for him sees that he's in the "line area" at the food court, and concludes that he'll arrive shortly.
- Bob is waiting for Bill to return to his office, while continuing to work in the lab. When Bill shows up on his buddy list as being in "Griswold's at APM", he walks over.
- While at his favorite cafe, Bill sees a graffiti claiming that the croissants are the best on campus, and he makes a note to try one sometime.

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The Location Stack: Multi-sensor Fusion in Action

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ABSTRACT
The Location Stack is a set of design abstractions and sensor fusion techniques for location systems. It employs novel probabilistic techniques such as particle filters to fuse readings from multiple sensor technologies while providing a uniform programming interface to applications. Our implementation is publicly available and supports many location sensor technologies. Specifically, our live demonstration tracks multiple people using statistical sensor fusion of RFID proximity tags and ultrasonic distance measurement badges. Participants are invited to don tracking badges and watch a projected visualization of the real-time probabilistic estimates of all participants' locations.

Keywords
Location sensing, sensor fusion, particle filters

INTRODUCTION
Location is essential information for many ubiquitous computing systems: We want our home to learn and respond to its inhabitants' movements. We want to capture and optimize workflow in a factory. We need directions from one place to another. We want to interact naturally with input-output devices casually encountered in the environment. Yet, to meet these goals, existing location-aware ubicomp systems can be improved in two areas:

1. Solid design abstractions can provide a common vocabulary for comparative evaluation of location systems.
2. Fusing readings from multiple different sensor technologies can exploit the advantages of each technology while presenting a single application programming interface that probabilistically represents location information.

Our contribution is in both of these areas. Based on lessons from a previous survey of location systems [1] we created the Location Stack, a common vocabulary and general framework for multi-sensor location-aware ubiquitous computing. In this demonstration, we highlight our Fusion layer's use of Bayesian filter techniques, more specifically, particle filters and multi-hypothesis tracking to estimate people's locations in real multi-sensor environments. Our implementation supports sensor fusion of many location sensor technologies including infrared proximity badges, passive RFID tags, ultrasonic ranging badges, active radio proximity tags, global positioning system receivers, infrared laser range-finders, 802.11b wireless clients, and, more importantly, any combination of these. Our architecture consists of scalable distributed services communicating with asynchronous XML messages and remote procedure calls, similar to many modern ubiquitous computing systems.

LOCATION STACK ABSTRACTIONS
The Location Stack codifies a set of layered abstractions based on properties identified in a previous survey of location systems [1] and the design experiences of several projects [2]. Figure 1 shows the Location Stack.

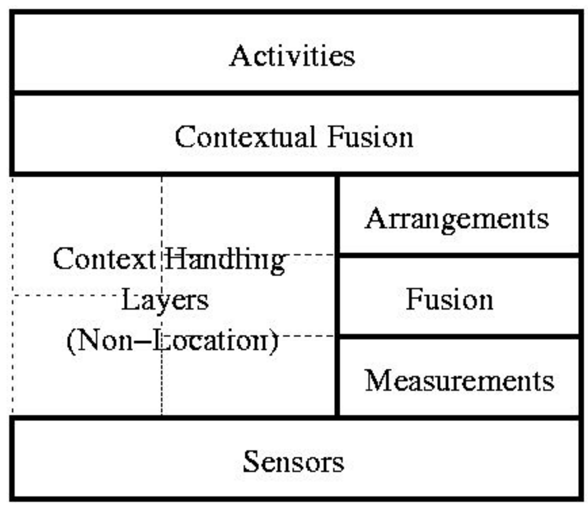

Figure 1: The Location Stack abstractions are a general framework and common vocabulary for location-aware ubiquitous computing systems.

We briefly discuss the layers and the interfaces they provide with particular emphasis on the fusion layer – the thrust of this demonstration.

Sensors
The Sensors layer consists of the sensing hardware for detecting a variety of physical phenomena. Our implementation has drivers for many common location technologies including infrared proximity badges, passive

RFID tags, ultrasonic ranging badges, active radio proximity tags, global positioning system receivers, infrared laser range-finders, and 802.11b wireless clients. Information is pushed up the stack as sensors generate new information about the changing state of the physical world. This demonstration uses passive RFID tags and ultrasonic ranging badges.

Measurements

Each sensor driver discretizes and classifies the data produced into measurements of type Distance, Angle, Proximity, or Position as well as several aggregate types such as Scan (a distance-angle combination). For example, infrared badges and RFID sensors both produce proximity measurements with likelihood models based on the power of the infrared emitters and the range and antenna characteristics of the radio. These measurement likelihood models describe the probability of observing a measurement given a location of the person or object. Such a model consists of two types of information: First, the sensor noise and, second, a map of the environment. The problem of constructing maps of indoor environments receives substantial attention in the robotics research community and is not our focus in this work.

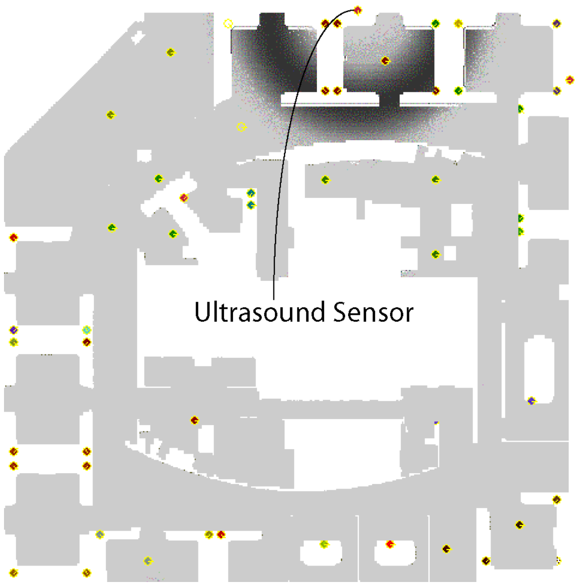

Figure 2: Measurement likelihood model ultrasound tags. Darker areas represent higher likelihood.

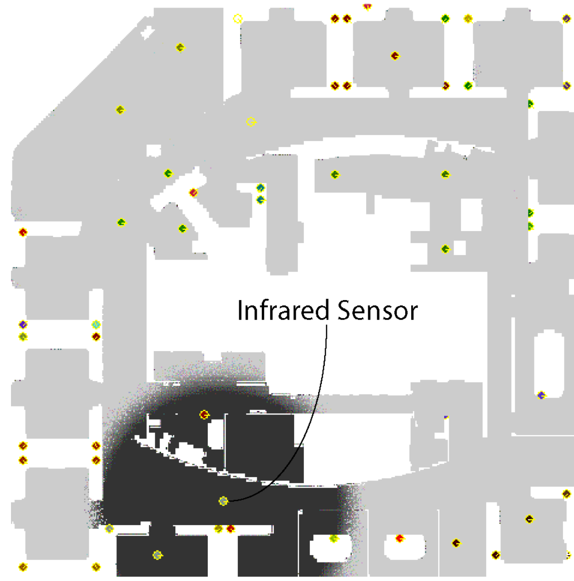

Figure 3: Measurement likelihood model for infrared proximity badges. Darker areas represent higher likelihood.

Figure 2 shows the likelihood model at all locations in our lab for a specific 4.5 meter ultrasound distance measurement. The likelihood function is a ring around the location of the sensor where the width of the ring is the uncertainty in the measured distance. Such noise may be represented by a Gaussian distribution centered at the measured distance. Furthermore, since ultrasound sensors frequently produce measurements that are far from the true distance due to reflections, all locations in the environment have some likelihood, as indicated by the gray areas in the map. White areas are blocked by obstacles. Figure 3 illustrates the sensor model for the infrared badge systems. Infrared sensors provide only proximity information, so likelihood is a circular region around the receiver. RFID tags are also a proximity technology and behave similarly.

Fusion

The Fusion layer continually merges measurements into a probabilistic representation of objects' locations and presents a uniform programming interface to this representation. In this demonstration we illustrate estimating the location of multiple people where each person wears an RFID tags and ultrasonic ranging badge. Due to these sensors' low accuracy (relative to robotics and motion capture sensors like precision scanning laser range finders), the belief over each person's location is typically very uncertain and often multi-modal, hence we apply a Bayesian filter techniques called particle filters which is commonly used in robot localization and is optimized for this type of scenario. Particle filters can naturally integrate information from different sensors. Refer to [3] for a general survey of Bayesian filtering techniques for location estimation or [4] for an in depth treatment of particle filters and Monte Carlo statistical techniques.

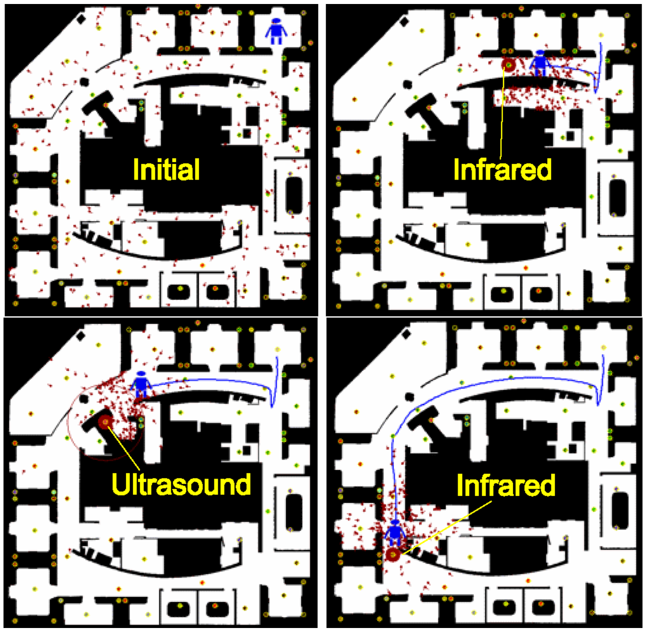

Figure 4: Sensor fusion of infrared and ultrasound sensors. Density of the particles reflects the probability posterior of the person's location.

Figure 4 shows snapshots from a typical sequence projected onto a map of the environment. In this example, the person is wearing an infrared badge and ultrasound tag and starts in the upper right corner as indicated by the icon. Since the start location is unknown to the system, the particles are spread uniformly throughout the free-space of the environment. The second picture (top right) shows the location probability after the person has moved out of the cubicles and into the upper hallway. At this point, the samples are spread over different locations. After an ultrasound sensor detects the person, their location can be estimated more accurately, as shown in the third (bottom left) picture in Figure 4. Later, after moving down the hallway on the left, the samples are spread over a larger area, since this area is only covered by infrared sensors that only provide very coarse location information (bottom right).

A single sensor fusion service running on a modern PC (1.8 GHz Pentium 4 with 512 MB memory) can perform real-time multi-sensor probabilistic tracking of more than 40 objects at a sustainable rate of 2 measurements per second per object. Objects are tracked in 7 dimensions (x, y, z, pitch, roll, yaw, and linear velocity). Higher performance (more objects or a faster measurement rate) can be realized by reducing the state space to two dimensions or through more advanced techniques such as our technique of constraining the particle filters to Voronoi graphs of the environment discussed below. Another way to increase performance is to distribute computation across multiple fusion services, although applying certain Arrangements layer operators then poses additional challenges.

There are two pieces of additional research we have contributed but are not highlighting in this demonstration. First, we have shown how particle filters can be used more efficiently by constraining possible locations of a person to locations on a Voronoi graph of free space that naturally represents typical human motion along the main axes of the environment. In experiments we found that such Voronoi graph tracking results in better estimates with less computation. Furthermore, the Voronoi graph structure can be used to learn high-level motion patterns of a person. For example, the graph can capture information such as "Rebecca goes into room 22 with probability 0.67 when she walks down hallway 9." More details on using Voronoi graphs with particle filters and on applying high-level learning can be found in [5,6]. Second, although also not shown in this demonstration, other work of ours at the Fusion layer has addressed the problem of estimating objects' identities in situations where explicit identity information is not provided by the all the sensors. In particular, we have introduced a technique to combine highly accurate anonymous sensors like scanning infrared laser range finders with less accurate identity-certain location technologies like infrared and ultrasonic badges [7].

Arrangements

We provide two operators to relate the locations of multiple objects. We provide a test for multi-object proximity given a distance and a test for containment with a map region. Because we operate directly on the location probability posteriors of each object, the results of these tests can also be probabilistic. For example the proximity test produces a pairwise confidence matrix that a given group of objects are within 4 meters of one another. Taken together, these operators provide a probabilistic implementation of the "programming with space" metaphor as used with great success in AT&T Sentient Computing project [8]. Future work in our implementation of the Arrangements layer is to provide an additional operator to test for more general geometric formations of multiple objects.

Context and Activities

The Contextual Fusion layer combines location information with other contextual information such as personal data (schedules, email threads, contact lists, task lists), temperature, and light level while the Activities layer categorizes contextual information into semantic states defining an application's interpretation of the world. Our implementation of the Context and Activities layers is in its infancy because few ubiquitous computing systems have been deployed which take sensor information all the way up to the level of human activity inference. To make inroads, we are collaborating with the Assisted Cognition research group, a group seeking to create novel computer systems that will enhance the quality of life of people suffering from Alzheimer disease and similar cognitive disorders [9]. Our goal for this collaboration is to design general interfaces for the Context and Activities layer based on usage patterns of the existing Fusion and Arrangements layers in support of these higher level learning tasks.

SUMMARY

Our demonstration highlights the primary capabilities of our Location Stack implementation: We show a highly flexible system which can track multiple people using statistical sensor fusion of information from multiple sensor technologies, in this case, RFID proximity tags and ultrasonic distance measurement badges.

The Location Stack abstractions structure location systems into a layered architecture with robust separation of concerns allowing us to partition the work and research problems appropriately. Our implementation is a publicly available Java package containing a complete framework for operating a multi-sensor location system in a ubiquitous computing environment. The implementation is typical of a modern ubiquitous computing system: a set of reliable distributed services communicating using asynchronous XML messages and linked using dynamic service discovery capability in the middleware. The Location Stack is deployed in our laboratory and workspace at Intel Research Seattle, operates nearly 24x7, and is used by other research projects as a reliable source of location information.

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A Novel Interaction Style for Handheld Devices

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ABSTRACT

Handheld devices are not as usable as they could be. The multitude of attempted solutions to the text input problem for mobile devices addresses such usability issues. Our novel approach to the handheld interaction problem makes use of animated transparencies and mouse-gesture optimized menu interaction. Our research explores techniques to create interface tools that permit the liberal and intensive population of a display with adequately sized controls, without compromise to the visibility of the underlying user interface. Additionally we strive to realize highly functional control elements that support manual interaction, even for hand held displays.

Keywords

Handheld, PDA, Mouse stroke, and Transparency.

INTRODUCTION

This paper addresses problems associated with handheld device interaction. It proposes the application of control elements composed of integrated superimposed animated graphical layering [1,3,8,15] or, more specifically, image multiplexing or visual overloading [7] combined with mouse gesture interaction [10,13] similar to marking menus.

The paper then goes on to identify the individual features and difficulties of the PDA interaction problem [9,12]. To demonstrate the benefit of our approach we have implemented a mobile phone interface that involves the application of visual overloading, standard gesture interaction and an approach of gesture optimized list interaction [10]. This application is used throughout the paper to provide supporting examples of our approach.

Constraints of Handheld Interaction

All proposed solutions to the handheld interaction problem fail to acknowledge the constraints of portability and compactness, ease and convenience of interaction and the deft conservation of screen real estate. This is perhaps further confounded due to the lack of a suitable solution, giving rise to multiple versions of essentially the same approaches, varying only in the design compromises made, such as proposing the use of larger control elements at the expense of screen real-estate. Consider the following influences on interface design for small handheld devices.

An important factor in the design of user interfaces for small devices is ease of use. In order to free up as much screen display as possible, input dialogues are reduced in size. To minimize the display area used, designers resort to using menus. Seldom used commands inevitably feature in hierarchical submenus, leading to an awkward, slow, and cumbersome interaction style [9]. Unnecessary interaction aids can be an obstacle to the user. Pointers (e.g., styli), clip on keyboards, and data gloves, impede device usability. To interact with the device the user must either don the interaction accessory or, say, pick up a stylus, which in the case of many portable devices, means that both hands are needed [5]. A number of approaches also incur a learning and skill acquisition overhead. Many small device interface mechanisms, such as optimized soft keyboards for text input, are not easy to learn to use [12]. The use of 2D alphanumeric gestures is another such example with a significant learning overhead [13].

Consideration of the contributing factors in the design of interaction models for handheld and mobile devices leads to the following design requirements:

- We should not rely on additional interaction aids, e.g. styli, as these are detrimental to the portability and ergonomic effectiveness of the device.
- A suitable balance between redundancy in input device features and availability of display area should be sought.
- The device should reflect an effective trade-off between display area, size of elements in the input panel, and usability.
- Interface skills should be easily learned [12].

IMAGE MULTIPLEXING WITH GESTURE INTERACTION

In view of the above requirements, we now introduce our interaction model for small devices. Transparency is commonly used to optimize screen area, which can often be consumed by menus or status dialogues. [2,6,9]**.** The conventional approach of using a layer of transparency to display a menu is done at the cost of obscuring whatever is in the background. This is not the image multiplexing effect we are after, but rather a compromise between two images competing for limited display area. Overloading, or image multiplexing, is the application of techniques such as dynamic signatures and animation [1,3,7,8,15] to permit the layering of multiple transparent images, whilst reducing the effects of visual rivalry between these competing layers, a sort of “intensive farming” of screen real estate rather than a compromise between background and foreground images.

The incorporation of simple gestures or mouse strokes [10,13] is an elegant solution offering the additional context required beyond that of the restricted point & click approach. This permits a larger population of control elements with a greater redundancy of related commands without compromise to their size, thus facilitating manual interaction. By using a mouse, pen, or touchpad, the user simply draws a 2D symbol to execute an action; we will refer to this as stroke or gesture interaction. However, gestural input is partly a consequence of implementing visual overloading, since it is necessary to resolve issues of layer interaction. To avoid the overhead of manipulating layers, such as moving them about, to address, for example, elements or widgets, which are beneath a layer, gestural interaction is used to provide the necessary context.

IMPLEMENTATION

Our implementation takes the form of a mock up of a mobile phone interface with a standard menu or list driven interface on a 12x5cm display. This approach was taken to assist in rapid prototyping and to avoid any difficulties with device specific limitations. We chose to use simple animated black and white transparent gifs. This we did to show that processor intensive alpha blending was not essential and adequate results could be achieved with simple well chosen animations.

Overview

Commands can be executed with either the standard "point & click" approach or the user can circumvent intrusive hierarchical menu interaction by drawing a symbol that starts over the relevant list item or button, which takes the user directly to the required dialogue or executes the desired command. Note that a stroke is not restricted in size.

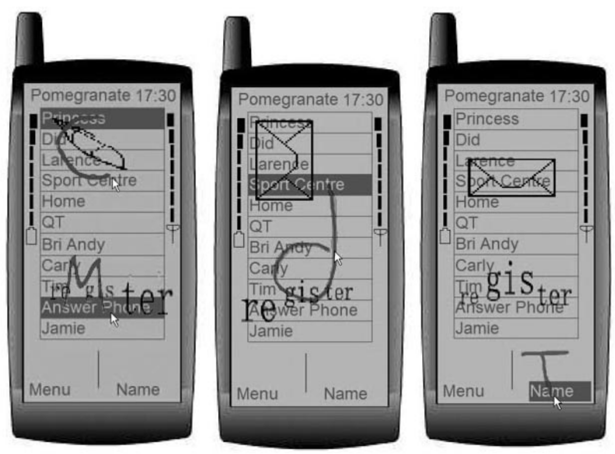

Figure 1. The initial screen contains a list of frequently dialed numbers and two animated overloaded controls. The darker traces show the execution of a stroke.

In addition, two overloaded control elements, depicted in Figure 1 are superimposed over the menu items, one of an envelope to access messaging functions and the others of the word 'register', to access the call register, which demonstrates the overloading of text.

We now discuss the interface components and consider some interaction scenarios to help explain the use and benefits of this interface design.

Gesture Activated Buttons and List Elements

In Figure 2 we see the use of the gesture activated "Name" button to search for a given phone number. By drawing a 'T' over it (left) the interface lists all telephone number entries that begin with the letter 'T' and by drawing a 'P' (middle) the list is further optimized to all elements that begin with the letter 'T' and contain the letter 'P'. This approach drastically cuts down on executions for selecting an entry, whilst possessing a greater cognitive salience.

Figure 2. A gesture activated 'Name' Button is used to make a search for a telephone number.

To further optimize the interface, drawing a symbol or tapping on the left of the list executes a command; such as a double-click to call a number or drawing a 'd' to access the 'list details' dialogue. Whereas, a symbol drawn on the right side of the list will further refine the search to any remaining items that contain the desired letter.

Redundancy of Interaction Styles

This form of interaction model is not restricted to gestural interaction alone, it can be used in the same way as a conventional mobile phone or by using the gesture optimizations. This allows the user to learn these gesture optimizations as they become familiar, thus avoiding any significant learning overhead. To access a list element the user can either tap over it or gesture over it. For example as depicted in Figure 1 (middle), the user can simply draw a 'd' starting over the list element, to go straight to the desired 'list details' dialogue, in this case from the item marked 'sport centre', or looking at the list of frequently called numbers (Figure 1), to access the details of a telephone number the user can click on the menu button and navigate a series of submenus to access the 'get details' option. Similarly, in the example from figure 2 the user can dispense with the gesture interaction and use a series of hierarchical menus by simply tapping on the option button and accessing a number in the conventional fashion.

A necessary example is that of dialing a number (see Figure 3), the use of gestures would be a less than adequate means of carrying out this task, so the approach resorts to a more conventional one where necessary.

Figure 3. How a number can be dialed. The appropriate gesture is executed over the 'Menu' button to access a dialogue to dial a number.

To dial a number the user either clicks on the 'Menu' button enabling him to access a hierarchical menu, containing an option to 'Dial a number' (as in conventional interfaces), or the user executes the appropriate gesture, an (upward line), over the menu button, to go directly a conventional dialogue more suited to the desired task. This approach demonstrates the practical integration of the two models of interaction.

Overloaded Icons

The initial screen has two overloaded icons (figure 1). As expected, executing the appropriate gesture over a list item will execute a command. However, if the gesture starts within a region of an overloaded control and the gesture relates to that overloaded control element the appropriate command is executed, thus disambiguating between competing overloaded controls and menu items.

For example, drawing an 'M' stroke over the 'register' overloaded icon, demonstrated in figure 1 (left), accesses the 'Missed calls' dialogue, whereas executing an 'r' accesses the 'Received calls' dialogue.

Text Input

Figure 4. A text input dialogue that embodies the same approach for the overloaded text input panel as used for the 'Register' overloaded icon (Figure 1).

Referring back to Figure1 (top left) drawing a 'C' for "compose" over the animated envelope would open a text input dialogue (Figure 4), whereas an 'I' or 'O' would invoke the 'Inbox' and 'Outbox', respectively. The text input or "Compose" dialogue makes use of an overloaded text input panel.

A letter is selected by starting a simple gradient gesture over a group of letters, as shown in Figure 4 (Middle, Left). The direction of the line determines the letter selected. In this example the 'L' has been selected, whereas an upward stroke would select 'K' and a left up stroke would select the letter 'J'.

The approach to text input enables the user to enter text easily without a complex combination of keystrokes via an adequately sized soft keyboard.

With respect to the design requirements discussed earlier, the benefits of our proposed design of a mobile phone interface can be summarised as follows:

- Practical one handed manual touch screen interaction
- Maintain adequately sized control elements
- The optimization of limited screen real-estate
- Avoid the use of memory intensive hierarchical menu.
- Reduction in the cognitive overhead of a visual search schema, e.g., scanning for a list element
- A greater cognitive purchase afforded by the gesture interaction
- Greater redundancy in the functionality of controls.
- More efficient number look-up e.g., the selection of a phone number within 1-3 gesture executions, rather than 3-8+ button presses.
- The incorporation of standard point & click with the overloaded gesture interaction exploits a redundancy of interaction styles, thus optimizing learnability.

PRELIMINARY EVALUATION

Ten subjects used our interface design to carry out a range of tasks such as those discussed above. The tasks were first carried out in the conventional way (through hierarchical menus), and then by the stroke-optimized route. After spending a short time learning to use the interface, the users readily completed the tasks unaided, and expressed a preference for the gesture optimized shortcuts and overloaded icons over conventional interaction styles.

The subjects reported they did not favor devices that relied on additional interaction aids, such as a stylus, and preferred our model, which supports manual operation. Subjects also commented that our interface is less awkward to use than systems without gesture interaction.

Moreover, we discovered that, with appropriate training, a user can input a text message, without using a stylus, at rates comparable to that of standard single finger soft keyboards (i.e., around 40wpm). This is achieved without the cumbersome interaction associated with common mobile devices. This represents a significant improvement over conventional text input for handheld devices with small display screens.

It has to be said that there is a slight overhead in learning the appropriate gesture, although a user could always resort to the conventional form of interaction if difficulties were encountered. Users commented they found the gesture approach to be both novel and useful and many reported they felt motivated to learn the necessary gestures. We intend to reduce the learning overhead by using the more familiar ‘Graffiti’ handwriting recognition alphabet found in many handheld devices.

CONCLUSION

This paper has proposed a solution to the problems and shortcomings of existing text input schemes, particularly for small devices. A prototype system, making use of gestures and visual overloading, was also described. It was demonstrated that this prototype makes effective use of screen area, and preserves the portability of the device, while providing a rich set of easily accessible features.

Our current work involves investigating the application of our techniques to support interaction for large screen devices such as Databoards, for public information displays, the desktop and for very small, e.g., wearable, devices [12]. We are exploring the effectiveness of visual overloading itself, and seeking to improve touch screen interaction, among other things. We also intend to explore the use of our techniques in a predictive text application.

FURTHER RESEARCH

In continuation of our work we intend to explore ways of providing better affordance, since poor affordance can be a major drawback of gesture interaction. We will explore the use of visually overloaded help-prompts to provide for goal navigation and goal exploration, such as gestures being used to call up an overloaded layer of commands related to a control.

We are currently designing experiments to support our theory that gesture interaction and animated icons are suitable for creating highly usable small devices and to examine the acceptability of animated transparencies with respect to distractibility.

Finally, we recognize that our future research will benefit from an investigation into theories of perception. Such work may help us to minimize, and govern the effects of, visual rivalry, perhaps by introducing 3D elements and dynamic shading and elements [4,14].

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WiFisense™: The Wearable Wireless Network Detector

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ABSTRACT
WiFisense is a wearable scanner for 802.11 wireless networks (WiFi) embedded in a handbag. Using emerging technology, in an everyday functional object, we create a device that helps people discover and qualify the wireless networks through which they pass.

Keywords
Wireless networking, WiFi/802.11, wearable computing, ubiquitous computing, network detector

INTRODUCTION
Wireless networks have recently arrived in many cities. Their bottom-up spread, while somewhat unexpected, is steadily expanding the Internet's communication territory. Multiple wireless beams radiating out of the wired backbone in homes and business offices are extending our connectivity to public spaces of the city such as streets, parks, cafeterias and plazas.

On a daily walk through a city we unknowingly pass through many wireless networks that exist in both public and private spaces. Intentionally or not, some of these networks are open and unencrypted. They are a useful resource for anyone with a mobile lifestyle and wireless connectivity.

CONTEXT
An early inspiration was to explore the border between the tangible and intangible in our perception of space. The idea that we are passing through electromagnetic, radio, WiFi waves, which are out there but invisible, triggers a lot of imagination about how it would be best to sense them and then portray them.

There have been projects in the past that attempted to look at network activity in a physical manner. Natalie Jeremijenko's Dangling String, a piece of plastic string attached to a motor that vibrates based on the amount of Ethernet activity, was an effort to visualize intangible data in a calm non-invasive manner [1].

Recent work on ambient displays [2] has demonstrated that they are successful as interfaces to more indirect, less intrusive communication. WiFisense extends that concept and uses the increasing pervasiveness of wireless networks as an ambient display in a mobile setting.

Anthony Dunne and Fiona Raby, in their project *Fields and Thresholds*, explore creating a sense of another space versus explicit representation [3]. One of their foci is on the merging of the physical body of objects with an appropriate technical behavior; design of objects to present their technological affordances in a proper physical form [4].

WiFisense addresses both sensing the intangible as well as integrating technology into everyday objects. It aims at a practical solution to the problem of detecting the increasing coverage of wireless networks in our lives. There is interest in the awareness of a network's presence not for the mere sake of awareness but for the desire to use it.

The practical need for discovering WiFi radio waves has existed since the very emergence of this standard in the late 1990s. From 2000 to 2002 the practice of warchalking [5] became popular as an underground movement for detection of wireless networks on a street level. WiFi hackers pervaded the streets, equipped with network scanning software on their laptops and chalk in their hands, marking signs denoting the availability of WiFi access points, their SSIDs, signal strength and whether they are public or private. Later, with the increasing popularity of WiFi and a proliferation of access points over larger areas, the movement evolved to the practice of wardriving in which a person drives a car through the city and uses software to detect the hot spots.

The impracticality of our current methods of network detection - walking with open laptops, driving with computer equipment in cars, searching for cryptic sidewalk drawings - combined with the daily need to stay connected while moving about demands that this process be less intrusive and more integrated into our actions.

Several computer equipment manufacturers [6, 7] have realized the need for WiFi detectors and are producing equipment towards that end. However, these new devices demand that you carry yet another object in your already crowded pockets and handbags. WiFisense differs in that it seeks to integrate the needed technology into the objects that are already a part of our everyday lives.

EXPOSITION
The first iteration of WiFisense is a handbag - a functional object that is easily carried through any space you wish to explore for connectivity. WiFisense currently gives most advantage to people with a laptop due to the fact that they can use the information it provides to get on the net. However, the device can be embedded in other objects such as keychains, belts, jackets, etc and we imagine the physical shape of WiFisense evolving with people's needs.

The actual Mylar design of the prototype was on some level a statement that technology can also be fashionable. We could make raw designs with loose cables, screws and bolts, but such obvious circuitry might intimidate rather than attract. The intent is to augment a useful object with relevant embedded technology, which also goes along with a fashion image. Creating various designs might make WiFisense appealing to more people.

Experimenting with light as a gentle means of communication, the bag uses LEDs for the physical display of information. When WiFisense does not see a wireless network, the LEDs look like simple beads. When a network is discovered the LEDs light up in patterns displaying the number of networks at a certain physical location and their corresponding signal strength. Attempting to capture one's attention only when the device finds relevant information, lights from the bag color the environment as a means of ambient feedback.

PROCESS

WiFisense scans for the presence of 802.11b networks. When it discovers a network, it uses the signal strength and encryption status to create patterns of light announcing the network's availability, quality and accessibility.

WiFisense goes beyond the currently marketed 2.4Ghz detectors [6, 7]. It uses an embedded controller and an 802.11 wireless card to implement its functionality. In a passive manner it scans for the presence of 802.11 management frames broadcast by all access points. The presence of these frames and the information that lies within them informs the device of an existing wireless node and its various features. Characteristics such as signal strength and sometimes the encryption status are available within these frames.

The controller uses eight rows of eight LEDs to announce a network's features with each row representing a single network . The strength of the signal is mapped to eight LEDs – the higher the signal strength, the more LEDs that light up. The LEDs flicker due to fluctuating signal strength – based on the proximity to the base station, the position in space relative to it, other activity on the same access point, and the building materials of the space.

The bag can display up to 8 networks at a time, creating a beautiful collage of multiple networks with various strengths overlapping in space.

RESULTS & FUTURE WORK

Seeing us wear the WiFisense bag in the streets of New York City, people have started conversations, amazed to find out that there is such a thing as wireless Internet access. A potential implication of this is that WiFisense can be successful as a means to increasing public awareness for this new technology.

However, we have already thought about what it means for possible subsequent functionality such as moving away from the passive act of scanning to joining and actively communicating on available networks.

Lastly, we are currently exploring various physical forms for future iterations of WiFisense.

CONCLUSION

WiFi is still an emerging standard for wireless Internet communication. By broadcasting information about the networks found, in the form of dynamic light patterns, we intend to increase public awareness for this new technology.

WiFisense explores the boundaries between the tangible and perceptible world and the rest that surrounds us – the intangible yet present. It turns a person's movement through space into a display of the unseen yet increasingly ubiquitous world of connectivity.

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Tejp: Ubiquitous Computing as Expressive Means of Personalising Public Space

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ABSTRACT
We present the project Tejp, which aims at exploring the potential of ubiquitous computing as an expressive means of personalising public space. The project consists of a series of experiments in which users deploy open low-tech prototypes in urban settings to create layers of personal information and meaning in public space through the parasiting of physical environments. Focusing the experiments on the aspect of physical interaction, we observe how emerging information content and user behaviours are influenced by the characteristics of the prototypes. This will result in design implications that will allow for a heightened degree of poetry and personal expression in ubiquitous computing.

Keywords
expressive ubiquitous computing, personalisation of public space, parasiting of physical environment, détournement

INTRODUCTION
How can people create their own ubiquitous computing infrastructures to deploy in the everyday environment, in order to make it more personal, meaningful and expressive? The project *Tejp* addresses this question by experimenting with technology-enabled layering of personal, location-based information on public space, enabling people to overlay as well as uncover personal meaning in their physical environment.

The project is a testing platform geared towards providing opportunity for open customisation and creation of ubicomp environments invested with personal meaning. It focuses on exploring the actual physical interaction between the users and the information space. Attention is also directed on the resulting content given to a physical place through this interaction. Avoiding imposing formulated content or fixed interaction procedures, we aim at allowing personal aesthetics, possible strangeness and poetry to emerge.

In order to achieve this, we develop a series of various low-tech prototypes to deploy in urban environments simply to see what will naturally occur. These prototypes are not meant to become end-products, instead we use them as concept illustrators and props for experimenting with people in real-life settings, in order to observe emerging content, behaviour, narratives and meaning.

More specifically, these prototypes allow us to explore how their characteristics and physical attributes influence the way people appropriate and personalise space through interacting with them. As a result, each of the prototypes consists of different combinations of media, structure and level of abstraction, while deliberately remaining straightforward and open.

PRELIMINARY STUDY
At the start of the project, we performed a preliminary study of urban visual cultures and interviews of public artists in order to gain insight into the aesthetics, the values and the acceptance of current alternative forms of communication and personalisation of public space, such as stickering and recent forms of graffiti. The study revealed current tendencies towards the discrete use of context and ephemeral situations into the pieces, an approach that is more widely accepted by the general public than other more classic forms of graffiti. This prompted us toward the importance of physically incorporating the information space to its local context and led us to basing parts of the design of the prototypes on the idea of *pararisiting* physical environments.

The concept of "parasitic media" introduced by Johnson [5] is further developped and refined by Martin [6] as "adding functionality to a pre-existing system (…) [and making] use of only that which you create which in turn remains invisible" and stays "within the system margin of error." Whereas parasitic media mainly focuses on mainstream media and corporate network systems, our approach to parasiting occurs on the level of the physical environment, where the prototypes re-use existing elements of physical environments or situations in public space as an intrinsic part of their functionality, while still maintaining a discrete presence.

We were also inspired by Situationist ideas of intervention in everyday life, in particular that of *détournement*, defined as "deflection, diversion, misappropriation, hijacking, or otherwise turning aside from the normal course or purpose" [1], which is usually used as a critique of the information content pervading public space in many examples we encountered during our study.

PROTOTYPES

We describe *Audio Tags* and *Glitch* as first examples of the types of prototypes we develop and experiment with in this project.

Audio Tags

Audio tags illustrate the notion of *overlaying* personal traces on public space. An audio tag contains an audio message that once recorded can be left at hidden places in public spaces. When passers-by lean towards the device, this personal message is whispered to their ears. People then have the possibility to record over the existing messages with their own.

The prototypes are made from hacked low-cost gadgets and are about a few cm^3 big. They consist of a small microphone through which an up to 10 seconds long audio message can be recorded onto a small sample buffer while holding a button, and a small speaker that reveals the content of the message when an IR sensor senses the proximity of a person (Fig. 1). After recording their message, people can attach the tags to walls or other structures in public space.

Virtual annotations of space have been explored by several projects, such as GeoNotes [3] in which location-specific text annotations on public space authoured by the users themselves are browsed through with PDAs. In its approach to augmening public space with location-based audio, the Audio Tag experiment is also related to projects like Augment-able Reality [7] in which virtual voice notes and photographs are accessible through an augmented reality wearable system, and Hear&There [8] where personal audio imprints are virtually linked to physical locations.

In the case of Audio Tags, we were interested in exploring physical rather than virtual interaction with the audio space in order for people not to need any particular device to access the information and for the audio to be better integrated in the public space. The Voice Boxes [4] that record personal audio message when opened are in this way similar to our experiment. However, while users of the Voices Boxes trigger the messages by manipulating the devices, the Audio Tag messages are triggered by physical proximity, in a implicit way. By being fixed on physical structures in the environment as parasites and by only making themselves discretly heard within a certain radius, as when whispering to someone, the tags open a space of intimacy inside the public realm. This proximity triggering combined with the small size of the tags that makes them almost disappear into the environment, helps ensure a serendipitous discovery.

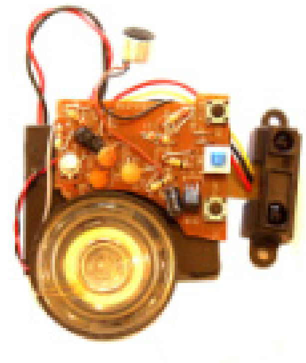

Figure 1: Audio tags: adding a layer of personal audio on physical structures

Glitch

As opposed to overlaying information, Glitch is about *revealing* a hidden layer of personal communication in public space. Interferences caused by passers-by's messages and phone calls, are loudly broadcasted at a public place with high traffic potential, such as bus stops or busy street corners. If the speaker array is f. ex. linearly disposed along a usual pedestrian path, the glitches stalk the mobile user during the whole phase of mobile communication initiation (Fig. 2).

The Glitch prototypes are arrays of powered-on loudspeakers picking up electromagnetic interferences from mobile phones. Some of them use a standard antenna and can be installed in a grid formation, while others parasite off existing metallic urban structures such as fences or trash cans in the city, re-using them as antennas in parasitic way.

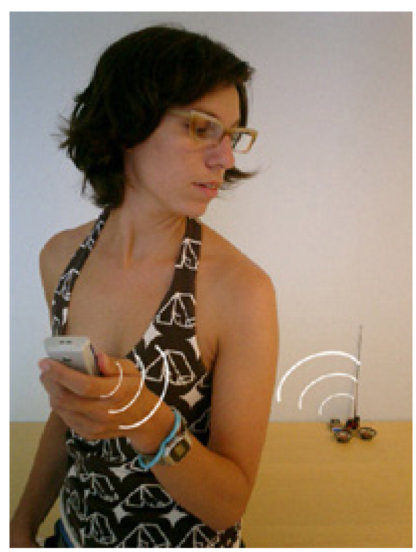

Figure 2: Glitch: revealing a layer of meaning by re-situating familiar phenomenas into unusual settings.

Earlier projects such as Live Wire [9] and Placebo [2] also make otherwise hidden communication networks visible in a way integrated into everyday contexts, respectively with wires dangling to the amount of activity in a computer network, and furnitures reacting to electromagnetic fields produced by mobile phones or other leaking electronic objects. A more recent example of this is WiFisense [10], a handbag covered with light diodes that light up when detecting wireless networks.

Glitch, on the other hand, follows the situationsist tactic of *détournement* [1], by re-situating the familiar auditory phenomena of speakers picking-up incoming calls or text messages before the mobile phone does, usually taking place at homes or offices, into the unexpected setting of outdoor urban environments. As the nature and origin of the noises are familiar to most people and easily identifiable, the speakers remain hidden, a situation of interruption is created, highlighting the virtual and pervasive layer of mobile phones communication. Moreover, Glitch differs from the previously named projects by its parasitic nature.

OUTCOME

Our hope is that through the accidental collaboration of various actors in the public realm, the project will result in physical networks of meaning, aesthetics and perhaps a critique of the everyday environment. The Tejp prototypes are tested on site through specifically crafted tactics and placement. Testing procedures and experiments range from outdoors workshops, to stake-outs and video-based analysis. Once having experimented with users in real urban settings, we will derive informed design implications based upon reoccurring patterns of people's (mis)use of the prototypes and emerging narratives, both from the perspective of active and accidental participants within the project. This implies observing changing content, placement, modes of initiation and interaction behaviours. Based on these design implications, we will be able to draw conclusions for and about expressive ubiquitous computing environments.

CONCLUSION

We have presented the project Tejp, which is a step towards a more poetic, strange, and personal expression in ubiquitous computing. Tejp explores how to empower people with open pervasive means of structuring and personalising their everyday environment through overlaying and uncovering meaning on public, physical space. Besides the two examples we have described, we will be experimenting with a series of other low-tech prototypes, resulting in informed design implications for this field.

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Telemurals: Catalytic Connections for Remote Spaces

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ABSTRACT

Mediated communication between remote social spaces is a relatively new concept. An example of this interaction is video conferencing among people within the same organization. Large-scale video conferencing walls are appearing in public or semi-public areas such as workplace lobbies and kitchens. These connections provide a link via audio and/or video to another space within the organization. When placed in these spaces, they are often designed for casual encounters among people within that community. Thus far, communicating via these systems has not met expectations. We explore a different approach to linking spaces and creating interaction through what we call social catalysts.

Keywords

Social interaction, mediated communication, mediated spaces, telepresence, remote connections

INTRODUCTION

In this work, we are creating an audio-video communication link between remote spaces for sociable and casual interaction. Some drawbacks to current systems that have been studied include lack of privacy, gaze ambiguity, spatial incongruity, and fear of appearing too social in a work environment [7]. We believe that many of these problems stem from designing interfaces that directly map to face-to-face interaction. A window of straight video appears distancing and over time, mundane. Audio-video connections between spaces should be designed as an alternate form of communication that is possible over a distance.

With this work, we are diverging from the approaches of current audio-video connections and focusing on encouraging social interaction by designing a series of social catalysts. We are not creating a substitute for face-to-face interaction, but rather new modes of conversational and physical interaction within the spaces.

SOCIAL CATALYSTS

The main idea of the social catalyst is to initiate and create mutual involvement for people to engage in conversation. For example, in a public space, it is not customary to initiate conversation with random strangers. However, there are events that act as catalysts and connect people who would not otherwise be communicating with each other.

Such a catalyst may be an experience, a common object like a sculpture or map, or a dramatic event such as a street performer. Sociologist William Whyte terms this phenomena triangulation: "A sign of a great place is triangulation. This is the process by which some external stimulus provides a linkage between people and prompts strangers to talk to each other as if they were not." [10]

Our hypothesis is that the creation of a social catalyst as an integral part of the social environment will aid mediated communication between spaces by providing a spark to initiate conversation and the interest to sustain it.

The social catalysts of our installation extend Whyte's triangulation principle into the display and interface of the connected space. The form of our catalyst is abstract. It alters the space and communicative cues between the two spaces. One such catalyst is a connection where current conversation of the users appears as graffiti in the environment. This allows the occupants to see they are affecting the space and might encourage them to alter it. While the possibilities are infinite, the challenge is determining which agents on the interface are effective as social catalysts and why.

In our linking of two spaces with the *Telemurals* installation, we are augmenting the appearance of the familiar audio-video wall interface with stimuli that are initiated at either end of the connection. The wall is intended to be not only a display, but an event in itself; the system becomes both medium and catalyst.

This work further emphasizes the design of the interface as a complement to the space. We want the communication link and display to blend into the physicality and aesthetic of the space and to make the interactions sociable and intuitive.

TELEMURALS

Telemurals is an audio-video connection that abstractly blends two remote spaces. The initial setup is straightforward. Two disjoint spaces are connected through an audio-video wall. Video and audio from each space is captured. The two images are then rendered, blended together, and projected onto the wall of their respective space. The difference between *Telemurals* and traditional media space connections are the image and audio transformations that evolve as people communicate through the system and the blending of the participating spaces.

Duplex audio is transmitted between the two locations. To provide feedback and comic relief, the audio is passed to a speech recognition algorithm. The algorithm returns text of the closest matching words in its dictionary. This text is then rendered on the shared wall of the two spaces. The goal here is to make it clear that the users' words are affecting the space without necessarily requiring 100% accuracy of the speech recognition system.

A current implementation of *Telemurals* is shown in Figure 1. Silhouettes of the participants in the local space are rendered in orange. The participants at the remote end are rendered in red. When they overlap, that region becomes yellow. The aim of this cartoon-like rendering is to transmit certain cues such as number of participants and activity level without initially revealing the identity of the participants.

Participation is required for this communication space to work. To reinforce a sense of involvement, we provide the system with some intelligence to modify its space according to certain movements and speech patterns. That is, the more conversation and movement between the two spaces, the more image detail will be revealed to the participants at each end. The silhouettes slightly fade to become more photo-realistic. This prompts the participants to move closer into the space to see. If conversation stops, the images fade back to their silhouette rendering. We want the participants to choose their own level of commitment in this shared space [6]. The more effort they exert, the more they see of both spaces.

Much thought has been given to the design of the renderings in *Telemurals*. We wanted to maintain the benefits of video in their simplest form. Adding video to a communication channel improves the capacity for showing understanding, attention, forecasting responses, and expressing attitudes [5]. A simple nodding of the head can express agreement or disagreement in a conversation. Gestures can convey concepts that aren't easily expressed in words; they can express non-rational emotions, non-verbal experiences.

Yet these cues are not always properly transmitted. There may be dropped frames, audio glitches. Lack of synchronicity between image and audio can influence perceptions and trust of the speaker at the other end. Other challenges include equipment placement. For example, camera placement has long been a reason of ambiguous eye gaze in audio-video links. A large camera offset gives the impression that the person you are speaking to is constantly looking elsewhere.

Figure 1: Current *Telemurals* implementation.

Figure 2: *Telemural* installation in Sidney-Pacific Dorm.

With *Telemurals*, we are creating an environment where rendered video maintains subtle cues of expression such as posture and hand motion, yet also enhances other cues. For example, changes in volume alter the style of the rendered video. By adding another layer of abstraction into the video stream, we can enhance cues in a manner that is not possible in straight video streams.

In this project, the abstraction of person, the blending of participants, the graffiti conversation, and the fading from abstract to photo-realistic are the social catalysts for the experience. This new wall created by filtering creates an icebreaker, a common ground for interaction, and an object for experimentation. How will one communicate in this abstracted space? How will their behavior affect their appearance and the appearance of the setting? How different is communication using photorealistic vs. non-photorealistic video? The goal here is to create new styles of movement and speech interaction by providing a common language across the two spaces.

Telemurals currently connects two common area halls of MIT graduate dormitories, Ashdown and Sidney-Pacific. The *Telemural* in Ashdown is located to the right of the main lobby. In Sidney-Pacific, the *Telemural* is placed in a high traffic cross-way connecting the gym, the laundry room, and the elevators (see Figure 2). This connection came about as the under-construction Sidney-Pacific Dormitory committee was looking to put public art in its public areas and create spaces to encourage students to gather. Ashdown, the oldest graduate dormitory on campus, was similarly undergoing renovations to create public spaces for social gatherings, and the two dormitories were open to the idea of creating a shared communication link. The sites within the dorms were chosen because they have traffic, are public to the community, and because a large video wall aesthetically blends into the space.

EVALUATION

This work combines the disciplines of technology, design, and communication. Evaluation of this work is therefore threefold.

Engineering

We evaluate if the system functions. Does it work? That is, does it transmit audio and video? Is the sound quality acceptable? Is the video quality and speed acceptable? Are the interface and networks reliable?

Design

This is in the form of a studio critique. Professors from various architecture and design departments and research scientists have been invited and have volunteered to participate in a series of critiques.

Ethnography

The field for this observation study is the semi-public space within the two chosen dormitories. The participants are graduate students who live in the respective dormitory and their friends. We are primarily interested in seeing, (1) how people use *Telemurals*, (2) if the catalysts attract them, and (3) how we can improve the system.

DISCUSSION

As an engineering project, *Telemurals* works. It runs on the school network and typically uses less than1MB of bandwidth with audio latency varying from 500ms to 1 second depending on network usage. The networking audio and image libraries are all written in C over UDP, and we use the Intel *OpenCV* library for image segmentation.

The video was reliable, the audio had acceptable lag, and the system ran continuously for over two months. The one technical challenge that could use improvement is the audio. Using just one microphone does not cover the intended space and the acoustics of each space play a huge role. We are experimenting with microphone arrays and with physical objects that one interacts with that contain the microphone.

Telemurals was evolving throughout its construction and connected installation period. We experimented with several different renderings of people at each end, we changed the fading algorithm, changed the hours of operation, and changed the *Telemural* wall site at Sidney Pacific. These changes were made according to suggestions and critiques throughout a five month period.

The *Telemurals* observation took place in May and June of 2003. Initially, *Telemurals* ran for two hours each Wednesday and Sunday night in conjunction with a coffee hour/ study break. Signage was placed in the entry ways of both spaces to describe what is being transmitted and the privacy concerns of the project.

We had requests from both spaces to increase the hours of the connection. *Telemurals* then ran every night for two hours and then ran continuously twenty-four hours a day.

We performed three different types of observations.

- Observation while immersed in the environment
- Observation from mounted camera video
- Observation from abstract blended video

The footage from these tapes was used to annotate patterns of use for this study and were then discarded. Initially, we were interested in observing:

- How long people speak using *Telemurals*
- The number of people using the system at any one time
- The number of people present but not interacting
- The number of unique users (if possible)
- The number of repeat users (if possible)
- The number of times and the duration that people use *Telemurals* in one space only
- Repeated patterns of interaction: gestures, kicks, jumps, screams

These are factors that we believe are indicative of levels of interaction. However, one must always be open to the unexpected and attempt to find other underlying patterns as well in studying the social catalysts.

Privacy

When running such a project and study, it would be irresponsible to ignore privacy concerns. The audio and video transmitted in the *Telemurals* interface is not saved or stored in any way. We hope to mitigate this problem with proper signage.

Summary

Overall time-schedule, social events, signage, trust, site selection, and a changing environment proved to influence population mass at the *Telemural* sites. The motion of people, the ambient noise, and the graffiti stemming from your own words and those of your remote companions, kept people at the site.

We discovered we had a larger population of use when *Telemurals* was up for shorter intervals of time. We believe it became more of an event - something that should not be missed. Nevertheless, we continued getting requests to run it continuously.

Dorm events such as meetings and social hours attracted large crowds. Oftentimes it was for comic relief. Other times it was because of the quantity of people. One person at the *Telemural*, whether at the local or remote end tended to attract more people. A wedding party proved to be the most interactive period with children repeatedly running back and forth across the wall. Food associated with these events also attracted people. Moving food in the field of view of the mural made it a popular spot.

There was a tremendous difference with and without instructional signage. There was original signage explaining *Telemurals* was an audio-video connection. However, people were not convinced either because there was no one at the other end or because it was unfamiliar. Later, detailed instructional signage was added and usage increased five-fold. With time, people also began to trust and understand the link better.

Changing the *Telemural* site at Sidney Pacific from a bright room with high ceilings and glass walls, to the other corner that was dimmer and closer to the elevators similarly increased interaction levels. The new space provided more of a surprise, better mural visibility, and more time to interact.

Ashdown and Sidney-Pacific have an interesting history. A good number of the inhabitants of Sidney-Pacific lived in Ashdown the previous year. Some students arranged meeting times to meet at their respective *Telemural*.

People preferred more abstracted silhouettes to photorealistic images due to the ubiquitous nature of the connection. The speech recognition algorithm provided positive feedback loops of people talking doing their best to hit a successfully translated phrase and comic relief.

Above all, having a person present at either end is a big attractor. This was even surprising during observation sessions when we sat near the *Telemurals* taking notes; we thought participants would be self conscious being watched. However, people would come just become someone was watching the wall.

Whether there is a person at the remote end or the local end, they attracted more people. William Whyte was right. "What attracts people most is other people". With *Telemurals*, we hope to facilitate that.

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Fluidtime:
Developing an Ubiquitous Time Information System

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ABSTRACT

Increasingly, people live and work with a new set of habits regarding time, such as the increased use of the mobile phone to quickly schedule or change appointments. However, aside from the phone, few tools or services exist that support this new way of life, especially when people interact with public or private services.

With these new habits in mind, the Fluidtime prototype system was created to provide people with personalised, accurate time-based information directly from the real-time databases of the services they are seeking.

This abstract describes the case studies that have been implemented, presents first insights from the trials and discusses the design issues these trials raised.

Keywords

Time, mobility, ambient displays, interaction design, service design

INTRODUCTION

We have to wait when our personal time schedules do not coincide with the schedules of the people and services with whom we interact. Since both people and services are in constant flux, precise appointment times are not the most useful means of coordination. When people are provided with continuously updated time information about a service or appointment, the activity of waiting becomes more tolerable. [8]

Currently, most people are left wondering if their doctor's appointment is on time, when their bus will arrive, or when their package will be delivered. The unpredictable nature of events requires a flexible model of time that is not reflected in the static and abstract nature of traditional timing systems.

People increasingly use the mobile phone for scheduling since it allows them to make instant appointments and change them according to unforeseen personal circumstances. Instead of arranging activities in reference to the clock, people can plan in accordance to the real-time information of the people or service they are seeking. This allows them to flexibly arrange and adjust their appointments by coordinating their own schedule with the changing availability of the service or of their friends. This use of telecommunication technology reveals an increasing trend towards flexible time planning. [7] With real-time information, people can adjust their behaviour accordingly and take control over how they wish to spend their time.

A survey by Joanna Barth [3] that was done as part of the research project investigates 19 working services, applications, and devices that deliver real time information about public services and private appointments. Especially in the context of travel, people can find real-time travel information at train stations or airports. More and more city transport authorities provide people with up-to-date information. This travel information is increasingly available through the Internet and recently also through SMS. For example, many airport websites provide a real-time update of the arrival and departure schedule. An example for real-time updates in the context of public transport in cities is NextBus Inc. [9] It provides information for several cities throughout the US. In Europe, in the city of Turin, Italy, travelers can use SMS to access real-time information of the arrival of buses. [1]

These few examples among many show a clear trend towards the use of communication technology for coordinating the timing of services. Providing people with up-to-date information is becoming more accessible and is appreciated by the customers. [5]

In the context of hospitals and medical examinations, where the timely coordination between doctors and patients is still characterized by standard procedures, where patients need to wait in order for doctors to have patients ready at te right time. But a survey in the UK has estimated that there are about eight and a half million missed doctor's appointments a year, which sums up to 150 million British Pounds of lost appointment time. [4] A department at the Homerton Hospital in east London started a trial that uses SMS messages to remind patients of their upcoming appointments as a possible solution to this problem.[6]

It is not only financial motivations that make hospitals use communication technologies to coordinate patient schedules. It is also the increased awareness for an improved doctor-patient relationship that inspires doctors and hospital authorities to look at new scheduling possibilities.

Time and money

Ever since Benjamin Franklin made his "time is Money" statement, time has become an important and valuable business factor. In some cases, time has been the only product that was sold.

Samuel Langley was one of the first ever to market time as a product in the end of the 19th century. [8] His product was standard time, which was used to set a common time standard on which a train schedule could be based. Langley broadcasted the observatory's time signal and other cities paid him in order to receive and use this standard time.

Especially today, people are willing to pay for time since it is a highly-valued commodity. A survey that was done after the implementation of the new traffic information system in Turin [5] indicates that people would be willing to give money for real-time arrival information. A report by Alpern et al. [2] shows possible revenue model of how money could be made on real time information for public transport.

In many operations, from travel services to home services, accurate time information is a by-product of upgrading the business operations to digital systems. It is the decision of individual management whether this by-product is offered to customers for free (in order to improve the service experience), or if it is used to generate revenue. The future will show which models will work and which ones the customers will not accept.

Fluidtime

The Fluidtime project aims to contribute to these developments by finding engaging, convenient and effective means to view and interact with real-time information. Especially through advances in wireless Internet technology, it is possible to create ubiquitous access to real-time information.

Current systems have the drawback that they are not accessible through easy-to-use interfaces or products whether the customer is at home, in the office or on the move. For instance, travelers first need to go to the train station in order to find out if the train is delayed, or in the case of a SMS-based updating systems, any timing changes are not reflected until the next SMS is sent. If, however, every fluctuation in the schedule produces a SMS message, the recipients could easily be flooded with too many messages..

With the Fluidtime project, we want to investigate the use of ambient displays that reside in the background or wireless mobile devices that allow the user to monitor the information constantly and utilize the advantages to the use of real time information. We hope to build a pervasive information environment that is subtle and pleasing to use.

PROTOTYPE DEVELOPMENT

The Fluidtime system

We developed a time information system and interface prototypes in order to investigate the opportunities and impact of using real time information. The system works by tapping into already existing real-time logistical information from bus companies and laundry services and makes it available to the Fluidtime users via wired and wireless networks. Using SMS, e-mail and the mobile and stationary Internet, the service performs simple tasks, such as time monitoring, and user reminding.

Prototype contexts

The two contexts that were chosen for the prototype development were the public transport in the city of Turin [1] and the laundry service at the Interaction Design Institute Ivrea.

On average 20,000 people use the public transport facilities in Turin every day. Turin transport authorities have already implemented a system that tracks all the buses and trams. The first service prototype makes this data visible to travellers at home, at work or on the move. They can find dynamic information on mobile screen-based devices; while at home or at the office, people can get the same information on mechanical display units.

The second service prototype is a scheduling and time monitoring system to help Interaction-Ivrea students organise their use of shared laundry facilities. The 50 students and researchers share the use of a washing machine. Having to book a time slot, remember to bring the dirty laundry, keep the appointment in mind, and check the washing machine in the basement to see when it's finished—all add up to a less than comfortable experience.

Using different interface modalities, the service performs simple tasks, such as reminding users in the morning to bring their laundry to the Institute, or letting them know when their laundry slot is ready or their washing is done. Since the system knows the users' profiles and how busy the day is, it can adjust it's behaviour regarding reminders from being either strict or more relaxed.

Ambient devices allow the laundry users to monitor the progress of the machine and know when it is time to collect the laundry. The system prototype also allows users to take advantage of a free laundry slot with enough advance notice if needed. It does this by both checking the schedule and getting confirmation from those who are affected.

INTERFACES

The challenge for interface design was to create a simple and effective system of interactions. The intrinsic problem with time planning systems is that they require time to be used. On one hand, they help us free up our time or organise our activities in a better way, but on the other hand, they require time to be operated, and thus reducing the overall effectiveness.

We developed two categories of interfaces: one that was meant to be mobile and accessed anytime and anywhere, and a second category that was stationary, and designed to be used in the context of the home or office. It is worth mentioning that with the physical object interfaces we focused on the exploration of the quality of interaction and information representation. We don't see them as proposals for products that should be built and go to the market tomorrow, but that explore some basic functionality and quality. Alternatively, using a generic mobile phone allowed us to explore interfaces that are on the market now and wouldn't require special investment from customers.

Mobile Interfaces

The interface is based on a Java software application that runs on a standard mobile phone (we used the NOKIA 6610) connects to a server to get the real-time information and then visualises the data.

We created an optional wristband that allowed test users to wear the phone interface on the lower arm, just like a regular watch. Once the application was activated, it allowed them to check any changes of time information just by looking at the display, since the application was always on and always connected.

FI1 (Fluidtime interface 1): Perspective visualisation

The interface shows how far a certain pre-selected bus is away from the chosen stop. (See Figure 1) The application permanently updates the visualization with data originating from the Turin transport authorities.

FI2: Iconic representation of time

An icon on the upper part of the screen indicates the state in which the user should be in order to catch the next bus. (See Figure 1) If the icon displays a tranquil character, the user can be relaxed. If the icon is a running figure, the user knows that the bus is due to arrive.

Figure 1. Fluidtime interface 1 and 2 (FI1, FI2)

FI3: Overview of three routes and stops

With this interface, the user has increased planning control. (See Figure 2) It allows the user to define up to three different routes at up to three different stops. This information is necessary for travellers that need to change buses. Test users also relied on it to decide which bus stop to walk to.

FI4: Washing status indicator

This interface shows the status of the washing machine, informing the user when it is the right time to go to the facilities in order to unload the machine (See Figure 2).

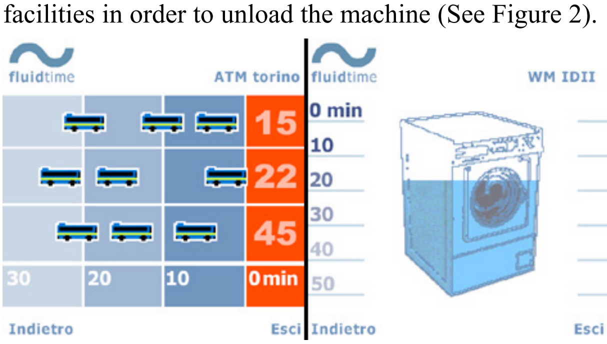

Figure 2. Fluidtime interface 3 and 4 (FI3, FI4)

Physical object interfaces

FI6: Mechanical display unit with icons

This is an object for the transport context. It has the dimensions of a small hi-fi stereo (See Figure 3) and is meant to be placed in the home or office environment. Through the glass fronts of the object, the users can see small iconic representations of the buses that move from the background to the right hand corner in the front. The position of the miniature bus tells the users how far the bus is from the bus stop. The user can configure the bus routes and stops through a web interface.

FI7: Mechanical display unit with shoes

This object looks just like a small shoe rack that people keep in their homes. (See Figure 3) When the user activates the object, the movement of the shoes indicates the distance of the actual bus. If the shoes move slowly the bus is still far away, and the user could walk slowly and still catch the bus. If the pairs of shoes start to "run" then the user would also need to run in order to catch the bus. Since the moving of the shoes creates an acoustic pattern, the user can listen to the information even if he is not in the same room as the object.

Figure 3. Fluidtime interface 6 and 7 (FI6, FI7)

FI8: Mechanical display with ribbons

This wall-mounted object has a discreet appearance and indicates the status of the washing machine. (See Figure 4) The turning angle of the central cube indicates the progress of the washing machine. Once the washing cycle has finished ribbons will appear and clearly indicate that is time to pick up the laundry. As soon as the washing machine door is opened the object turns back to its initial state.

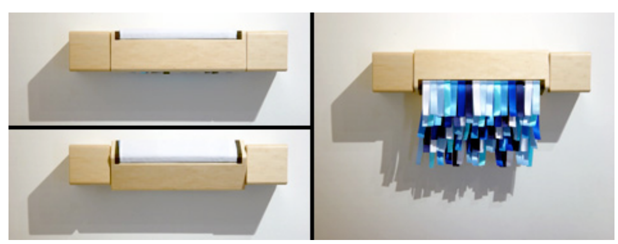

Figure 4. Fluidtime interface 8 (FI8)

TRIALS

The interfaces for mobile phones (FI1 – FI3) described above were tested in Turin between May and June 2003. Four candidates in their early thirties were given a mobile phone, with the applications installed on them and two of them received a wristband for optional use. A fifth user received the interface FI7 to test. A small printed manual described the use of the applications. Since the applications were quite simple, the users required not much learning.

All of the candidates were commuters that used buses everyday to travel to and from work. The candidates were interviewed three times during trial period. These interviews aimed to capture their use habits regarding the prototypes, the functional value of the interfaces, the usability and aesthetic quality, and the emotional and social attitudes of the test candidates

Looking at the use habits, we concluded that the interfaces were consulted on a daily basis. Each one of the users interacted with it either on their way to the bus stop or once arrived. Only in cases where the apartment or office was close to the bus stop, they started the application before leaving the place. If people could estimate the time it would take them to the stop (e.g. using elevator) they only started the application once out on the street.

Over time, the users gained experience in estimating their timings. One of the users adjusted her "leaving the office" routine over time. She would start the application and if the bus was still distant, surf the web or chat with colleagues, until the bus was due to arrive.

The applications' release used by the trial candidates did not allow the storage of frequently used bus routes and stops. This turned out to be the biggest handicap of adoption. As mentioned in the introduction of the interfaces section, if time applications take too much time to operate, the value gained by the time information doesn't equal with the effort put into accessing the information.

A second usability handicap was the fact that the application can only be started from within the application menu of the mobile phone. Again, this effort is too big in order to be useful on a frequent or daily basis.

All users found the interfaces aesthetically pleasing and gave them marks like "beautiful", "cute", or "entertaining" On a social, psychological level, the team found interesting that real-time services not only support those who like to plan ahead and want to compare different route possibilities in order to save time or be more efficient, but that it also gives people less inclined to plan more possibilities to seize the moment. This supported our hypothesis that time information devices don't necessarily save time, since they depend on the person that uses it. In the case of Fluidtime, the aim is to give people more control over time -- it is the user's choice that of how to deal with the information.

CONCLUSIONS

The aim of the project was to develop a prototype infrastructure and a set of interfaces that allowed users to access real-time information in the context of everyday life (commuting and doing the laundry).

It was important to provide the fully functional prototypes to the test users in their particular everyday life contexts in order to study the direct influence of the new technology into their daily habits and rituals

In ubiquitous computing environments, the flow of everyday interaction has to be as smooth as possible. The value gained by new applications is often not equal to the effort put into learning and using them.

Ubiquitous solutions are difficult to test in the everyday life context, since many factors influence the results of the investigation. Nevertheless, we found it particularly helpful to spend time with the users while employing the system on the streets in their everyday environment.

ACKNOWLEDGMENTS

We thank the Interaction Design Institute Ivrea for supporting this work and the entire team that made it possible including Joanna Barth, Crispin Jones, Alberto Lagna, William Ngan, Laura Polazzi, Antonio Terreno, and Victor Zambrano. We also want to thank the faculty and staff at the Institute for providing helpful comments and feedback for this project.

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Pulp Computing

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ABSTRACT
We are investigating the integration of paper artifacts into personal and inter-personal computing environments. We will demonstrate portable paper interfaces to media collections and active photos that allow uses to access annotations in both web-based and printed representations.

Keywords
Paper interfaces, hypermedia, physical hyperlinks, mobile computing, World Wide Web

INTRODUCTION
The Pulp Computing project at HP Labs [7] is investigating how to integrate paper artifacts into personal and inter-personal computing environments. Our basic research question is: given that paper plays such an important role in our lives [9], how can we best enable people to work between their collection of paper-based artifacts and the digital resources stored on the web and in their PCs?

Our approach to paper is to view it as a compelling type of "UbiMedia ": the intersection of ubiquitous computing and hypermedia [1]. What we mean by that is, first, that we can print physical hyperlinks [4] to digital resources on paper, in the form of optical tags such as barcodes and glyphs, or the form of electronically readable tags using conductive inks, such as those developed by the Paper++ project [6]. Those physical hyperlinks can reference any content or services available on the Web. Not only can users insert tags into their documents − providing electronic functionality in the printed versions − but virtual objects can print references and even interfaces to themselves on paper, for access by users with various types of "smart pen" as a reader.

Second, paper is very portable, and so it is suitable for exchange between people, and also for transport into and out of ubiquitous computing environments. Ideally, users should be able to take advantage of their smart paper artifacts and acquire useful smart paper artifacts wherever they go. For example, a user can take a print-out of a meeting back to the office to find links to the attendees and the content that was presented. Smart paper should just "work" in any given environment.

Many have investigated augmenting paper with electronic functionality, including notebooks [11], post-its [5] and photographs [3]. Our distinct emphasis is (a) on interaction models for working between paper and electronic resources that apply even when the user is nomadic; and (b) empowering non-technical users to author hyperlinks between paper and electronic resources. We aim to support spontaneous usage of smart paper, as opposed to relatively long-term form-filling and augmented-book applications [10].

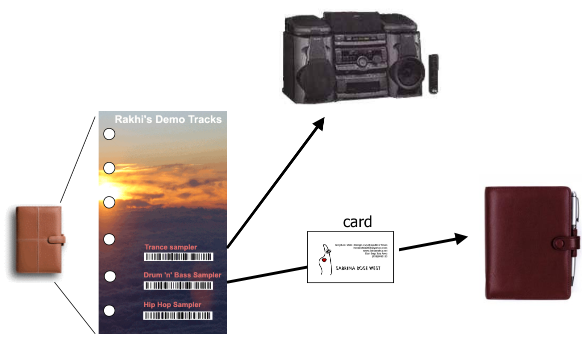

Figure 1: Fil-o-media

DEMONSTRATIONS
To illustrate the first steps in our research, we intend to demonstrate both the following prototypes.

Demonstration 1. Fil-o-media:
Portable Paper Interfaces to Media Collections
The demonstration will be of (a) a "fil-o-media" (c.f. fil-o-fax, a portable ring-binder for diary entries etc. [2]) − which contains paper links to a user's music, graphics, video and document collection; and (b) a model for users to exchange content via personal cards. The demonstration will involve the paper artifacts plus off-the-shelf handheld wireless devices for dereferencing the hyperlinks. We will demonstrate how to transfer content from one user's fil-o-media to another (Figure 1). One user selects content from their fil-o-media, and "binds" it to a personal card: that is, they place a reference to the content in a hyperlink on the card. Then they give the card to the other user, who can later bind the content into their own fil-o-media − or simply keep the card − to play on output devices of their choice.

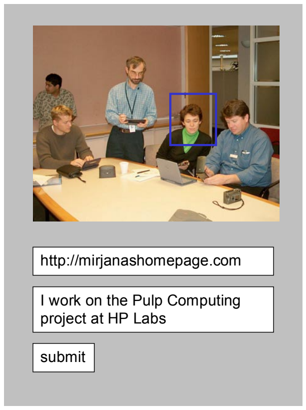

Figure 2: Dynamic annotations of web-based images

Demonstration 2. Active Photos

An "active photo" is one with both web-based and printed representations, each of which has links to annotations in the form of text, audio, video or hyperlinks to web pages. The annotations may apply to the entire image or parts of the image. The photos can be taken and annotated on the fly, e.g. during a meeting or at a conference (Figure 2). The annotations can be viewed from prints of the photos as well as on the web.

We shall demonstrate how a conference attendee can annotate themselves in a group photo with text such as their home page, or a spoken message. Those annotations can be experienced on a public display at the conference or at any time from the printed "informal proceedings" of the conference (Figure 3). Printed images have certain advantages such as being of higher resolution, and easy to pass around and share. Our current implementation uses the Seiko InkLink technology [8] for identifying "hot spots" in a printed image.

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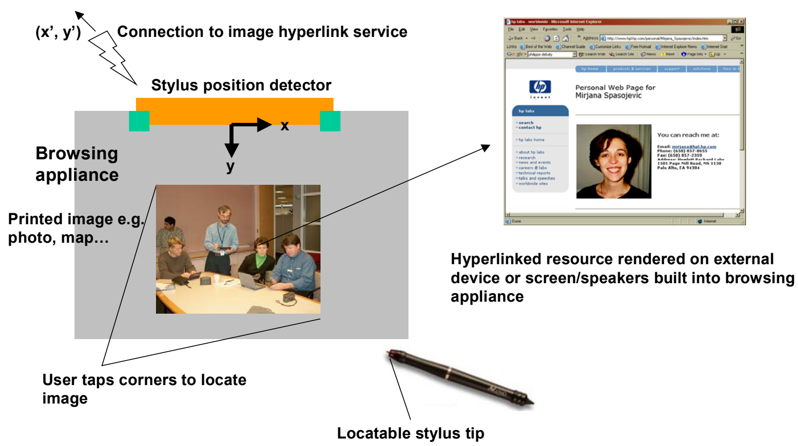

Figure 3: Accessing annotations from a printed image

Living Sculpture

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ABSTRACT
In this paper we introduce the concept of Living Sculpture and its philosophy. Next, we present "Octofungi", an eight-eyed, eight-legged Living Sculpture. We conclude with a look at Living Sculpture's future.

Keywords
Artificial Life, Robotics, Living Sculpture, Octofungi

INTRODUCTION
Living Sculpture is the name of the current body of work by artist Yves Amu Klein. Living Sculpture represents a series of works that attempts to bring emotional intelligence and awareness to sculptured life forms. To date, computing via embedded controllers and genetic evolution servers has been an integral part of every Living Sculpture. In turn, Living Sculpture has brought computing into the traditional gallery setting and made it the brains of man-made life forms. "Octofungi" is one such life form. Octofungi is an interactive sculpture that exhibits simple reflexive autonomous behavior, learns its surroundings and interacts with them. The future of Living Sculpture promises works on the micro-scale as well as giant environmental pieces. These works will require new computing technologies and expand the role of computing in our world.

Is this ubiquitous computing? Art and sculptures are part of our culture. They are everywhere; in our house, parks, gardens, museums, etc. Similarly living sculptures may be found in the same environments. Living sculptures are ubiquitous in the sense that they fall into our cultural desire of having art surrounding us. They are also computing because they are behavioral sculptures.

LIVING SCULPTURE
We first adopted the term Living Sculpture in the early 1990's to describe the new breed of robotic sculptures Klein was creating. Living Sculptures are a natural evolutionary step in classical sculpture. In the same way Alexander Calder and Jean Tinguely brought motion to their art to create kinetic sculpture [1], Klein wanted to bring emotional intelligence and behavior to sculpture to create a new form, Living Sculpture or Behavioral Art. The process of creating a Living Sculpture is challenging due to the complexity involved in having that sculpture integrate multiple changing inputs and react in real time.

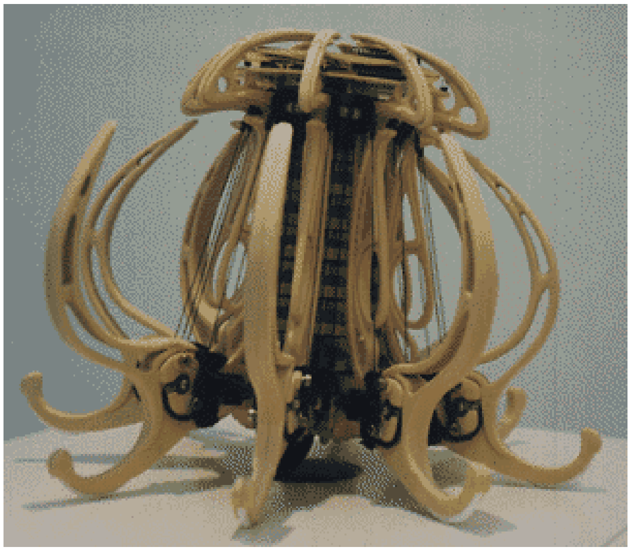

Fig. 1. The eight-legged *Octofungi* (1994-96), a 12-inch-tall sculpture of colored polyurethane, micro glass beads, and natural fibers. Driven by a neural network, *Octofungi* moves its legs in graceful patterns somewhat resembling the movements of a sea anemone.

From finding appropriate materials to developing technologies for gesture, locomotion, sensory input, and behavior, countless technological and physical obstacles have to be overcome to achieve a unified sculpture. The work is an attempt to find a symbiotic balance between classical artistic expression and contemporary technologies.

Living Sculpture also incorporates a sense of biological design. When we observe a living organism, we can see detail and complexity on any scale or from any angle. A Living Sculpture should embrace this intricate detail as much as possible. As a design progresses from the inner basic systems to the complex outer systems, surprising and elaborate aesthetic and behavioral effects may emerge that exceed our expectations. The goal is to make Living Sculptures interesting and exciting from any perspective. As with living organisms, the details of Living Sculptures are not simply for aesthetic purposes. Each line and curve should have a significant effect on the functionality and aesthetics of the piece in order to survive the design process. In a sense, the principles of natural selection are applied to a Living Sculpture in progress.

A Living Sculpture should be interesting (appealing to our senses) not only in appearance but also in behavior. A sculpture should respond appropriately as people interact with it, and different people should provoke different responses from the sculpture. Living Sculptures are imbued with both instinctive behaviors and more complex responses. For example, an aggressive viewer may trigger a defense mechanism within the sculpture, while a gentle viewer may experience a more subtle and pleasing reaction. The more time the viewer invests in developing a constructive relationship with the sculpture, the more interesting the response should become. We attempt to make pieces that show depth of design as well as depth of behavior. Functionality and aesthetics are tightly linked within the works and create a sense of unity and homogeneity. Our audience will enjoy all these features of a living sculpture, which are implemented in Octofungi. However, it is sometime difficult to construct behavior in a demo set up since the learning process can take hours.

THE PHILOSOPHY OF LIVING SCULPTURE

Living Sculpture is also a philosophical as well as a social-political quest that asks questions and challenges our existence with our creations. Creating life as been portrayed by many writers as a dangerous and insane enterprise. The idea of another intelligent life form frightens religious institutions and they condemn it as profanity. History has shown that we as a species are both attracted to and afraid of the unknown. We feel that caution is definitely in order. However, if taken seriously, artificial life can help us understand our own existence. It may even provide us with a means to transform into our next evolutionary form, a being of the cosmos. Living Sculpture is about bringing these ideas with their pros and cons into a dynamic and interactive dialogue. Here the sculptures strive to understand us as we try to grasp their significance.

Some questions that we might ask ourselves include: Should we have Artificial Intelligence and Artificial Life in our society? If we do achieve artificial life forms, what right should those life forms have? What is life? Is life dependent on carbon-based structures found on earth or is it information, which is independent from its basic material?

OCTOFUNGI

Octofungi has eight legs and eight eyes and lives on a pedestal in a museum’s gallery or collectors favorite spot. Viewers interact with Octofungi by waving their hands over its eyes. Octofungi reacts to viewers by moving its body based on its interpretation of the viewer's actions. Octofungi is a reactive piece. It is sensitive to changes in light and reacts upon these changes. To interact with the sculpture, a person only needs to move his hands above the eight light sensors placed around the brain frame. Depending on the interaction of the participant, Octofungi will manifest different behaviors.

When Octofungi is at rest or at an emotionally neutral state it is an inanimate object like a vase; Octofungi is symmetrical sculpture in a classical way. To stimulate Octofungi people will cast shadows of varying degrees of darkness, speed, and direction relative to it’s eight photo-cells “eyes” by moving their hands above the eight light sensors placed around the brain frame.

The photo cells use an analog-to-digital convert to convert the analog stimulus to a digital signal that is send to a Kohonen neural network. The neural network knows its environment; it can distinguish between an intruder and a periodic activity such as a fan or a slight variation in light from a window. In the Kohonen neural network, the neurons compete to decide the winner or next position. The network will consider Octofungi’s current state including the position of its eight legs, which may be 1 of 256 positions. Since the Octofungi has eight legs and each leg can only accept a single winning position our neural network can have none to eight winners.

The winning positions are transmitted from the neural network processors to the shape memory alloyed driver (SMA) processor via a serial line, which sends a pulse width modulated (PWM) signal to each of the eight legs. As the legs move a digital encoder will give a feedback of the position of the leg. The feedback is also send to the neural network where it is used to learn the discrepancies of the legs mechanism and environment such as friction and obstacles. The neural network acts as the brain by controlling the sculpture form giving it a life-like behavior.

Is Octofungi Alive? Octofungi is quite a complex system but it lacks elements that are indispensable to any life form. First it does not look for food. If we consider the intake of energy as eating, Octofungi is fed intravenously, but it does not "know" that it needs to eat and it does not know how to get food. However, plants are also "wired" in a sense to the nutrients in the ground and to the sun's energy. Plants, however, know how to search for these nutrients and energy by moving their roots or leaves closer to the sources.

Octofungi's awareness at present is purely instinctual. It has no higher thought processes. It is probably comparable to a non-social insect such as a moth or to a mollusk such as a snail. Although Octofungi presents some of the same elements as simple life forms, it still lacks full autonomy.

Only Octofungi's behaviors are presently controlled by its will. Nonetheless, we believe that the line that separates the living from the inert is fuzzier than we think.

THE FUTURE OF LIVING SCULPTURE

Living Sculpture started by making simple reactive sculptures. Today we are making evolvable behavioral art forms and tomorrow we hope to bring more technologies to my pallet in order to show how biology and technology could merge into our future forms. Here we describe four of the projects to come:

Lumedusa

Lumedusa is an intelligent micro-robotic wearable Living Sculpture. Lumedusa is hydra/squid-like creature with six tentacles that lives in a pendent containing its aqueous solution. Lumedusa will be approximately 4-5 mm across when fully assembled. Lumedusa is designed so that it can be micro-machined as a flat device and then fold up into a 3 dimensional robot using its EAP actuators. Lumedusa's body will be composed of silicon plates connected by polypyrrol(PPy) micro-actuators and illuminated by polypyrrol(PPy) LED's. Lumedusa will be tethered to it's pendent via a flexible umbilical cord used to communicate with it's brain, a micro-controller built into the back of the pendent.

Cello

Our cells are a tight swarm of microorganisms all working for the colony... us. As we eat we are essentially recycling organic mater to repair our damaged cells and give birth to new ones. When the swarm matures it will spend a great deal of time and energy for the sole purpose of creating a new colony. And then the cycle continues… Cello embraces this idea. Cello is a sculpture that is made of hundreds of cells that can combine together according to their genetic code. During its lifespan, Cello will add cells to the colony to grow or replace cells where there's damage. After a genetically dictated period of time Cello will die so that other Cellos will live by reusing the cells. Cello's cells are identical in shape but not in behavior. As the body is being formed cells become specialized to serve the colony. A Cello begins life as one cell, but for Cello life never ends.

Arius

Some Living Sculptures are wild creatures going on about their business eluding us, like a pack of lions or a flock of migratory birds. This is what Arius and many of its descendents will be. A flock of hydrogen balloons that no one wants to mess with due to their explosive contents. The flock of Arius will float away along the pacific coast as some strange birds from a different time. As creatures of the sky and sea, they use the sun as their source of energy and water, and as their food. They can fly at great speeds with their hydrogen engines or glide peacefully at sunset. They can communicate with each other using sounds and light signals or use GPS to provide their positioning via radio signals. However, most of the time, they will use their intelligence and senses to navigate. Arius is one step closer to a fully independent creature.

Space Ribbon

Space Ribbon is a sculpture that will travel in orbit around our planet to remind us of the beauty of Mother Nature. Our transformation begins in our mind. I hope to be able to create a colony of space ribbons so that we can admire their dance at sunset and sunrise. For a few minutes each day they will remind us that we should all play and smile. They will then disappear to re-introducing us to our beautiful night sky. They will remind us not to pollute our atmosphere with light and chemicals, as we can already see our night vanish in the glow of our cities. Space Ribbon is composed of a body and two long ribbons made of electro-active polymers that can bend like the tentacles of the nautilus. Each side of the ribbon is covered with gold-plated electrodes that reflect the sun's light while at the same time move it's tentacles.

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Place Lab's First Step: A Location-Enhanced Conference Guide

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ABSTRACT

This demonstration explores how people's existing notebook computers, the WiFi access points in a city, a carefully selected cache of web pages, and some software glue can be combined to provide a location-enhanced conference guide. Although location-aware applications, tourist guides, museum tours, and the like are well known to the research community they have yet to see widespread availability. Part of the reason for this is that exotic infrastructure or additional mobile hardware is generally required. In contrast we are pursuing a low-overhead client-based software-only approach. Users load a software package on their WiFi-notebook computers that adds WiFi cell-site positioning to the browser and lets them easily find location-relevant content about the conference hotel and surrounding neighborhood. An unusual aspect of our approach is that it requires no network connectivity: a web page cache provides content and beacons from existing WiFi access points provide location.

Keywords

Location-aware, tourist guides, WiFi, wardriving, context-aware, ubiquitous computing.

INTRODUCTION

The goal of Place Lab is to hasten the broad adoption of location-aware computing. Our approach is to develop an open-source software base and foster community building in a cross-organizational initiative involving universities and research labs. Place Lab will address both the technological and the social barriers to truly ubiquitous deployment of location-aware computing. In this demonstration, we are taking a small first step that demonstrates how to provide an entirely client-based location-enhanced conference guide for the Ubicomp conference venue. Place Lab leverages the fact that many cities and towns around the world (e.g., Manhattan, downtown Seattle, the business district of Athens, Georgia) have wireless hotspot coverage so dense that cells overlap. WiFi is now in the mainstream: 300 U.S. McDonald's restaurants are offering one-hour connections to customers buying a value-meal [4]. As this trend continues, it is likely that wherever you open your notebook computer or take out your PDA you have a good chance of finding that you are within range of a hotspot. Wireless hotspots can offer a kind ubiquitous information access, if you have a usage subscription with the carrier. What is missing and what Place Lab will enable, is a way for your computer to know its location – to map the hotspots around you to a physical location worldwide. We use the term *WiFi positioning* to denote this capability of client-computed location using wireless hotspots.

Location-based computing is one of those technologies that, like the web, increase in worth the more ubiquitous it becomes. More users will motivate creative developers to produce more applications, services and content, which drives investment in infrastructure, and greater usage. To bootstrap this cycle, Place Lab lowers the cost of entry: it

Figure 1: Seattle and other cities have WiFi coverage so dense that cells overlap. Each WiFi access point beacons a unique identifier that can be used as a lookup key for course grain location. In this image each dot is the position of a WiFi AP mapped in a single "wardrive" of down Seattle.

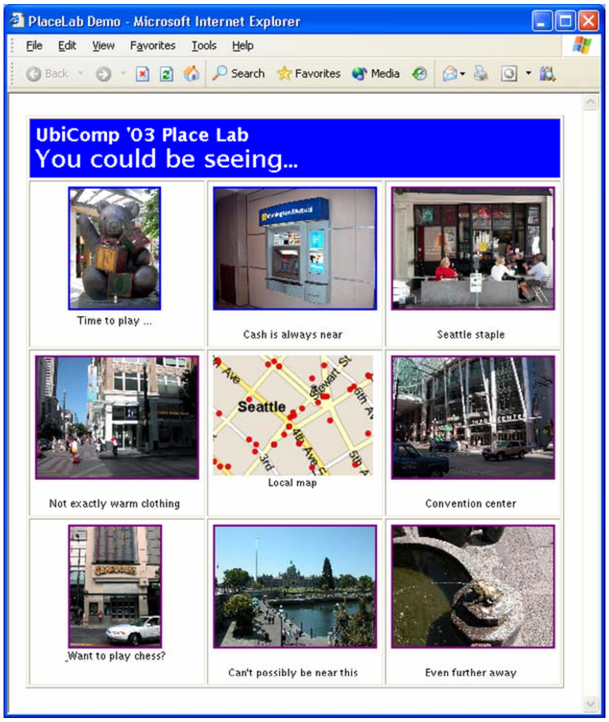

Figure 2: The main page of the Place-Enhanced Conference Guide presents images of interesting "sights" from around the conference venue (conference Hotel). The user's location is detected through WiFi hotspots that have been previously mapped. The content (images, factoids, opinions, and links) are both manually created, culled from the Web prior to the conference, categorized, geo-coded, and placed in an install package. When a particular sight is selected, more detailed information is displayed. The entire web site runs without network connectivity and uses beacons from the last seen WiFi hotspot to approximate location.

only requires a mobile computer to have standard WiFi capability. Whenever a user's computer is in the presence of a beaconing access point, it looks up the MAC addresses of nearby hotspots in a cached directory and determines the user's location. This location can then be made available to both local applications as well as enterprise and web services. In the case of our demo, the user's location is used to present relevant tourist information such as historical nuggets, nearby restaurants, hotels and points of interest. Achieving the full Place Lab vision [6] requires that a number of technical and social issues to be addressed including: how to build, maintain, and distribute the hotspot database, privacy mechanisms to help users control who can see their location data, and how to code web content for its relevance to different locations.

THE CONFERENCE GUIDE APPLICATION

At UbiComp 2003 we are demonstrating a proof-of-concept system to launch our community development effort. We have developed a stand-alone system that conference participants can download and install onto their laptops that will give them a location-aware conference guide for the neighborhood that surrounds the Ubicomp '03 venue, similar to GUIDE [3] and Cyber Guide [5]. We now describe what we hope the user experience will be, how the demo system will be architected and finally describe what we expect to gain from the experience.

In our demo, users will interact with the conference guide via a standard web browser accessing HTML pages. Sample pages are shown in Figures 1 and 2. All of the pages generated by the system will be coded for location relevance. The map view on each page will place the user on a map of downtown Seattle (or a detailed map of the conference Hotel). The page will also present images of nearby locales. The users can drill down from the basic view to find interesting images, facts and opinions.

One of our concerns designing the conference guide was that the location algorithms we are using provide rough grain information. Although we expect that in time other researchers will apply better algorithms to improve this aspect of Place Lab, we knew that it was possible that position reports could be off by a city block or more! Our first interface had a text-based style and included specific descriptions of computed position. We decided to generalize the interface with imagery, including a map containing of few blocks, in order to avoid confusion if the positioning broke down.

The user should find the tool to be responsive to changes in their location and have a fairly high density of places of interest within a few blocks of the conference venue. To simplify the design of the system and to make it available to as many users as possible, the prototype will not require that the user have network connectivity. Rather, the content will be bundled with the software, allowing the Place Lab pages, as well as the pages for the places of interest to be cached locally. The demo system the users install will contain four main components. The first is a WiFi spotter that can identify locally available base stations. The second component is a cache of web pages for the places of interest around the conference. The third is a customized database that maps both base station MAC addresses and web pages to geographic locations. Lastly, the system contains a small web server to make web pages available to a web browser.

When a user points their browser at the server port on their local machine, the web server runs a PHP script that takes the user's location as provided by the spotter and selects and renders an appropriate set of nearby places of interest. Using a local web server limits the types of services that we can provide, but eliminates a number of hard technical problems such as how to ensure user's privacy (not a problem since they are running locally), how to handle periods of disconnection (not a problem since we don't rely on connectivity), how to deal with a large database of MAC addresses (our database will be very small) and how to tie legacy content to physical locations (we plan to do this by hand for our sample corpus).

OFF SITE VERSUS ON SITE

One of the risks we see with our demo is that people may not take their notebook computers when they leave the conference center or hotel. In a way we are presuming a usage model of mobile workers who pull out their notebook computers in coffee shops, airports, copy stores, internet cafes, hotel lobbies, and this may not match the conference attendees. In an ideal world the conference guide would be provided on smaller devices that people do carry. In the future, as WiFi PDAs are more widely adopted, we will likely following that avenue. In the meantime, we are very interested in learning how and why people travel with and open their notebook computers and this demonstration will be an opportunity, through informal interviews, to gather data.

In order to give the conference guide experience to people who never take notebooks offsite, we will provide smaller grain information and services keyed to the hotspots in the conference center and hotel. Much of this content will have to be created by hand, but we see a nice opportunity to create color and fun. For example our team might photograph and interview the bartender and include a hotel bar page, as well as scan the hotel restaurant menus.

For location inside the conference center we will use the existing conference APs and may add "warmspot" access points with a smaller range. These additional beacons may be necessary to provide complete coverage of interesting areas.

CONCLUSIONS

Our demonstration will be continuous and will be available to volunteer users from the start of the conference. During the demonstration session, we will show the location-enhanced browser to all attendees and seek more volunteers. The feedback provided by these users will be invaluable for our research and development team. We will ask volunteers to release their usage (location and click) data to us for anonymous and aggregate analysis. (The release will be handled through a clear and concise form they can optionally sign when they download their demo. If they do release their usage data, we'll ask them to email us the data when they return home. No one will be required to divulge any data without their explicit permission.) We hope to learn about the coverage hotspots currently provide for the paths taken by users and the breadth and depth of web navigation at the different locations.

More importantly, however, our hope is to this conference venue as a springboard for the start of our community-building effort and approach to collaborative ubiquitous computing research. Our goal is to build awareness for our activities and enlist collaborators and users. This demonstration is a first step in an iterative design process that we expect to gather momentum and a wide range of applications.

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AuraLamp: Contextual Speech Recognition in an Eye Contact Sensing Light Appliance

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ABSTRACT

In this paper we present AuraLamp, a lava lamp augmented with an eye contact sensor and speech recognition capabilities. The lamp listens to simple voice commands such as "On" or "Off", but only when the user looks at the lamp. It demonstrates how we may coordinate communications between a user and many ubiquitous appliances by sensing when the user pays attention to a particular device. Rather than competing for the user's attention, devices enter a turn taking process similar to that used in human group conversation. When the user is speaking to the lamp, the speech recognition lexicon is automatically limited to the vocabulary of the lamp, thus increasing recognition accuracy.

Keywords

Attentive User Interfaces, EyePliances, Context-Aware Computing, Ubiquitous Computing, Notification Systems.

INTRODUCTION

With the advent of ubiquitous computers, we have seen a considerable increase in the number of digital appliances at the disposal of each user. However, most ubiquitous appliances are still designed to act in isolation, as if they were the user's only computer. Each appliance may notify the user of incoming communications or computer activity independently, without any consideration for the user's engagement with other devices. Devices now relay volumes of email, instant messages, phone calls and appointment notifications, producing an intricate web of annoying 'attention grabbers' within which a user can easily become entangled. We believe that by coordinating communications on the basis of user activity, or more generally, user attention, devices may engage in more polite and respectful interactions with users – in ways that do not fragment their limited attention [8].

More and more frequently, users are also engaged in *remote* interactions with their digital appliances. Many ubiquitous appliances are either worn, or embedded in everyday objects without a significant visual or manual computer interface. As the accuracy of speech recognition interfaces increases, we believe users will come to rely more on voice commands in their interactions with such appliances. However, without specific naming conventions, speech recognition engines cannot determine which device, among many, the user is speaking to.

In this paper, we discuss the design of ubiquitous speech recognition appliances that use the eye gaze of the user to determine when to communicate. By augmenting ubiquitous devices with "eye contact" sensors that determine when the user looks at them, appliances obtain knowledge about the current engagement of a user with the device. Such information not only aids in the use of deictic references in speech interfaces, it also provides a significant source of information for determining when devices should *avoid* communications with their user [8]. We focus our discussion on a prototype light fixture called AuraLamp, a light fixture that listens to voice commands only when the user looks at it.

Visual Attention and Human Group Communication

We were in part motivated by work performed in the area of social psychology towards understanding the regulation of human multiparty communication. In human group conversation, attention is inherently a limited resource. Humans can only listen to, and absorb the message of one person at a time [1]. In group conversations, humans have resolved this conflict by allowing only one person to speak at any given time. By using nonverbal cues that convey attention, we achieve a remarkably efficient process of speaker exchange, or *turn taking* [1]. Turn taking provides a powerful metaphor for the regulation of communication with ubiquitous devices. According to Short et al. [9], as many as eight cues may be used to indicate an upcoming exchange of turns: completion of a grammatical clause; a socio-centric expression such as 'you know'; a drawl on the final syllable; a shift in pitch at the end of the clause; a drop in loudness; termination of gestures; relaxation of body position and the resumption of eye contact with a listener. In group conversations, only one of these cues indicates to *whom* the speaker may be yielding the floor: eye contact [12]. Eye contact indicates with about 82% percent accuracy whether a person is being spoken or listened to in four-person conversations [12]. When a speaker falls silent, and looks at a listener, this is perceived as an invitation to take the floor. According to a recent study, 49% of the reason why someone speaks may be explained by the amount of eye contact made with an interlocutor [10]. Humans use eye contact in the turn taking process for two reasons:

1) Eye fixations provide the most reliable indication of the target of a person's attention, including their conversational attention [12].
2) Eye contact is a *nonverbal visual* signal, one that can be used to negotiate turns without interrupting the *verbal auditory* channel.

In many cases, the eye gaze of the user, as an extra channel of input, provides an ideal candidate for ubiquitous devices to sense when their user is paying attention to them, or to another device or person. By tracking whether a user ignores or accepts requests for attention, interruptions by ubiquitous appliances can be made more subtle and sociable. As demonstrated by Maglio et al. in a Wizard of Oz experiment, when users interact with devices using a speech interface, they do indeed tend to look at the device at which the command is directed [4]. This principle is known as Look-to-Talk [6], and it allows for devices to deduce when to listen to the user.

AuraLamp

AuraLamp (Figure 1) illustrates an attentive gaze and speech enabled appliance, or *EyePliance* [7]. It is a lava lamp augmented with an eye contact sensor and speech recognition capability. By looking at the lamp, a person indicates attention to the device, thereby activating its speech engine. When the user does not look, its speech engine deactivates and does not listen to the user. This avoids problems of multiple appliances listening at the same time, removing ambiguity in user speech command interpretation. Since only one appliance is the active listener, users can use deictic references when referring to the device. Having only one of several appliances be the active listener allows the use of a single centralized speech recognition engine, as it greatly reduces the speech processing load for the total set of appliances. AuraLamp responds only to the two actions it is capable of – turning on and turning off. By switching the active speech recognition lexicon on the server to that of the EyePliance currently in focus, the accuracy of speech recognition is increased, while at the same time presenting the user with a small reusable vocabulary. AuraLamp is a model for how we may use visual attention with speech to interact with any household appliance. Each speech command in the lexicon is associated with an X10 home automation command. A serial interface routes these commands from the speech processing server to the electricity grid [13]. Over standard electrical wiring, the commands reach a simple controller unit capable of turning the appliance on or off. The X10 interface makes it easy to extend our interaction model to any appliance in the household.

Figure 1. *AuraLamp light fixture with embedded eye contact sensor.*

Sensing Eye Contact

AuraLamp senses the user's looking behavior through an embedded eye contact sensor mounted on top of the device. Eye contact sensors are cheap eye tracking input devices especially designed for the purpose of implementing Look-To-Talk with ubiquitous appliances. Unlike traditional eye trackers, their only requirement is to detect the user looking straight at the device. We designed a sensor that can be built for less than $500, consisting of a camera that finds pupils within its field of view using a simple computer vision algorithm [11] (see Figure 2). A set of infrared LEDs is mounted around the camera lens. When flashed, these produce a *bright pupil* reflection (*red eye* effect) in eyes within range. Another set of LEDs is mounted off-axis. Flashing these produces a similar image, with black pupils. By syncing the LEDs with the camera clock, a bright and dark pupil effect is produced in alternate fields of each video frame. A simple algorithm finds any eyes in front of the camera by subtracting the even and odd fields of each frame [5]. The LEDs also produce a reflection from the surface of the eyes. These appear near the center of the detected pupils when the onlooker is looking at the camera, allowing the detection of eye contact without *any* calibration. Eye contact sensors obtain information about the number and location of pupils, and whether these pupils are looking at the device. When mounted on a ubiquitous device, the current prototypes can sense eye contact at up to a distance of 2 meters.

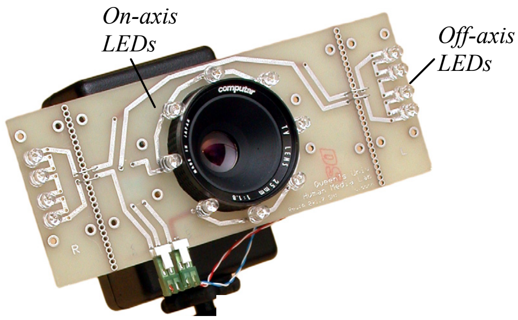

Figure 2. *Standalone eye contact sensor with camera lens and on-axis and off-axis illumination circuitry.*

By mounting multiple eye contact sensors on a single ubiquitous device, and by networking all eye contact sensors in a room, eye fixations can be tracked with great accuracy throughout the user's environment. When there are many people in the room, the number of devices actively listening is bounded by the number of people looking at devices. However, if a person looks at the device while another person is speaking, AuraLamp may incorrectly process the speech. By adding increased sensing capabilities to the room to determine who is looking, for example iris detection, proximity sensing, directional microphones and RFID tags, AuraLamp may be able to more accurately establish who is speaking, allowing it to determine whether it is the intended target of the spoken commands.

Our current prototype eye contact sensor is light and small enough to be attached to any household appliance (see Figure 1). In AuraLamp, the eye contact sensor is positioned on top of the light fixture, and has a visual range of approximately 40 degrees. Sensor data is sent over a TCP/IP connection to a system that synchronizes communications between a user and all EyePliances. This system, called EyeReason, also processes all speech from the user, interpreting it according to the lexicon of the currently attended device.

EyeReason

The EyeReason system coordinates communications among many EyePliances and the user by keeping track of user activity with each device. It operates as a centralized server that EyePliance clients such as AuraLamp may connect to. Devices report to the server whether a user is working with them by tracking manual interactions and eye contact. When the EyeReason system determines a device is in the focus of user attention, it raises the priority of communications between that device and the user. Typically, EyeReason allows the device with the highest priority to take the floor. When a speech recognition EyePliance such as AuraLamp takes the floor, EyeReason turns on its speech engine and switches the lexicon to that of the focus device. Figure 3 shows the EyeReason architecture. For each user, EyeReason maintains a list of connected devices.

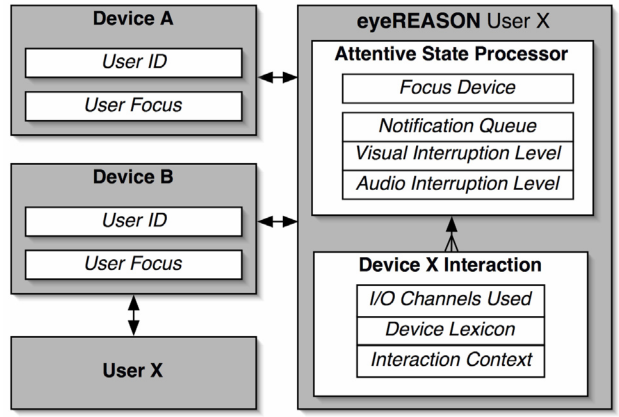

Figure 3*. EyeReason architecture.*

When a user interacts with a particular device for a prolonged period of time, the server determines that it is the focus device. Requests from competing devices to deliver information may be suppressed by the server, or routed to the focus device depending on the content of that information. In the case of incoming email, the server determines the priority of the message using a Bayesian model, similar to that employed by Horvitz in the Priorities System [2]. In the case of speech interaction, devices need to be in the focus of user attention before the system allows the user and device to converse. By opening and closing communication channels on the basis of Bayesian statistics of user-device interaction, EyeReason acts as a gatekeeper determining which device is allowed to take the floor. EyeReason thus provides a facility to coordinate communications among EyePliances by modeling user attention for devices and their communications. With AuraLamp, the EyeReason architecture simplifies the process of augmenting a standard appliance with gaze and speech capability. By embedding an eye contact sensor in an appliance and specifying an appropriate XML speech grammar, a device instantly becomes an EyePliance. If the appliance receives eye contact, a wireless headset processes speech commands using the XML lexicon specified in EyeReason to perform tasks which can either be processed through an X10 device, or directly interfaced into the appliance. If neither is possible, EyeReason still recognizes that a user is engaged with the device.

Gaze Activated Speech Lexicons

Because speech commands are processed through a centralized server, new forms of attentive interactivity are permitted without increasing the complexity of each appliance. With the Look-to-Talk paradigm as a foundation, EyeReason acts as more than just a gatekeeper for interactions with ubiquitous appliances. It integrates a speech recognition system that dynamically activates the control context of the device as the user shifts focus. The gaze actuated speech recognition encapsulated in EyeReason eliminates contextual ambiguity when interacting with a device via a voice channel. Since

EyeReason allocates voice control only to the EyePliances currently in focus, it allows duplicate voice grammar definitions across devices. EyeReason uses the Microsoft Speech API 5.1 SDK to implement these context-sensitive grammars through XML-based lexicons. Processing speech by AuraLamp through EyeReason involves two steps. First, the AuraLamp device driver detects activity information representing the attention of the user by polling the associated eye contact sensor over a TCP/IP connection. When a sufficient level of eye contact is detected, the driver loads the EyePliance's context specific grammar. When an EyePliance driver activates its grammar, EyeReason automatically deactivates grammars for EyePliances not in the focus of user attention.

OTHER EYEPLIANCE PROTOTYPES

We have developed a number of other EyePliance prototypes that form part of the EyeReason architecture. Apart from Look-To-Talk interfaces, these include appliances that use eye contact sensing in novel ways to streamline interactions with the user with a minimum of interruptive requests for attention. The Attentive TV uses an eye contact sensor to determine whether someone is watching it [7]. If nobody is watching, the TV pauses its feed. When the viewer returns, the program resumes. This concept can generalize to other devices that are fitted to use visual cues of attention to perform meaningful actions. EyeProxy [3] is an attentive desk-phone that consists of a pair of actuated eyeballs augmented with an eye contact sensor. The proxy acts as a surrogate for a remote person's eyes. It demonstrates how a device like a phone may request attention from its user by simulating eye contact, rather than by producing a disruptive auditory notification. When a remote person wishes to engage in a phone conversation with the user, EyeProxy conveys that person's interest by orienting its eyeballs towards the user's eyes. The user can pick up the phone by producing a prolonged fixation at the EyeProxy. If the user does not wish to answer the call, he simply looks away.

We are currently in the process of evaluating the principle of turn-taking EyePliances. Initial results are encouraging, suggesting that the use of eye contact sensing to regulate communications with ubiquitous appliances may in fact improve the efficiency of verbal interactions.

CONCLUSIONS

We presented AuraLamp, an attentive gaze and speech enabled appliance, or EyePliance. AuraLamp is a lava lamp augmented with an eye contact sensor and speech recognition capability. The lamp listens to simple voice commands such as "On" or "Off", but only when the user focuses his attention on the lamp. AuraLamp demonstrates how ubiquitous speech-enabled appliances may enter into a turn taking process with the user, allowing the use of deictic references to refer to any appliance. Focusing the active speech grammar to that of the currently active EyePliance increases speech recognition accuracy, while at the same time presenting the user with a small reusable vocabulary.

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The Ubiquitous Computing Resource Page (www.ucrp.org)

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ABSTRACT
Ubiquitous Computing is a field of research that is attracting increasing attention in academia, business and the general population. The International Conference on Ubiquitous Computing is an annual event that brings together members of the ubiquitous computing community to exchange ideas and share recent results. However, aside from the conference, and its archival proceedings, there are few resources that are available for learning more about the history, current state and future prospects for this exciting new field. We are building the Ubiquitous Computing Resource Page, which contains a collection of content from a wide variety of online sources, and organizes it along the dimensions of people, projects and organizations involved in this field. The web site will also provide mechanisms for the community to share information about news, events and other activities related to ubiquitous computing.

Keywords
Ubiquitous computing, information architecture, online resources.

INTRODUCTION
Ubiquitous Computing is a multidisciplinary field of research that explores computing technology as it moves beyond the desktop environment and becomes increasingly interwoven into the fabrics of our lives. The increasing power and decreasing size and cost of a variety of technologies enables computers to be carried, handheld, worn, or embedded in things, places and even people. The research issues in this field include the design, implementation and deployment of these technologies, as well as the impact these technologies have on people and society.

Since the early articulation of this new paradigm of computing by Mark Weiser [Weiser, 1991], and the pioneering work he led at Xerox PARC [Weiser & Brown, 1997], a large number of other people and organizations have engaged in research into ubiquitous computing. Over the years, a few workshops were held on ubiquitous computing, and related areas [Abowd & Schilit, 1997; Coen, 1998]; the field started reaching critical mass with the first Symposium on Handheld and Ubiquitous Computing [Gellersen, 1999], which has evolved into an annual, top-tier, international conference [Abowd, et al., 2001; Borriello & Holmquist, 2002].

The working papers and proceedings from the collection of events that have been convened for researchers in ubiquitous computing, as well as surveys of the field [Abowd & Mynatt, 2000] represent important resources for anyone wishing to learn more about the field. However, given the increasing availability and utility of online resources, we are creating an online repository of information about ubiquitous computing that augments these archival publications, focusing on the people, projects and organizations involved in the field.

RELATED WORK
Other fields have created online resources that provide considerable value to others in the communities exploring those fields. The field of human-computer interaction (HCI), for example, has the *HCI Bibliography: Human-Computer Interaction Resources* (www.hcibib.org, [Perlman, 1999]), which is organized into four major areas:

- Learn about HCI
- The Bibliography
- HCI Columns and News
- Developer Resources

These areas are then further subdivided into a multitude of subareas. According to information on the main page, the site has been accessed over 600,000 times since April 1998 (when the site was revised, having been created in 1988), and has performed over 1 million searches for its visitors.

A more specialized resource exists for researchers in the fields of Machine Learning and Case-Based Reasoning (www.aic.nrl.navy.mil/~aha/people.html). This page contains an alphabetized list of researchers, and their corresponding homepages, who are (or were) involved in machine learning and/or case-based reasoning. Although this resource is not as extensive as the HCI Bibliography, the listing of researchers – and their affiliations – provides a quick overview of who's who in the field.

An online resource for intelligent environments (www.research.microsoft.com/ierp) was created shortly after a symposium on that topic in 1998 [Coen, 1998]. This collection of material on projects, organizations, hardware and events relating to intelligent environments is clearly relevant to ubiquitous computing, but as it has not been maintained, it now represents a snapshot of the state of research in this area circa 1998-2000.

THE UBIQUITOUS COMPUTING RESOURCE PAGE

We are creating the ubiquitous computing resource page (UCRP), an online resource that can be used by researchers, educators, students, the press and the general public to learn more about the field of ubiquitous computing, to allow members of the community to share information easily outside of conferences, workshops and other gatherings, and to do so within a framework that allows easy maintenance via contributions from members of the community. The resource page is available at www.ucrp.org.

The development work is divided into two phases. The aim of phase I, collection development, is to assemble a collection of resources of sufficient size to attract members of the Ubiquitous Computing community. At present, the collection emphasizes breadth of coverage rather than depth and primarily focuses on people, projects, and organizations. The aim of phase II, community development, is to enable the collection of resources to be self-sustaining through peer review and discussion. At present, people may submit resources to a moderator for inclusion. In the future, we would like to move to an open model with rich opportunities for open-ended collaboration and collection development.

The UCRP has been implemented in ASP.NET using the Community/Portal starter kit[1]. The starter kit provides a variety of features for content management and online communities.

Resources are organized into the following categories: People, Projects, Organizations, UbiSites, News, and Events. These categories are now described.

People

Each person listed in the UCRP is represented by their name, affiliation and publications. The person's name is linked to their homepage, the affiliation is listed, and publications are represented by links to other resources (currently the ACM Digital Library, www.acm.org/dl, and the DBLP Bibliography Server, www.informatik.uni-trier.de/~ley/db/index.html).

We have seeded the resource with members of the UbiComp 2003 Conference & Program Committees. The resource page is now open to any person who wishes to add themselves to the listing or submit resources. The site is moderated to prevent abuse.

Projects

Each project listed in the UCRP is labeled with its name, which is linked to the project homepage, and a brief description of the project, copied or adapted from text on the project home page or from a publication associated with the project. The space limitation is intended to ease scrolling through the list of all projects, which are listed in alphabetical order.

Although we have considered adding links to both people and organizations associated with the projects (unidirectional or bidirectional), our initial version does not have such links, in order to simplify the initial organization and subsequent maintenance of the collection.

We have further simplified the ontology represented by this collection by including large-scale initiatives – that incorporate many projects, sometimes from many organizations – in the list of "projects". Thus our notion of projects spans a broad range of endeavors by researchers in ubiquitous computing.

Organizations

Organizations represent another category that has varying levels of granularity (as with projects and initiatives). For example, academic researchers are associated with their university, their school, their department, and any number of centers or groups or labs. Academic researchers with joint appointments have even more options, and researchers who have joint appointments across industry and academia have even more options.

While representing a hierarchical organization structure in the UCRP that reflects the organizations in the ubiquitous computing community would be ideal, we believe the maintenance of such a structure would be burdensome, and so we are currently implementing a flat organizational structure.

UbiSites

UbiSites is a generic term used for resources that fall outside projects and organizations but do have potential relevance to those interested in UbiComp. Example UbiSites include previous resource lists, online publications, and recommended reading lists. UbiSites are open to submission and are moderated.

News

News items can be posted on the UCRP, with a title, brief textual description, and link to the source of the news item. Currently, only administrators may post news items, but we hope to soon allow anyone to submit a proposed news item to a moderator, and eventually to have the system be more self-regulated (for news, and in general).

[1] Community/Portal starter kit is available at http://asp.net/Default.aspx?tabindex=9&tabid=47

Events

Events of interest are currently associated with a calendar on the UCRP. Events include such things as conferences, workshops and events of interest to the community. As with news items, events may be submitted to a moderator for consideration.

Other Resources

While we hope the UCRP becomes the primary online resource for the field of ubiquitous computing, there are a number of other resources developed by other people and organizations that will continue to be useful to the community. We will link to these resources from the UCRP (and hope the UCRP, in turn, is linked to from them).

DISCUSSION

Methods used to gather resources include such popular search engines as Google, Teoma, and Vivisimo as well as online publication databases such as DBLP and the ACM Bibliography. Initial search results have revealed previous attempts to create a UbiComp Webpage bibliography or resource list, but most sites represent a small area or time-frame in the last five years, rather than a living collection.

There are a variety of community features provided by the ASP.NET framework, which, for example, allow discussions, newsletter generation, e-mail updates, enable content to be syndicated with RSS, enable use of Web Services, and so on. As we gain experience with the UCRP, we hope to explore such features with the aim of developing a self-sustaining community.

Ubicomp.org, the Home Page for the *Annual Conference on Ubiquitous Computing*, has many features that are intended to foster online community awareness and discussion, through its Community Directory and Discussion Forums sections. We hope to work with the webmaster so that the UCRP and ubicomp.org can complement each other effectively. Ubicomp.org has traditionally provided support for the conference, whereas we hope ucrp.org will provide greater continuity and persistence, and prove to be a valuable resource for a broader population.

One of our most basic challenges has been the determination of whether a resource is indeed related to ubiquitous computing. With so many definitions and terms – ubiquitous, pervasive, disappearing, sentient, ambient – it is difficult to characterize what is *not* an example of ubiquitous computing. We hope the UCRP will serve as a forum for discussing the very definition of ubiquitous computing.

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Proactive Displays & The Experience UbiComp Project

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ABSTRACT

The proliferation of sensing and display technologies creates opportunities for *proactive displays* that can sense and respond appropriately to the people and activities taking place in their vicinity. A conference provides an ideal context in which to explore the use of proactive displays, as attendees come together for the purpose of *mutual revelation*, eager both to learn more about others and what others are doing and to tell others about themselves and what they are doing. We will deploy a suite of proactive display applications that can aid and abet this desire for mutual revelation in the context of a paper presentation session, a demonstration and poster session, and informal break areas at the conference.

Keywords

Ubiquitous computing, proactive computing, human-computer interaction, computer-supported cooperative work, social computing, community computing, RFID, public displays, ambient displays.

INTRODUCTION

Computer displays are proliferating, as the technology advances and the costs decrease, showing up in an increasing variety of physical contexts, such as airports and train stations, retail stores and even billboards along the roads [Barrows, 2002]. At the same time, sensing technologies are also proliferating, from sophisticated multi-purpose sensors [Kahn, *et al.*, 1999, Gellersen, *et al.*, 2003] to rather simple radio frequency identification (RFID) tags and associated readers. We have begun to explore how these two trends may converge to create opportunities for *proactive displays* that can sense their context – nearby objects, people and/or activities – and respond with appropriate content.

Any proactive display application must address a number of research challenges:

- What *contexts* are most amenable to the successful deployment of a proactive display?
- What kinds of *content* are best suited to the context(s) in which the displays are situated?
- What levels of *interaction* are most appropriate to the content and context of use?

People are increasingly concerned about the privacy of their digital information, and their concerns are being magnified by the proliferation of sensing technologies [cf. Chai & Shim, 2003]. Thus, proactive display applications must represent a compelling value proposition in order to succeed, providing enough benefit to overcome concerns about the use of digital information in physical contexts beyond the desktop. We believe that a conference provides a setting in which such value propositions can be articulated and demonstrated

Conference attendees typically share the goal of *mutual revelation*: seeking to learn more about others and their work, as well as being open to opportunities to tell others about themselves and their own work. Attendees also routinely reveal some information about themselves – such as their names and the institutions with which they are affiliated – through conference registration forms before the conference and badges they wear at the conference. We seek to facilitate the process of mutual revelation using technology, while minimizing disruption or deviation from common practices of conference attendees.

The International Conference on Ubiquitous Computing is particularly well-suited for a deployment of proactive display applications, where attendees' familiarity with sensing technologies is likely to reduce the fear of the unknown, and increase their openness to participating in experiments with this kind of technology.

COMMON INFRASTRUCTURE

All of the applications we will deploy at UbiComp 2003 share a common infrastructure.

RFID Tags & Readers

Conference attendees will receive, as part of the registration packets they receive onsite, passive RFID tags that they can insert into their regular conference badges. Printed information about the information associated with the tag, the applications deployed at the conference, and the privacy policy regarding any information collected throughout the conference, will be included with the packets (and available via all online registration pages). Each proactive display installation will have at least one RFID tag reader associated with it, to allow it to sense the tags worn by the conference attendees nearby. Our current system utilizes the Alien Technology 915 MHz readers and tags. We may make provision for the inclusion of other sensing technology and/or communication protocols, such as Bluetooth [cf. Want, *et al.*, 2002].

Application Clients & Servers

The RFID reader for each application will be connected to a local computer, which will run the application and access a server containing both profile information about the attendees as well as other sources of content that might be shown on the proactive display. The profiles will reside on a central server so that any updates made during the conference can be propagated immediately to the different client applications. Each application client will provide the capability for an administrator to stop the application, in case of unexpected and unwanted behavior.

Profile Creation & Maintenance

Conference attendees will be given the option to opt-in to any / all of the proactive display applications by creating profiles during the registration process. No information will be used in proactive display applications unless an attendee provides explicit consent to use that information. Attendees will be also be given the option of creating or modifying their profiles during the conference at a computer adjacent to the conference registration table, and at one or more kiosks in the Demonstration & Posters area of the conference.

PROACTIVE DISPLAY APPLICATIONS FOR UBICOMP

We plan to deploy three applications at the conference: *AutoSpeakerID*, which displays the picture, name and affiliation of a person asking a question at the microphone during a question & answer period following a paper or panel presentation; *Ticket2Talk*, which displays explicitly specified content (a “ticket to talk” [Sacks, 1992]) for any single person as he or she approaches a proactive display in the coffee break area; and *Neighborhood Window*, which displays a visualization of implicit or “discovered” content (from explicitly provided homepage information) for a group of people who are in the neighborhood of a proactive display in an informal, open area at the conference. These applications are described in more detail in the sections below.

AutoSpeakerID

After a paper presentation during UbiComp (and other conferences), people often approach a microphone stand in the audience to ask questions about the work described in the presentation. Everyone in the audience knows who the presenter is, but don’t always know much about the person asking the question. A diligent session chair may remind the questioner to state his or her name & affiliation, but this is often not the case, and even when encouraged to identify themselves, questioners’ names or affiliations may not be heard clearly by others in the audience (especially if the questioner is hurrying to get to his or her question).

Since conference attendees ought to be prepared to state their name and affiliations, verbally, anytime they rise to ask a question during a paper (or panel) presentation, we propose to augment this common practice by using a proactive display as a visual aid. An RFID reader at the microphone stand will identify the RFID tag worn by the person approaching the microphone, and communicate this to the AutoSpeakerID application which will, in turn, display a picture of the person, along with his or her name and affiliation, on a display near the front of the room.

Those who do not wish to have their profile information displayed when they approach a microphone stand can either opt out of participating at registration time or at any point during the conference using a kiosk in the registration area, or may simply either remove the RFID tag from their badge or leave their badge at their seat when they go to ask the question. They may also, of course, choose to “game” the system by wearing another person’s tag.

We are, with this application and the others, very eager to learn whether, how and why people participate in the system.

Ticket2Talk

A paper / panel presentation session is a rather formal context in which to deploy a proactive display. We also have applications we plan to deploy in more informal contexts, such as a break area or a demo or poster session.

One such application is Ticket2Talk, which will run on a large plasma display – in a portrait mode orientation [cf. Churchill, *et al*., 2003] – and cycle through visual content explicitly contributed by attendees that represent “tickets to talk”: some visual marker for a topic about which the attendee would be happy to talk with someone. This may be a research poster the attendee is presenting at this, or another, conference, the cover of a recently published book, a picture of a favorite pet, vacation spot or piece of art.

The ticket to talk will be displayed in the central region of the screen, with a picture and name of the attendee who posted the ticket to talk appearing at the top, and a collection of thumbnail pictures & names of other people whose RFID tags have been detected near the display appearing in a row at the bottom. Each image will be selected for display based on a priority determined by both the recency of the attendee’s badge being detected (higher priority for more recently sighted badges) and the recency of the attendee’s ticket having been shown (higher priority for less recently displayed tickets). Images will be displayed for a preset interval, probably in the range of 5 to 10 seconds. There will also be a time limit on the duration for which a ticket might be in the queue of potential content to display: although we want to focus on content for those currently gathered nearby, we also might maintain a small amount of “history” about people who have passed by recently.

We will deploy this proactive display next to a table used for a coffee urn during a break. The serial nature of the movement of people through the line will correspond to the sequencing of tickets, providing each person who comes through the line – who has chosen to participate – an opportunity to both learn more about those nearby in the line and allow those same people to learn more about him or her.

The goal of this application (and Neighborhood Window) is to provide opportunities for conversation for attendees who do not already know each other. However, we also want to ensure *plausible ignoreability*, i.e., no one should feel compelled to strike up conversation with a fellow attendee who happens to be nearby. By cycling through content, one can simply notice the stream of tickets, without acting on any particular one. Even if the opportunity for direct conversation is not taken, we expect that the displays will contribute to raising the level of awareness about other attendees' interests – helping people learn things about their colleagues that they may later choose to act on (e.g., at a demonstration or poster session, or the conference reception).

Neighborhood Window

Another context in which we plan to explore the utility of proactive displays in a conference setting is the demonstration and poster session. Attendees often mill about such a session, forming ad-hoc groups as they cluster around a demonstration or poster of interest. The Neighborhood Window application will display a visualization of interests of those in its vicinity, based on the collection of words found on their respective homepages.

Although we could simply run the Ticket2Talk application on a display in the demonstration and poster session, we want to take advantage of this context to explore other dimensions of proactive display applications (and people's experience with them). Neighborhood Window utilizes *implicit* or latent profile information that can be attained through attendees' explicit profiles, and generates visualizations of this content based on the group that is nearby.

In addition to offering attendees the capability of providing their pictures, names, affiliations and/or tickets to talk, we also offer them the option of providing a link to their homepages in the registration process. An offline application then analyzes the content of their homepages, collecting words and phrases, and constructing a profile vector that can be used to select content that is likely to represent interests shared by those near the display, but not widely shared among the more general population.

For example, two UbiComp attendees approaching the urn may have references to "motes" or "ambient displays" on their homepages, and these phrases may be highlighted in the visualization that depicts people's names, associated words and phrases, and the links between them. Our goal is to provide opportunities for attendees to start topical conversations, or at least become more aware of the interests they share with others in the community.

EVALUATION

Our goal is to introduce technology to bridge the gap between people's digital profiles and their presence in the physical world to enhance the conference experience for all. We are assuming that the applications we have designed will have a positive impact, but we will be carefully assessing the experience at the conference, to see how these applications impact attendees' experience – and why.

We want to allow others to learn from our experience, so that the community as a whole may be able to better design future proactive display applications, and other types of applications that seek to enhance the experience of groups of people using information from digital profiles.

Our plan is to collect data using both qualitative and quantitative methods. Observations and on-site interviews will be conducted throughout the conference. This data will then be coded and evaluated for trends and themes in interaction. A follow-up questionnaire will also be conducted to gauge the impact of the proactive displays on the attendees' overall conference experience, and to identify areas for further research and development.

RELATED WORK

Previous work [Woodruff, *et al.*, 2001] has explored the use of technologies to encourage conversations among small groups during museum visits; we are seeking to broaden the context and scope of people who might engage in conversation, and to use situated, peripheral displays rather than handheld devices. Other researchers have explored the use of ambient displays [Mankoff, *et al.*, 2003; Weiser & Brown, 1997] and other forms of public displays [O'Hara, *et al.*, 2003]. We seek to extend this work through the use of sensing technologies (in this case, RFID) that enable to public displays to be more proactive – responding to the people nearby, as well as other elements of the local context.

GROUPCAST [McCarthy, *et al.*, 2001] is an earlier application that runs on a large display that responds to the people nearby. However, GROUPCAST ran in a corporate environment where all the passersby were members of the same company (indeed, most were members of the same research group within the organization), and had profiles for approximately 20 people. We seek to extend this work by deploying applications in a less restricted context, with a much larger number of people from multiple organizations.

There has also been some other, promising, research into the use of technology to enhance the conference experience for attendees. The Intellibadge system [Kindratenko, *et al.*, 2003] included a suite of visualization applications based on aggregate information collected through active radio frequency (RF) tags worn by approximately 20% of the attendees of the SC 2002 conference. As an example, one application showed the distribution of interests among the people attending each parallel session (e.g., the number of compiler people vs. middleware people, etc.). Our work explores applications that directly react to the small number of people in the vicinity of the displays, rather than showing more general, aggregate data regarding the overall conference population.

nTAGs (http://www.ntag.com, see also Borovoy, *et al.*, [1998]) are devices that include infrared and radio frequency communication capabilities, as well as a small display and buttons for interaction. These devices have also been deployed at a conference, with a similar goal as our work (creating conversation opportunities and raising mutual awareness among the people attending the conference). We believe that the use of large, situated displays that react to RFID tags embedded in ordinary conference badges worn by attendees fits more closely into existing practices at conferences. Also, showing content that may spark conversations on a peripheral display leaves more room for plausible ignoreability – it is easier to glance at (and ignore) a display on the periphery than to ignore content shown on a display worn by a person in front of you – and thus will engender different types of interactions (and reactions) among the conference attendees.

Yet another approach to enhancing the conference experience is being explored by SpotMe Conference Navigator (http://www.spotme.ch), a handheld device that people can use to detect other devices used by attendees with similar interests. The profiles used by SpotMe contain many of the same elements as the profiles we have designed, but as with the nTags, we believe that using a handheld device is less proactive, and deviates further from existing conference practices, than the use of displays that may show content on the periphery of attention.

One of the reasons we are planning on extensive evaluations during and after the conference is to facilitate our ability to compare experiences with Proactive Displays with experiences with other technologies and approaches at other conferences.

CONCLUSION

We have designed a suite of proactive display applications intended to enhance the conference experience for attendees by providing conversation opportunities and fostering greater awareness among the community. UbiComp 2003, as a community that is exploring the use and implications of new display and sensing technologies, will provide an ideal venue in which to deploy these applications, assess their impact, and further the research agenda in this area.

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Networking Pets and People

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ABSTRACT

I believe that ubiquitous computing can offer more than just an interface for humans and digital information. I propose that we can now introduce the other beings that share our houses to our technology. In this paper, I will describe a mechanism for networking a interactive cat toy to be accessed from anywhere on the internet. The World-Wide Web is primarily perceived as information space but can also be considered as activity space. With this device a pet can be interacted with from anywhere in the globe through a browser window.

Keywords

network, cat toy, pet, interactive, remote, shelter, feeding

INTRODUCTION

When we think of ubiquitous computing we often think of humans linking to computers, humans to humans and/or computers to computers. What about the millions of other living things sharing our living space that we call pets? This project is an attempt to provide a network node for pets and pet owners to interact over the internet.

This may seem like a bizarre proposition but ask any pet lover if they wish they could play with their pet from work or check up on them while traveling. A human beings devotion to their pet often borders on a parent child relationship.

Besides allowing pet owners to play with pets from home I also see the network being deployed in animal shelters as an online marketing tool to get publicity for animals. Hopefully by luring people to play with dispossessed animals over the internet animal-human connections will be made and pet adoption rates will increase.

Consider that the toy will have to be designed for optimal animal interaction. It's not just a toy but an animal interface center, a pet equivalent to a monitor and keyboard. Which brings us to another point. If all the nodes are linked for two way communication on the network then stay at home cats could conceivably play with each other via the network .

Humanitarian Considerations

It's fun to think of playing with a pet while traveling, keeping an eye on your cat while you are away is a longing for most dedicated cat owners. The parental guilt felt when leaving Fluffy at home is considerable but relieving the stress of a pet owner is only a fraction of the intended purpose for this device. The initial goal of the Networked Cat Toy is to provide a conduit for interacting with animals stuck in shelters. The device is not ment to be a surrogate for actual human contact but rather a first contact mechanism. I can imagine people talking about the adorable kitten they played with on the internet the other day and perhaps developing an initial attachment that way that would lead to adoption, or volunteering or a web based cash donation.

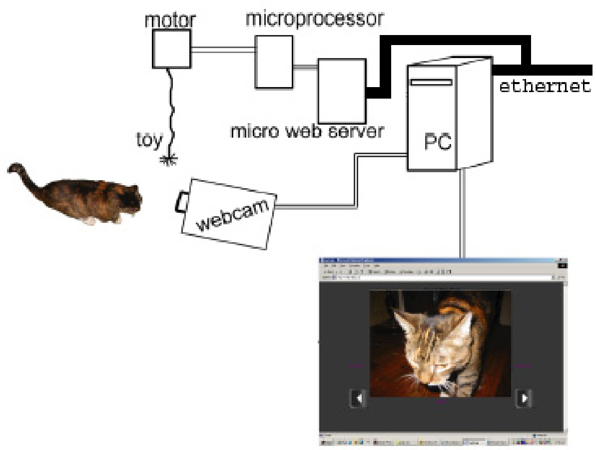
What it does

This prototype allows the user to play with a house, or shelter bound animal while at school or at work. The live webcam feed providees visual feedback while playing with the cat and the feeder can also be used to feed the cat while the owner is on vacation.

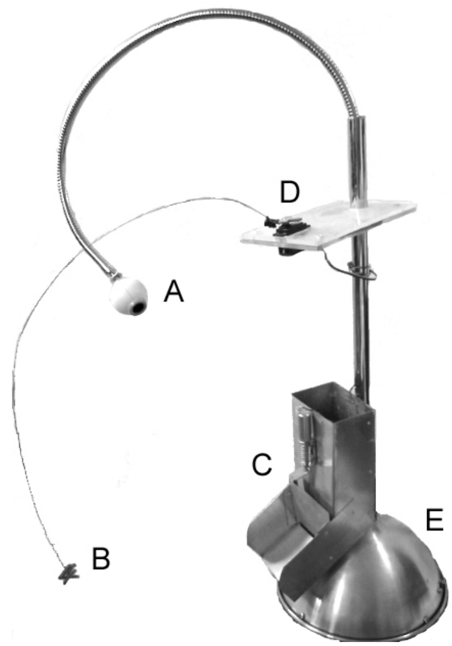
System

The system (fig.1) is centered around an embedded network device that takes messages from internet browsers and transmits them to events in the real world. Clicking on a link in the web page can make the toy move or the feeder feed. The web cam simply sends a live video image so the user can see that the cat is being fed of playing with the toy.

The prototype as it is now requires a microprocessor and embedded network device, a PC and a webcam. A microcontroller is basically a very small, simple computer that can be programmed to control simple tasks. An embedded network device, depending on manufacturer, allows a microcontroller to be accessed and controlled over a broadband internet connection, like DSL or cable. A PC is used in this prototype soley as a means to network a video camera. In future versions the camera and microcontroller will be integrated into the micro web server.



Technology Prototype Fig. 2



Physical Prototype Fig. 2

Physical Design

The device (fig. 2) is designed with a flexible camera mounting (A) which allows the user to configure the view of the feeding mechanism (C) or toy (B). The user moves the cat toy through a servo motor (D) mounted on a moveable platform mounted to a central post. A network device functioning as a micro webserver and interfaced to a microcontroller is contained in the weighted base (E)

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Responsive Doors

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ABSTRACT
Responsive Doors is an ambient computer display system embedded in common doors. It is designed to optimize the behavior of people in relation to air quality. The project is situated at boundaries between climates, specifically doors. There, air quality information is well contextualized because users are about to enter a place with a potentially better or worse climate. Applications for the door display include places which generate hazardous materials or pollution, but also places with poor air quality due to high human occupancy and poor ventilation. The Responsive Door displays massive sets of CO2 data collected on both sides of a door. The display itself is embedded in the door. On the display, color-coded (red and blue) concentric wedges grow and shrink from 0 to 180 degrees to reflect CO2 levels of each correspondingly color-coded (red and blue) side of the door. The constant changes of the CO2 ratio drive animations which rotate the wedges around the center of the diagram constantly like arms of a scale. The wider wedges (higher CO_2) rotate to the bottom half of the display and narrower wedges (lower CO_2) rotate to the top half of the diagram. The resulting motions draw attention to the diagram only when a change in air quality occurs.

Keywords
Media Art, Visualization, Information Display, Air Quality, Contextual Computing.

INTRODUCTION
My original research project proposed to investigate two key questions:

- Are computers limited to delivering quantitative information, or can they deliver values such as ambiance, community, poetry, reflection, luxury and comfort?
- Which types of interfaces and which types of content can motivate the distribution of digital content beyond the gray box of the desktop computer?

Methods
I approached these questions in three creative research projects, PING (2000-2001), Oxygen Flute (2001-2002), and Responsive Doors (2001-2003). These projects were based on previous dynamic art projects, especially "Homage to New York, 1969, by Jean Tinguely and Billy Kluver, and "Mori", 2000, by Ken Goldberg et al.

Coming from art practice, my research method is to build an instance of an idea, to present that instance to visitors in a public context such as a museum, and to collect feedback from visitors and from personal observation. This feedback informs the questions and ideas which lead to the next idea. I conducted the research "genetically", in the sense that each project created a subsequent child project, which was more successfully answering my research question than its parent. While this method lacks scientific evaluation rigor, it affords much flexibility and responsiveness: It allows for a reframing of initial research questions, and also for the integration of positive results and useful observations on subjects we did not intent to study.

Responsive Doors is an ambient computer display system designed to optimize the behavior of people in relation to air quality. To inspire behavior optimization without being didactic, we developed a very light, almost playful system which gently organizes people in two team situations (inside the door and outside the door) and measures and compares their air consumption. The consumption ratio is displayed in an animated graph. The graph is calm, but animates vividly when better air quality switches from one side of the door to the other. This animation dramatizes the ambient display by emphasizing the ratio of two comparable sources of data rather than displaying the progression of only one source of data.

The Responsive Door consists of five elements: A door to a room, a transparent, passive-light, LCD display[1] mounted in the door like a "data widow", a pair of CO2 sensors attached inside and outside the door, and a networked CPU. The CO2 sensors continuously transmit CO2 data from inside and outside the room to the CPU. The CPU collects this data and averages it over several time spans, such as 1 second, 30 seconds, 1 minute, 5 minutes, 1 hour,

[1] This display was developed specifically for this project by Greg Niemeyer. We described it in earlier grant papers as a digital stained glass window. This display is also a part of the Responsive Door Patent Application.

1 day, 1 week and 1 year. The average data generates an innovative graphic which displays the CO2 values inside and outside as segments of a ring. The display is animated, changes in the levels of CO2 generate an action surplus, an animation which dramatizes the change of levels and displays which climate, the indoor or the outdoor climate, features better air.

The subtle drama of the graphics is designed to reflect the subtle, but increasingly vital question of air quality. In office settings, air quality is a significant factor in productivity, and the Responsive Door device can inform people about this question in an ambient, intuitive and aesthetic fashion. The Responsive Door Device could also improve monitoring of air quality conditions in heavy industry settings, where CO2 deprivation or other air quality factors can lead to fatigue and fatal accidents. Even in a home setting, a front door with a Responsive Door device could enhance behavior: the device could inform occupants of the need to let in fresh air, or it could inspire them to bike to work on a day where air quality is poor outdoors.

Discussion

The relevant advantage of the Responsive Door device over normal air quality meters is the dramatized comparison between two sets of data. Traditional sensors answer the question: What is the air quality in parts per million of CO2. This device answers the question: Which side of the door has better air, or will "win the air quality battle"? That question is much more accessible for most audiences, and also leads to more effective modifications of behaviors. Nobody wants to be on the losing side of the battle.

The basic concept is to use game and entertainment principles as well as narrative strategies to engage viewers in the consideration of fairly dry data. The main purpose of narratives is to make information interesting, engaging and memorable, but most narratives deal with static information. Information technology can make stories out of real time information in real time. Thereby, our highly developed sense of understanding stories can be invested in understanding difficult and abstract sets of data very directly.

This observation requires further studies as it provides a connection between traditional media, such as television, and information technology. In combining the two, dramatic renderings of real-time data could become the news of the future, and new media technology would be much more invested in the authoring of media content. In games, and particularly in pervasive games, players can generate narratives for information they acquire as the game unfolds. The narrative itself is an emerging history which makes information relevant and memorable. Immediate applications of this concept are also conceivable for financial markets, where large sets of data often confuse observers, and the dramatic representation of such sets of data in real time would provide observers with rapid cognition and therefore, competitive advantages.

Conclusion

This project has not been extensively tested at this time. First observations confirm that information can generate non-quantitative values such as ambiance, community, poetry, reflection, luxury and comfort if the interfaces for input and output are carefully tailored to non-quantitative interpretations of the information in question.

The question of developing such interfaces touches on three traditional areas of the arts in addition to the technology: Drama, Architecture, and the Visual Arts.

Qualities of such interfaces include the action surplus, coupling, and responsiveness. Action surplus is the amplification a system provides for a user action. Action surplus can exceed, match or disappoint the user. Coupling is the presentation of intangible information with several tangible means, such as image and sound. Coupling can be too explicit and feel didactic, too vague and feel confusing, or "just right" and feel self-evident (no manual or wall label needed). Responsiveness is the speed of the interaction between a human body and a system. Responsiveness can be too slow: then it makes users think the system is dull. It can bee too fast: then users feel the system is too hard to control. It can be "just right" and in sync with human response rates and other patterns relevant to the human sensory system. Then, users feel the system is an extension of their own bodies, or even can feel the system as being "alive".

Resulting "just right" interfaces are specific to the types of information provided. One general problem with information technology is that the standard interface is not tailored to specific types of content. The resulting interface is not particularly well matched with any type of content, it is usually bland. Often, interfaces are also not thoughtfully contextualized within the environment of the interface. Artists and designers can help solve this problem by matching interfaces to content more deliberately, with greater aesthetic variation and with more consideration for the changing relation between a device, its interface and its context. For example, windows for different programs on a PC could look distinct, they do not all have the same fonts, frames and borders. Windows could also look different depending on the location of a computer: why does an interface look the same in Toronto as it looks in Tijuana?

The Responsive Door is a possible candidate for of a successful match between content and interface. A door regulates indoor and outdoor relations. It is therefore a good site to place a device (coupling) which describes air quality inside and outside. The display itself is well matched to the door, with blue elements describing the blue side of the door and red elements describing the red side of the door. The responsiveness of the system to changes matches that of the expected dissipation of air in a room. Neither irritating nor dull, the display elegantly draws the user's attention only if there is a dramatic change in air quality.

In conclusion, I think that the viability of using information technology for non-quantitative purposes depends on the degree to which the interface connects humans to information on human terms.

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Squeeze Me: A Portable Biofeedback Device for Children

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ABSTRACT

Squeeze Me is a squishy portable biofeedback device for children ages 8 to 11 that are experiencing stress related to a medical condition or treatment. It takes physiological input from hand temperature and pressure (sensors), and outputs a light pattern that helps the child initiate a relaxing and entertaining activity. By helping a child understand and manage his or her medical related stress symptoms, *Squeeze Me* empowers a child who is faced with a potentially intimidating experience. *Squeeze Me* can be used in a range of environments (home, school and the hospital) because it is portable.

Keywords

Children, biofeedback, physiology, emotions, personal care, stress

PROJECT STATEMENT

The idea for *Squeeze Me* originated during a course using technology to help patients in the Montefiore Children's Hospital in Bronx, New York. Montefiore is a high-tech children's hospital that aims to provide patients with high quality medical care in an environment that encourages learning and exploration. There are no traditional waiting rooms, no infamous hospital smells or sparse and sterile looking areas at Montefiore. Each floor is designed and decorated for specific age groups. Each patient bed is equipped with plasma screens and wireless keyboards so that patients may browse the web and watch TV and movies on-demand.

Our team became interested in developing a playful and therapeutic experience for children who are chronically or temporarily ill. As we observed the hospital environment and heard about the typical experiences of patients, we were told about the stresses involved with hospital stays and treatments. For example, the hospital serves a number of dialysis patients who visit on a regular basis and often have long, boring waiting experiences during the course of treatment. Despite Montefiore's unusually humane approach to the hospital experience, there were such unavoidable waiting periods. The wait time and boredom only add to the children's existing anxiety and stress arising from their condition. Existing forms of entertainment and play for the children were limited to TV (Jerry Springer being the most popular show), toys and a few online learning applications, which seemed to act mainly as distractions. We saw the opportunity to empower these children, and wanted to give them a personal device that would aid them in recognizing their stresses and working to relieve them.

After some brief research into non-invasive stress relief options for children, we chose to pursue a biofeedback experience that would offer both information and a self-care option to the patients.

Current State of Bio-Feedback

The human organism maintains itself through homeostatic mechanisms. The major means utilized to maintain balance among these mechanisms is feedback control [1]. Biofeedback is a process in which a subject receives information about his or her physiological state. This information can be used by the subject to understand, monitor and manage his or her emotional and physical states. The most common readings for biofeedback are EMG (muscle tension) and hand or foot temperature.

Biofeedback procedures are often cumbersome, may be somewhat invasive and typically require a desktop computer. Probes are attached to various areas of the body (neck, sphincter, wrist or frontal lobes). Current biofeedback devices are typically used in a doctor's office and are administered by a doctor or biofeedback practitioner. The patients are taught exercises to help manage their state while receiving visual and/or auditory feedback. Exercises learned in sessions can be continued anywhere, but without the equipment there usually no feedback device that lets the user know if their work is making a difference.

Divergence: *Squeeze Me*

Our intent was to create a personalized, portable "buddy" that helps a child understand and monitor his or her condition, and potentially guide them through exercises if needed. We did not want our device to resemble systems typically found in biofeedback programs, such as linear narrative or reward based feedback. *Squeeze Me* offers children a direct and immediate connection between the feelings they are experiencing and the feedback displayed to them. With *Squeez eMe,* feedback about the user's current physiology is given using varying colored LEDs that light in groups or patterned sequences. A skin temperature reading is triggered when the starfish is held and contact is made with the surface mounted thermistor. Based on that reading (which is continuous) LEDs of a specific color appear (blue for cool, green for normal, yellow for slightly warm and red for warm). If the child squeezes a leg of the starfish, the color temperature feedback display shuts off and is replaced with multi-colored light patterns, reflecting the child's hand pressure. The patterns can then guide a child through breathing exercises. The continuous readings and feedback allow the child to see if the exercises are working. Through repetition of the exercises, focused concentration on the activity and the visual and tactile appeal of the device, the child may be calmed and/or distracted, with the likely result of reduced stress.

The portable device does not require a child to be tethered to a computer, giving him or her freedom to play in a relaxing environment. It would also allow children to share what they have learned and compare their bio-readings.

PROCESS

Audience selection

After researching the characteristics of various age groups we focused on ages 8- 11. Children of this age are able to connect cause and effect, and capable of logical and organized thought. [2] For this reason, we believed this age to be ready to learn more about their bodies, and able to conduct self care activities. Research in the current toy market reflected that this age group seems to be maturing away from babyish toys, but is still playful and curious and interested in natural forms.

Biofeedback consultation & research

In parallel to audience research, we investigated the current state of non-invasive biofeedback applications for children. We consulted with a pediatrician to understand the medical perspective on biofeedback. Her guidance led us to focus on a soothing and entertaining application and steer away from a traditional therapeutic application. Most of what exists she felt was dumbed down and not engaging for children. She also advised considering more general feedback, rather than quantitative (e.g. temperature). The staff at Montefiore also agreed with this sentiment, as they felt high temperature readings in particular might cause heightened stress in a child who was already ill and anxious. We then consulted with a child psychologist who uses biofeedback, to understand her typical practices and patient needs. Subsequent web-based research provided us with examples of screen-based applications that were narrative or generally game-like.

After evaluating what we learned about current practices, we critiqued the existing methods, and held several brainstorming sessions about characteristics we thought could improve upon existing solutions. We developed a few general concepts and then discussed those with peers, classmates, and instructors. We then presented one to the Montefiore hospital staff, including teen-aged volunteers who worked closely with patients in our age range, and who in some cases had previously been patients themselves. We focused in on the handheld, light based feedback features, to allow children portability and also to offer clear but non-distracting feedback (sound and music were considered as feedback but identified as potentially disruptive in a hospital setting). Other concepts included a screen projector or installation for visual feedback and pulsing sound based feedback as well as some networked application to allow the devices to communicate with each other.

Design of form and interaction

Shape, materials and interaction design happened in parallel and simultaneous phases. Our team began materials research and quickly identified rubber for the object body. We'd evaluated popular toys among our age group earlier in our process and recognized that squishy matter was popular among our audience. Thus we wanted to offer an inviting, touchable surface that would allow for squeezing.

We developed several prototype shapes, including both abstract and representative shapes in different silicone hardness. We tested the shapes with our classmates initially to determine if certain shapes were more hand-friendly than others. We focused on an apple and several shells, as those seemed to be the easiest to hold. With some basic functionality -- light based feedback responding to hand temperature -- implanted into the molds; we then tested more extensively with several children in our target age range.

The children responded well to the sticky and squishy traits of the *Dragon Skin* and favored the shells for shape. They also enjoyed seeing the lights respond to their touch. Many children tested the limits of our prototypes, squeezing as hard as they possibly could. A few commented that they wanted to see a response to their squeeze in addition to their hand temperature. (This made sense in context of children without stress symptoms using the device) With these observations, we decided to pursue both temperature and hand pressure feedback for our project. We also discovered that this age group liked a range of colored lights. One child did remark that he wanted to see his exact temperature. Since *SqueezeMe* is not intended to be a thermometer, but instead a general indicator, we noted the feedback, but thought this feedback was not enough to make it a development priority.

The shape was still in question, as we'd not received much detailed feedback in that direction from the testing. We then asked several children in our target age group to play with some *Sculpy* clay. Their assignment was to create as many shapes as they wanted. The only requirement was that the shape be something they would like to hold, carry around with them, and play with whether they felt well or sick. All of the shapes produced were animal related -- from dog bones to clam shells. The starfish model that came out of this 'test' provided our best option to date. It was recognizable, hand-friendly for a variety of hand sizes, and offered a good surface for visual feedback. The shape then led us to our current functionality and we refined the interaction. The thermistor could be mounted on the starfish body, where we observed most people would touch when picking up the object. The legs, which could be squeezable, each had the potential to trigger a different type of feedback.

Sensors and circuit construction

Our sensor evaluation included thermistors and galvanic skin response (GSR) for the hand touch feedback; force sensing resistors (FSR) and flex sensors for the squeeze feedback. The first two attempts with thermistors brought failure -- both types were too delicate to be touched repeatedly, too slow in capturing and transferring the data, and too sensitive for heat mounting to other parts of the circuit. In consultation with YSI Temperature we selected a high precision thermistor with a sizeable surface area that would withstand repeated touch and capture the temperature data quickly. Due to deadline limitations we only briefly evaluated GSR and were not able to produce reliable results. With the thermistor functioning, we decided to postpone GSR evaluation to later in the project lifecycle.

For squeeze feedback, we looked at flex sensors first and quickly dismissed them as an option. The ones we had access to were too delicate for repeated squeezing and bending. We tested various sizes of the FSRs and found them to be reliable and responsive to the squeeze.

Additional Testing

With a working prototype (see photos above right) we demonstrated *Squeeze Me* for the hospital staff, and then participated in a semi annual group show at NYU. Approximately 250 people interacted with *Squeeze Me* during the show, from grandparents to children. Feedback was positive, and observing usage was invaluable. Most people expressed interest in the device, and felt it would result in stress reduction. We were surprised at how roughly some children interacted with it, which led us to consider a more protected environment for the light circuit. Generally it performed well, with some issues with drift in thermistor redings due to heat that we're currently addressing.

Colored LEDs responding to 'normal' hand temperature

Pattern Feedback responding to hand pressure

PROJECT PARTICIPANTS

Development Team: Christine Brumback, Ed Guttman and Amy Parness collaborated on concept, design and development of this project.

Advisors: Dr. Jan Leupold (child psychologist), Marianne Petit (ITP instructor), Dr. Kim Putalik (pediatrician), Jeb Weisman and staff (Montefiore Childrens Hospital), provided insight and feedback on the conceptual, design and behavioral aspects of this project. Ken Allen (YSI Temperature), Tom Igoe, Greg Shakar, and Jeff Feddersen (ITP instructors), provided technical advice and assistance in sensor selection and circuit design.

DATES AND DURATIONS

The project began in January of 2003, and we expect to continue research and development into 2004.

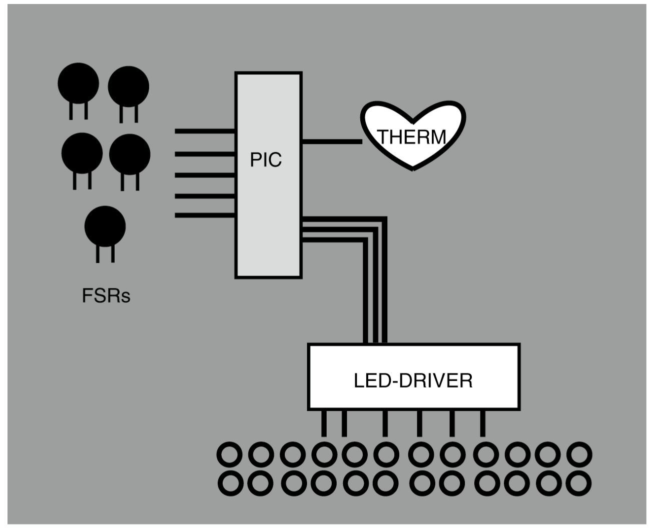
SOLUTION DETAIL

Body

The body of the *SqueezeMe* was molded in *Dragon Skin* Silicon. We made clay positive in the shapes that we wanted and used them to create a negative mold.

Sensors

The temperature is read by a high-precision thermistor mounted on the top surface of the device. It is insulated to protect it from extraneous readings. The prototype previously tested was made with a FSR embedded in one of the device's five legs and the system was built around a BX-24 chip. Currently we are incorporating an FSR in each of the five legs. In order to better accommodate the increase in sensors, we are now developing with the PIC16F876 from Microchip. The chip contains the software, reads the sensors and tells the other chips what to do. Each sensor is attached to a separate pin while the rest are multiplexed to allow for 24 LEDs. There will be a thermistor on the inside to monitor internal temperature and one mounted on the outside. These will be cross-referenced to calculate drift. (See diagram below for working schematic)



FUTURE ENHANCEMENTS

In the next iteration, we are in the process of making *SqueezeMe* waterproof. Not only would this allow for cleaning and sanitation of the device, but would also allow for more portability. We also plan to evaluate other shapes for different kinds of users. Modular devices that children can put together themselves would engage the child in a deeper learning environment. [3] We would also like to add optional auditory feedback to the device, to aid in feedback of exercises.

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The Personal Server: Personal Content for Situated Displays

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ABSTRACT

The Personal Server is a small, lightweight, and easy-to-use device that supports personal mobile applications. Instead of relying on a small mobile display, the Personal Server enables seamless interaction with situated displays in the nearby environment. The current prototype is supported by emerging storage, processing, and communication technologies. Because it is carried by the user and does not require data to be either hosted in the local infrastructure or retrieved from a remote web-site, it provides a platform that increases users' control over their personal data. Furthermore, it enables additional novel applications, such as a personal location history, that would not be appropriate for the computing infrastructure.

OVERVIEW

The Personal Server (PS) [1] is a system designed to provide access to a user's personal applications and data, stored on their mobile device, through large-screen displays in the infrastructure. The device itself does not have an built-in display, allowing it to exist as a small, yet powerful, mobile device. By providing a flexible platform for personal information access, the PS concept explores issues in personal information control, trade-offs between mobility and situated displays, and environmental customization.

The Personal Server is designed to overcome several shortcomings of current mobile systems, some of which are listed below:

- *Usability* – most mobile devices have a small screen that makes it very difficult and inconvenient to access content. By enabling access through displays located in the nearby environment, the Personal Server allows the use of large screen displays to access one's data without having to carry a bulky laptop around.

Figure 1: Personal Server Prototype

- *Accessibility* – the Personal Server enables quick and easy access from multiple potential access points, not requiring access through the device itself, which may be conveniently and safely located in the user's bag or pocket.

Attention – the Personal Server platform is capable of automatically interacting with local environment on the user's behalf, not requiring them to immediately respond to location-triggered events or notifications.

The underlying concept behind the Personal Server is creating and presenting an individualized digital presence surrounding the user, making it easer to access personal content and also allowing the environment to adapt to personal preferences. A crucial metric in evaluating mobile systems is often ease of use and the user's attention level. By allowing easy access through any nearby convenient display, and not restricting access through a phone or laptop, the Personal Server enables streamlined ubiquitous interaction and thus ranks very highly with respect to the aforementioned metrics.

The current operational prototype of the Personal Server is an instantiation of the overall concept, and is designed to demonstrate the novel characteristics of the device. Although currently a stand-alone device, in the future the Personal Server may be integrated with other mobile devices such as a cell-phone, laptop, or wristwatch – providing the same functionality without burdening the user with an additional device. Rapid advances in three technology areas directly enable the Personal Server concept:

- *High density storage* – high-density storage technologies, both solid state and magnetic, are increasing at an extremely high rate, doubling approximately every 12 months.
- *Power efficient processing* – both the power efficiency and computational capability of embedded processors is rapidly increasing, enabling smarter and more powerful devices that also have higher battery lifetimes.
- *Short range communication* – emerging short-range wireless standards afford easy, low-power, ubiquitous point-to-point wireless connectivity.

Specifically, the current prototype has an Intel® XScale™ family processor, Bluetooth™ wireless radio, and a compact flash slot for permanent storage. The resulting device is about the size of a deck of cards, and supports a full Linux distribution with up to 4GB of removable storage. As a baseline, it supports web-browser and file-share access, but is also capable of running any compatible client- or server- side application.

Three applications demonstrate the unique capabilities of the Personal Server:

- *Personal data access* – personalized content, such as a photograph collection, music collection, or working documents, can be stored on the Personal Server platform and easily accessed from nearby situated displays.
- *Location collection* – information from short-range beacons in the environment are collected and managed by the device, allowing for location-based services that do not constantly require the user's attention.
- *Environmental customization* – personal preferences, such as music selections or immersive game profiles, can be automatically transferred to the environment, allowing proactive customization of the immediate vicinity without direct user involvement.

These applications highlight how the Personal Server overcomes the difficulties with current mobile platforms by exploiting three important emerging technology trends. It provides a small, powerful, and non-obtrusive platform for supporting mobile interactions. As technology becomes more ubiquitous, the connection between mobile users and the environment around them will become more important, strengthening the need for personalized mobile systems, such as the Personal Server.

DEMO APPLICATION HIGHLIGHTS

For the conference demonstrations, the three applications mentioned above highlight the Personal Server's core capabilities: personal data access, location collection, and environmental customization. Multiple devices, each carried by, and associated with, a particular individual, provide the personalized content for each of these applications. By exposing the unique data contained on each device, these applications highlight how advances in mobile storage, processing, and communication can be used to enable new types of personal interactions.

For example, Fred's Personal Server may contain pictures from his recent vacation to Japan, a web-page describing him and his general interests, and his personal collection of rare bluegrass music. Additionally, the device could contain detailed research data describing his power and latency measurements of emerging wireless networking protocols. Also, his personal profile may indicate that he loves Thai food, hates coffee, and likes to browse through antique shops.

The personal data stored on Fred's mobile device can be easily accessed through any number of nearby situated displays, allowing convenient access to data without relying on a small-screen display. For example, Fred could walk up to an available display and show his friend a collection of photographs from Japan. Similarly, he could show his other colleague his latest research results. Streamlining this basic interaction through a simple web and file-sharing interface, supports a mobile lifestyle without requiring a bulky mobile platform, such as a laptop

The second application, termed the Ubiquitous Walkabout, receives information from nearby information beacons and other devices to form a picture of where users travel and who/what they have been around. Data is collected in real-time as the user passes by nearby points of interest, and can be viewed later on a situated display. Because the Personal Server gathers and records the data, users maintain control over their personal information: it allows them to track themselves, but does not require the trust of any third-party or the use of infrastructure such as GPS. Additionally, since the system knows that Fred is partial towards Thai food and antique shops, it will highlight any Thai restaurants or antique stores he regularly walks by, but doesn't notify him about coffee shops.

Finally, the Personal Server provides a platform for customizing the music or audio present in communal spaces. Because of the significant storage capacity, Fred can store a considerable collection of bluegrass music on his device, creating, in essence, a "ubiquitous MP3 warehouse" that makes his music available through music players in the environment. Although his tastes in music are rare, he can listen to his music when he likes, although he is not likely to find his favorite bluegrass playing on the radio. Furthermore, the environment can combine music from other nearby users' to automatically mediate the music played in a particular space, customizing the local experience. This concept is similar to MusicFX [3], except music is sourced off of users personal devices, instead of being provided through a centralized agency.

As an alternative to playing entire songs, the system can play a different short sound chirp or show a representative graphic associated with the participants in the immediate vicinity, served from their mobile devices. For example, one person might choose the sound of a chirping bird, while another, a snare drum hit. This conglomeration of personal media signatures automatically constructs a dynamic environment based on the identity of nearby participants, creating an immediate and dynamic demonstration of environmental adaptation as individual participants come and go.

Current mobile devices already possess many of the technologies necessary to implement a Personal Server, such as processing, storage, and communication. However, accessing stored content through situated displays and other devices has yet to be fully explored. The Personal Server concept provides a platform that will spur many of these explorations and discussions.

SUMMARY

The Personal Server demo environment consists of several demonstration stations that detect and respond to devices representing individuals. The display stations, either in the form of large public displays or smaller touch-screen displays, will show content served from nearby users' Personal Server devices. At any given time, only a few devices will be in the vicinity of the display station, adapting the local environment to the preferences of nearby individuals.

The individual demonstrations have been selected to highlight personal control over information. Although it relies on public infrastructure to access content stored on the user's mobile device, the Personal Server controls access to personal data, providing a balance between mobile and ubiquitous computing. These demonstrations provide a concrete discussion point for conference attendees to explore ideas surrounding personal information control and access.

ACKNOWLEDGEMENTS

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Ambient Wood: Demonstration of a Digitally Enhanced Field Trip for Schoolchildren*

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ABSTRACT
This demonstration shows parts of the Ambient Wood experience project which has taken place in an English woodland setting during the past year. The project provides a playful learning experience for schoolchildren on a digitally enhanced field trip. A WiFi network was installed in the woods to enable communication with PDAs, and a collection of innovative devices was designed to aid interactive exploration of the woods. Most of the devices that were employed are available for conference attendees to use along with a facilitator's terminal. A video of the schoolchildren using the devices in the woodland is also shown.

Introduction
The Ambient Wood project is a playful learning experience which takes the form of an augmented field trip in English woodlands. Pairs of children equiped with a number of devices explore and reflect upon a physical environment that has been prepared with a WiFi network and RF location beacons. The intention is to provoke the children to stop, wonder and learn when moving through and interacting with aspects of the physical environment (see Figure 1). The children are able to communicate with a remote facilitator using walkie-talkies and are sent questions and information by a remote facilitator using the network and handheld PDAs.

A variety of devices and multi-modal displays were used to trigger and present the added digital information, sometimes caused by the children's automatic exploratory movements, and at other times determined by their intentional actions. A field trip with a difference was thus created where children discover, hypothesize about, and experiment with biological processes taking place within a physical environment.

Two spaces were designed for the initial trial run, and each activity space offered its own aims with focus on the different kinds of technologies and activities that have an overall link into habitat distributions and dependencies. These aims are: Exploring, Consolidating, Hypothesising, Experimenting, Reflecting. Pairs of children around the age of 10 years

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Figure 1: Using the probing device to find (i) moisture and (ii) light levels and (iii) reading the resultant visualisation on a PDA screen

collaboratively discover a number of aspects about plants and animals living in the various habitats in the wood during a visit lasting around one hour. Their experiences are later reflected upon in a 'den' area where both pairs of children share their findings with each other and the facilitators. The children hypothesise about what will happen to the wood in the long term under various conditions e.g. drought or lack of light through the trees.

Following on from a successful run late in 2002, the experience was enhanced for children visiting the wood in June 2003. Building on the experiences of the previous year we continued exploring our theme of augmenting the experience with digital tools. An 'Ambient Horn' was added to enable the children to have more control over when digital sounds within the wood were heard. The Horn provided a way to access sounds representing processes invisible to the eye, and to events that had happened at a different time.

The Demonstration
The demonstration consists of most of the devices which were used as part of this project; a simplified wireless network which enables a remote facilitator's application to be shown in conjunction with handheld Jornada PDAs; and a display showing a video of the children using the devices in the woodlands. The devices, laptop and Jornadas are all interconnected and functioning as designed and used.

The Network Infrastructure
The project required that data should be collected by the children; their positions in the woods be monitored; and that location based information could be triggered. This was achieved by the use of 418MHz license exempt transmitters with

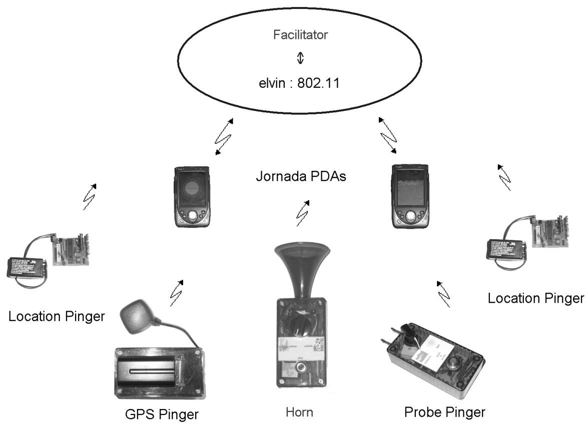

Figure 2: Ambient Wood Device Architecture.

limited ranges broadcasting to receivers attached to handheld Jornada PDAs. We call these devices 'Pingers' based on the simple design proposed by Hull et al [1]. A wireless Personal Area Network (PAN) based on this Pinger technology was provided for each of the pairs of children as well as an 802.11b WiFi local area network accessed through WiFi CF Cards in the Jornadas. The WiFi network assisted communication from remote facilitators, and enabled real time monitoring of the children's activities. In the woods we experimented with three WiFi access points strategically located with extension antenna in the trees. An area of approximately 4 acres had good coverage though this varied according to season and climate. In our demonstration we are using a single access point.

As well as a Jornada and a small Pinger receiver, the pairs of children carry with them various pinging devices including a combined moisture and light 'Pinging Probe', an 'Ambient Horn', a Dead Reckoning Pinger, and a GPS Pinger (see descriptions below). In addition the receiver was able to detect proximity to Location Pingers situated at interesting places in the environment. The contextual information was processed locally to create notifications of events to a network server as they happened. For the original trials wireless loudspeakers, and an unusual interactive display, the Periscope [2], were deployed in the woodland. The system architecture employed Elvin (a content based notification and messaging service [3]) originally connected to a MUD environment [4, 5], and later to a bespoke application. This architecture is illustrated in Figure 2.

The Remote Facilitator

Each of the pairs of children had a remotely located facilitator who they could relay information to using a walkie-talkie. The facilitator in turn could send the children information in the form of 'cards', which were displayed on the PDA, and sounds, also played by the PDA. These were sent from the facilitator's laptop PC using the WiFi network. The cards showed images of plants and wildlife; illustrations of natural processes such as photosynthesis; or alternatively could pose questions to stimulate the children's thought processes. The facilitators were also able to monitor the progress of the children through the woods by using a GPS tracking system.

The Pinger Devices

The design issues for a 'Pinger' are size, cost, power consumption, range, transfer capacity and error rate. In its simplest form our Pinger design consists of a single PIC microcontroller connected to a FM transmitter module operating in the 418MHz license exempt band. Its footprint is 3cm x 3cm; it costs less than $20 in small quantities; has a six month battery life when powered by two AA batteries; has an adjustable range between 2m and 100m; sends an 8 byte packet at 1Hz; and is 95% reliable i.e. approx one packet in twenty is corrupted or lost. The pinging devices were all designed to be stateless with varying degrees of redundancy based on the level of interaction required with each device. Five types of Pinger were employed in this project:-

- **Location Pinger** This is the basic design, providing a location beacon. A datapacket is constructed containing a location identifier and is Manchester encoded and transmitted at 2,400 baud. The range of the transmitter is governed by the antenna configuration extending from 2m with no antenna to over 100m with a quarter wavelength whip antenna. For our applications a helical antenna with a range of around 10m is normally used. The Location Pingers were set to transmit at slightly greater than 1Hz to avoid periods when contention might occur with the GPS Pinger (see below). This guaranteed a ping being received within two seconds of the user entering the 10m radius location. These location Pingers were deployed at points of interest in the environment such as in thistle patches and reed beds.
- **GPS Pinger** The GPS Pinger uses an Garmin GPS25 oem board with an antenna on a short cable. The output of the GPS receiver is decoded using a PIC and a minimal datapacket containing the local position data is constructed whenever a valid fix is obtained, usually at 1Hz. This too is encoded and transmitted in the same way as the location beacon. A GPS Pinger is carried by each pair of children in a small backpack. The data provides a timed record of the children's movements and is further augmented by the Dead Reckoning Pinger.
- **Dead Reckoning (DR) Pinger** The GPS positioning signal was frequently degraded by the tree canopy. To compensate for this a dead reckoning system was devised which used an accelerometer to detect movement, and a two-axis electronic compass to sense heading. Whenever movement above a threshold value was detected, a ping datapacket was transmitted containing heading, amplitude and sequential identifier bytes. The sequential bytes helped to identify when pings had been lost. This enabled a simple form of dead reckoning to be implemented to augment the

GPS data [6].

- **Pinging Probe** A Pinging Probe was designed to provide interaction between the physical world, by sensing moisture and light levels, and the digital world by graphically displaying the results on the PDA. Again a simple data-packet is constructed with bytes representing the values measured and which type of measurement the children were interested in as indicated by a rotary switch. The Pinging Probe was set to transmit at 10Hz to ensure that there was no detectable latency in the interaction.
- **Ambient Horn** A novel audio player, the Ambient Horn, was designed to play tracks cued by Location Pingers, and to transmit ping notifications each time a sound is played. During the first run of Ambient Wood experiments with hidden loudspeakers failed to generate consistent interaction with the children - the sounds were **too** ambient. This device was subsequently designed with the intention of providing the children with a greater level of stimulus using the prerecorded audio effects. The audio tracks were stored on a sound chip and then cued when a location trigger was received. The Horn produced a 'honking' sound and LEDs flashed when the new track was cued; and the track played when a push button was activated. A physical horn extension provided both an organic metaphor for the device and encouraged the children to listen to, and to probe for, sounds (see Figure 3).

Device Performance

The Pinging Probe device - used for both collecting and subsequent viewing of the data - provided a thoroughly engrossing experience. The pairs of children made frequent probes for both moisture and light, usually with one child doing the probing and the other holding the PDA, reading off the visualisation. Sometimes both children would look at the PDA screen together, and other times the one holding it would tell the other what they had seen on the screen. The probe design was particularly successful as the digital information resulting from the children's activities was tightly coupled with the activity, and the children readily understood the connection between the two.

Initially the Location Pingers were less successful. While the technology performed as intended, we had engineered the digital information to be presented to the children in a more pervasive way i.e. where their bodily presence in an area triggered the digital information to appear on the PDA, or sounds to be played through nearby wireless loudspeakers. In these contexts, the children did not have control, but relied on the serendipity of their movements as to whether they passed in the vicinity of the Location Pinger. The children were never quite certain when this would happen and were often surprised when they heard a sound or saw an image on the PDA screen. Part of our intention of using this pervasive technique was indeed to introduce an element of surprise and the unexpected. Another reason was to augment their physical experience, by drawing their attention to certain aspects of the habitat they might not have noticed otherwise, and providing relevant contextual knowledge that they could integrate with what they saw. Sometimes this approach worked, and the children related the digital information that was being sent to them on the PDA with what they saw in the wood in front of them (e.g. a real thistle). However, at other times, the children were too engrossed in another activity and so would miss the beginning part of a voice-over or not even notice a sound. In these moments, the children were often reluctant to switch their attention to what was happening on the PDA from what they were already doing.

Figure 3: Children using the Horn, PDA and Walkie-Talkie.

The audio playing Horn device was designed to address this problem and was successful in giving control of the sound playing to the children. While this was less 'ambient' it still gave the opportunity for the serendipitous triggering of sounds and also enabled the children to replay particular sounds on request. The similar physical design of the Horn and Probe encouraged the children to seek sounds associated with locations by probing with the Horn. We repeatedly observed the children associating sounds with locations.

The GPS Pinger performed well enabling positions to be recorded for all the children's activities. The need for the Dead Reckoning Pinger was largely obviated by the use of a high gain active patch antenna with the GPS receiver. Nevertheless initial results from the DR Pinger indicated that this approach could be useful in situations where poor GPS reception is experienced. Figure 4 illustrates the combined positioning performance of the GPS and DR Pingers. We also experimented with virtual location beacons created using the GPS data however these were found to be unsatisfactory due to inaccuracy, drift and occasional spurious readings.

The PAN, though simple with no protocol stack or handshaking, worked well partly due to the redundancy inherent in

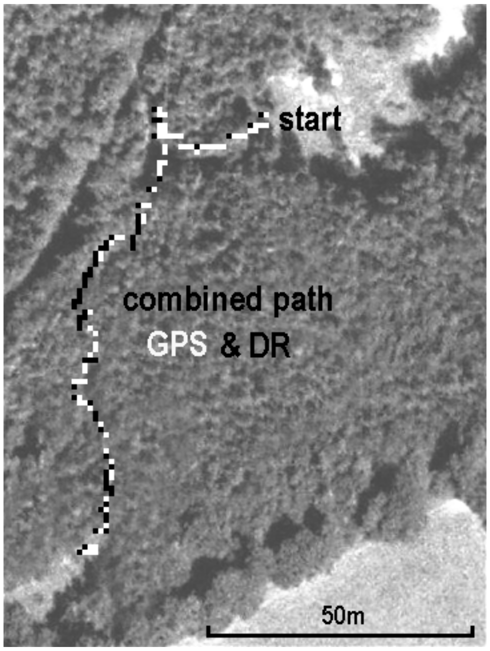

Figure 4: Aerial Photograph showing Position Sensing using GPS and Dead Reckoning. The white pixels represent the readings from a GPS receiver, the black pixels show the positions estimated by dead reckoning.

the design. By setting the transmission rate of the Pinging Probes to be significantly higher than for the GPS and Location Pingers it was ensured that the Probes appeared to function with no latency and took priority over the other Pingers. Any delay in receiving a location ping was not critical as the user interaction appeared to be serendipitous in any case. The GPS pings provided a monitoring function and were not critical to the progress of the trials. While we estimate that around 5% of the pings were lost, in practice the users of the system were not aware of any latency or data loss in the PAN.

Contribution

This project is notable for its location away from any infrastructure whatsoever. It required careful consideration of power requirements and the effects of woodland on RF propagation under differing climatic conditions. It also benefited from a lack of any possible external RF interference. The range of uses of the Pinger technology is unusual and its integration to form a PAN for collecting minimal data packets extends the concept of using devices such as Smart-Its [7] and the Berkeley Motes [8] for the collection of pervasive data. The Probe and Horn devices both had great appeal to the children who enjoyed using them constructively to learn about the environment. We believe that these inventions may inspire others to develop further interesting ways of interacting with ubiquitous computing systems.

Acknowledgements

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'Wall_Fold': The Space between 0 and 1

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ABSTRACT

The *Wall_Fold* installation analyzes personal space in the contemporary reality of portable computing and wireless communication. It conveys a more sensitive and complex environment than the typical Modernist white cube. The physical architectural element generates an ambiguous spatial condition: smooth and flexible folds between the inside and the outside, open and closed. The space thus becomes continuous and dynamic.

Six pairs of servomotors, connected by flexible bands, create a smooth surface. The motors alternate between two positions (0° & 180°), stretching the binary ON/OFF into a continuous transition, a whole grayscale or gradient between 1 and 0.

Keywords

Personal space, Smooth space, interactivity, installation

INTRODUCTION

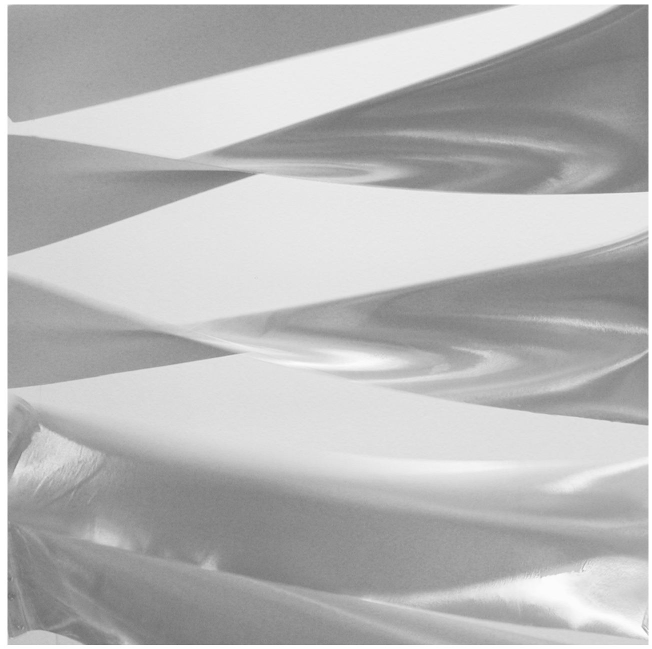
Wall_Fold is a theoretical prototype for a 'smart' architectural partition with programmed behavior and changing patterns. It may suggest domestic or public interior wall partition, or an interactive opening. It can be developed further into a full three-dimensional spatial version. The installation generates a subjective, hybrid, flexible, immersive and dynamic personal space. It leaves the existing Modern space intact and undermines it with digital media.

CONTEXT AND BACKGROUND

Modern architecture

Modern architecture, which includes many of the spaces we inhabit today, has emerged out of the industrial revolution. It is based on standard, industrialized, rational, functional, efficient and orthogonal spaces. It evolved from Le Corbusier's 'Radiant City' and C.I.A.M (Congrès Internationaux d'Architecture Moderne, founded in Swiss in 1928) proposals for 'The Functional City'.

In contrast to the traditional city patterns, Le Corbusier envisioned hygienic, regimented large-scale high-rise towers, set far apart in a park-like landscape. His rational city would be separated into discrete zones for working, living, transportation and leisure [2]. Consequently, C.I.A.M was committed to standardized functional cities with a similar scheme in its 1933 congress [3]. These ideas had a profound influence on public authorities in post-war



Europe. The rigid coding scheme was adopted in many urban reconstructions after World War II. However, the functional planning strategy was later criticized for being inhuman, inhospitable, socially destructive and damaging for the urban fabric.

Zoning

In the practice of 'Urban Planning', the preparations of zoning maps and strict coding documents are still the standard and most common approach to planning. In response to the increasing criticism of the crudeness and rigidity of modernism, the four categories of C.I.A.M - dwelling, work, recreation and transportation, were extended to include more groups, such as: industry, commercial district, retail, natural resorts, public services and more. 'Mixed-use' areas started to appear on the planning maps, breaking the zoning blocks into finer grains. For example, the same building was divided into commercial areas at the lower floors and residential areas above them.

Zoning in 'my scale'

At the present, technological and communication developments, such as the Internet, wireless phones, modems and hand-held computers, have a major impact on our lives. The work environment has been tremendously influenced; a large part of the work is done with computers, and Internet connectivity has altered communication with clients and co-workers. Time and place are now much more flexible (24/7). Our social lives and leisure time are changing as well.

The modernist zoning (the assignment of human activities into separate areas) has become obsolete. In the same manner, the functional Modern apartment design, which ‘zones’ family activities of leisure, work, eat, rest and bath, must be adjusted. With increased possibilities to stay at home, (for work, education, communication and more) the design of the personal space needs to be changed.

Technology is getting closer to the personal scale and at the same time allows the individual to connect to ‘everyone’ from ‘everywhere’, as a node in the global network. Our customized and intimate relationship with technology should challenge architecture to evolve from the ‘standard’ and ‘universal’ values of modernism to support these new needs and living patterns.

Modern architecture was characterized by the reference to new building materials, such as steel, concrete and glass, and by the industrialized production process that became available due to the technological inventions of that era. In the same manner, contemporary architecture should reflect to the current technological developments of computation and communication, which affect our everyday lives. This project employs micro computing and sensors to explore new ways of architectural expression.

Alternative contemporary theories

Looking for alternative theories for complex and sensitive spaces, I turned to the French philosopher Gilles Deleuze and the contemporary architect and theorist Greg Lynn.

Gilles Deleuze

In ‘1440: The Smooth and the Striated’ [4] Deleuze and Guatarri define a ‘smooth space’, in contrast to a ‘striated space’, as amorphous, heterogeneous, nomad, intensive, rhizomatic and haptic. They point out that in reality the ‘smooth space’ co-exists in a mixture with the ‘striated space’.

Greg Lynn

In ‘The folded, the pliant and the supple’ Greg Lynn recounts the advantages that architecture can gain by introducing ‘smooth’ systems: *“Pliancy allows architecture to become involved in complexity through flexibility. It may be possible neither to repress the complex relations of differences with fixed points of resolution nor arrest them in contradiction, but sustain them through flexible, unpredicted, local connections”*[5]. The fold encourages architecture to become more sensitive to the complex changing needs of the contemporary person, and the ‘smooth mixture’ allows continuous co-existence of different conditions, while maintaining their identity.

Context in Contemporary Art

The work of some contemporary artists can serve as precedents to formal approach, space transformations and the use of new technology by artwork.

Contemporary sculptures

James Turrell's installations are powerful examples of space deformation with immaterial assets. They succeed in altering the viewers’ perceptions of air, light and shape. He creates conditions that are neither ‘object’ nor ‘image’ and manipulates space using light and form.

Gordon Matta-Clark explored architecture’s inextricable relationship to private and public space, urban development and decay. His provocative approach to conventional building and his social criticism undermined the rational and function of buildings, using ‘negative’ actions like subtracting material from walls and floors. His site-specific installations, the "building cuts," in which he cut into and dismantled abandoned buildings, created unexpected aesthetic qualities, views and accessibility in an unconventional spatial way.

Anish Kapoor creates curved biomorphic shapes that exist as an indeterminate form between object and space. Many of his pieces have been incorporated into the walls and floors of exhibition areas. He intends to provoke the audience into a permanent doubt about the way it comprehends reality. The theme of duality reappears in many of his pieces: positive and negative, physical and mental, present and absent, form and non-form, light and dark, male and female, place and non-place, solid and intangible.

Kapoor has often incorporated into large-scale works more literal versions of interiority, being drawn repeatedly towards the use of concave and convex shapes to create areas of emptiness, pockets of absence within dense material. His work challenges our sense of natural boundaries, interior and exterior, and undermines the conventional space with new geometry. He establishes physical precedents of ‘smooth’ space deformations.

Kinetic and Electronic Art

Kinetic art explores how things look when they move. It is about processes of motion and evolution. It creatively employs inert materials as carriers of forces, so as to extend three-dimensional works beyond the static occupation of space into time and motion. Some kinetic sculptures engaged the viewers’ interaction with moving forces, and are generally regarded as a precursor to the digital, computer, and laser art of today.

The artist Alan Rath [6] manipulates electronics as both formal and metaphorical elements. He creates inventive sculptures that comment on the symbiotic relationship between humans and machines. Unlike the mobility in many of the kinetic works, that depends on chance elements, such as air movement and temperature, Rath programmed his machines to ‘understand’ and respond to their environment. Some of his sculptures are programmed to move in response to the presence of people around them. Some robots interact with each other and some have an algorithm of randomness. His work focuses not only on the movement of the sculpture but on its behavior and movement patterns -- how it reacts and actively responds to the dynamic environment and the viewers.

Rath's work is an example of robotic aesthetics that embodies human gestures and organic qualities. His work choreographs form, movement and interaction to create new meaning.

The *Wall_Fold* installation is interested in continuing Rath's investigation using new media and virtual space to convey doubt in, and deform real space. It explores the alteration of the physical space by the use of digital media. This allows me to add new attributes to architecture, such as interaction with the viewer, dynamic changes over time, sound, movement and immateriality, while preserving the physical nature of the space itself.

Previous investigation

In my previous work [7] I investigated the relationship between architecture and media, while criticizing modernism rigidity and reductively. I have experimented with two main strategies (or platforms):

Web Art: bringing space into media

Extension of screen-based applications by exploring three dimensional (3D) space and navigation (using 3D modeling software, animation and interactive programs, such as Maya, Flash and QTVR).

Example: *VOLUME 1.0* **-** 2002 [with Inbar Barak]

The term *volume* refers to the intensity of sound and to the dimensions of a space. In this work, the *volume* is interpreted in the same duality - SOUND and SPACE are defining, and evolving around, each other. The position of the sound-object deforms the space by changing its perspective and depth. In return, the transformation of the space influences the sound level and panning. This project simulates reality, by positioning sound in space, and at the same time extends the real into the potential of the virtual, by allowing the user to move the usually static space around the sound-objects.

Installations: bringing media into space

Merging and overlapping real and virtual, in an attempt to deform the architectural space by using images and 3D models (Maya, VRML, Director, C, sensors). These installations took advantage of the efficiency and availability of the Modern space and undermined it, while leaving it intact and trying to activate Deleuze's 'retroactive smoothing' [8]. Modern space and media were blended together to create smooth space and extend their dimensions beyond the traditional perception (i.e., media was materialized into a 3 dimensional space and the Modern 'white cube' was stretched beyond its limited orthogonal rigid characteristics).

Example: *FluxSpace* Ross Gallery, New York 1999 (Maya/VRML 3D animation, projectors and speakers) [9]. Using a 3D virtual model of the gallery, and projecting it back into the same space, real and virtual spaces overlapped. The superimposition of sound, light, text and color reconstructed, distorted and deformed the virtual model, and thus influenced our perception of the real space. The gallery functioned as a filter of data and media. The project allowed the viewer to be simultaneously in real and virtual spaces and perceive these spaces from the inside, as an immersive environment, rather than as a detached spectator. The gallery was projected with a rendered reality and was in a constant state of flux.

INSTALLATION

Concept

The goal of 'Wall_Fold' is to create a 'smart' physical architectonic element with programmed behavior and changing patterns, in order to generate visual and tactile qualities. Computation and media are used in a physical way, trying to achieve a subjective, temporary, hybrid, flexible, immersive and dynamic personal space.

This installation takes advantage of the availability, efficiency and rationality of Modern design. At the same time, it criticizes the rigidity and stiffness of Modern architecture. I propose a strategy, which opposes the basic approach of Le Corbusier and the modernists: 'destroy and rebuild' – but leave Modern space intact and 'undermine' it with digital media. This is the act of smoothing out ("retroactively") using embedded computers (micro controllers).

Develpement

First prototype: one-dimensional LED sequence

An experiment with a simple system of two micro controllers (e.g. a microprocessor which operates as an embedded system, in this case I used PIC 16F877) connected by wires to each other, and light-emitting diodes (LEDs). The micro controllers were programmed with a simple logic code, which consisted of 'IF' statements, and sent 0 or 1 signals between them. Every time a signal was sent (0 or 1), the program turned a correlated LED ON or OFF. An adjustable delay period was set by viewer's input (in this case, using a potentiometer: a component with variable resistance). This experiment created a close, linear, binary system: the LEDs turn ON or OFF in a sequence over time. It was a one-dimensional situation: LED = point (0 dimensions) turning ON/ OFF on the axis of time, while the state of each LED was determined by the state of its adjacent LEDs.

Second prototype: Servo sculpture

In this phase I challenge the setup of the one-dimensional LED sequence and transform it into a two dimensional surface. I translate the logic of the code into spatial architectural qualities. The surface is made out of pairs of servomotors connected by flexible vinyl strips (see image

in the first page). Instead of switching LEDs ON and OFF, it turns and folds the surface inside/ out. Like a 'Moebius strip' (a single topological surface with only one side and one edge) which continues from the inside to the outside, this experiment creates a pliant system that dynamically evolves through different variations, and flips the space from inside to outside and from closed to open. My intention is to create a continuous transition, a whole grayscale between 1 and 0. The experiment is generated by simple code, but results in a much richer spatial condition.
Similarly to the users' input in the first prototype, this version may in future development react to the viewers' proximity by changing the speed of the motors and the rotation patterns.
The limited static conditions of 'open', 'close', 'inside' or 'outside' are now only a single option in this multiple and variable sets of complex positions, which are dynamically changing to adjust to the individual needs and wishes. For example, the partition can be 10% closed at the top while 90% is open, or 40% inside and 60% outside. This way, I materialize the 'smooth mixture' concept, described by Greg Lynn as: *"intensive integration of differences within continuous yet heterogeneous system. Smooth mixtures are made up of disparate elements which maintain their integrity while being blended within a continuous field of other free elements".* [10]
In the 'mixing' and 'folding' process I experiment with the following dualities: input/ output, on/ off, front/ back, single/ plural, light/ dark, sedentary/ dynamic, shiny/ matte, 0°/180°, open/ closed, and inside/ outside.

Prototype Technical Description

Pairs of servomotors are mounted to a 2' x 2' Plexiglas frame and controlled by micro controllers (PIC16F877) (and future input from proximity sensors). The micro controllers' code consist of 'IF' statements, sending signals to rotate the motors in relation to the positions of adjacent servomotors, programmed patterns and input from the sensors. Between each pair of servos a horizontal vinyl fabric band is stretched, creating a surface that follows the logic of the program. The motors are alternating between two positions, from 0° to 180° and back, and translating the binary ON/OFF signals into a continuous transition.
The fabric strips have two distinct sides: silver, smooth and shiny front and a white, interwoven and matte back.
I read this configuration as a two-dimensional condition, as a surface, which is dynamically twisting between inside and outside, open and closed.

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Digital Poetry Modules

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ABSTRACT

This article details a system of digital word modules, based on the popular phenomenon of refrigerator magnet poetry, that alleviate the tedium of public "in-between" places by providing a means of interactive play.

Keywords

Social awkwardness, digital word modules, magnetic poetry, digital text.

CONTEXT / MOTIVATION

This project was originally conceived as a digital solution to the social awkwardness endemic to elevators. Thus, its design parameters reflect the limitations of its original location. However, since many public spaces share the psychic and physical characteristics of elevators, it has the potential to be useful in spaces far beyond its original context.

The Elevator Space

Muzak is regarded by many as a lite-pop monstrosity that is to elevators what bubonic plague was to medieval Europe. But muzak originally served a purpose, "piped into elevators to help people feel safe in this new form of technology." [1]

Nowadays, of course, elevators are considered a very old form of technology, and most people feel comfortable enough in them for muzak to serve as more of an irritant than a comfort. But for many people, anxiety remains, even if it is more of a social fear than a physical one. A number of emotions can be felt between various combinations of people, such as boredom, shyness, flirting, or awkwardness – few of them comfortable. The goal of this project was to eliminate, or at least minimize, these emotions.

DESIGN PARAMETERS

As noted, this has not been the first attempt at making the elevator experience more meaningful. We decided that there have historically been three broad strategies that have been used to engage elevator riders -- that is to say, **music** (as in Muzak), **glass** (views of the outside) and **screens** (to display news, weather, etc).

What all of these strategies had in common was that they relied on **distraction**, rather than interaction. We felt that this was a limiting view of how to improve the elevator experience, especially with the opportunities for interaction provided by digital technology. Our challenge was to build an installation that could solve the same problems in a more interactive way -- not only between people and the outside world, but between each other.

Theoretical Parameters

The first step in this project was to list a set of general design parameters that this project would have to follow to be successful. In our view, any elevator installation would have to be:

- *Immediately understandable*, since one's stay in an elevator is an ultimately brief one;
- *Unobtrusively engaging*, because people should feel at ease when interacting with the technology, yet still absorbed in the experience;
- *Easily ignorable*, as riders sometimes do not want to be disturbed, whether they are already interacting with a friend in the elevator or simply want to be left alone; and
- *Warmly inclusive*, to encourage riders to interact with each other, not just with the technology.

Practical Considerations

Of course, elevators have their own specific, practical demands. Electricity is often difficult to access, and an installation cannot be too large or obtrusive in the cramped space due to fire codes, building regulations, and the comfort of its passengers. Thus an installation should ideally be small and self-powered. Since the solitude of an elevator can also invite larceny or vandalism, the installation would also ideally be self-contained and inexpensive.

THE SOLUTION

The best inspiration for a digital installation that could satisfy each of these parameters was found in the now-famous magnetic poetry sets found stuck on refrigerators across the country. After all, an elevator is like a refrigerator -- a cramped gateway to a more interesting destination.

Magnetic poetry sets consist of hundreds of tiny magnets, each imprinted with a different word in various parts of speech. They can be arranged on an refrigerator in combinations from the ridiculous to the sublime, allowing for the entertainment of the "author" while providing a means for indirect communication of jokes, ideas, and various degrees of poetic thought to others visiting the space.

Refrigerator poetry is often not "poetry" *per se*, but the limited wordset provided by the magnets does force approximate compositions that reflect many of the ambiguities of verse. Although it takes some thought to build a sentence that rises above nonsense, building meaningful sentences is possible. Many of the fragments created reside in the realm of the cheerfully cryptic, much like most of the proverbs found in fortune cookies or badly translated philosophical texts. This does not detract from the magnetic poetry set; rather, the strangeness of the sentences that arise does not mean they are any less self-expressive. Best of all, each "poem" can be modified by future visitors, allowing for a uniquely indirect, asynchronous means of communication.

The idea of poetry as a "calming snapshot" is at the heart of New York City subway's "Poetry In Motion" as well as refrigerator poetry magnets and this digital poetry installation. "Poetry encourages us to slow down and focus on what's meaningful in life," Andrew Carroll, director of the American Poetry and Literacy Project told a newspaper in 1999. "It's like a little break. It doesn't take long to read a poem. When you're on the road, sometimes it's hard to sit down and open up a whole novel. You want just a little snapshot of an emotion or an experience."[2]

INSTALLATION DESIGN

With this in mind, we designed a series of digital modules to be installed in elevators, with the idea that these modules could be manipulated to create sentence fragments in much the same way as magnetic poetry words are used on refrigerators. Each module contained a one-row LCD screen and a potentiometer knob used to select words on the display. The modules are currently mounted using strong suction cups.

These modules serve the same purpose as the magnetic words in a refrigerator poetry set, although the words encapsulated in each are not static but dynamically selected. Each module contains around 200 words in a given part of speech; there are noun modules, verb modules, adjective modules, and so forth. Arranged together, they form phrases that range from the cryptic to the profound to the entertaining to the baffling. Since the words are pre-selected, what results is not necessarily poetry per se, but rather more like one-sentence proverbs or brief unfinished haikus.

PROTOTYPE

Each module is based on a simple battery-driven circuit. A microcontroller (in this case, a Microchip PIC16F876) prints different words from a given array to the LCD depending on the potentiometer's value. Around 200 words can be stored on each. Future prototypes would use either advanced microcontrollers or flash memory to store more words. We believe about 1,000 words on each module would be ideal.

Software

A Perl program on the chip development computer currently builds word collections automatically from a given web source. They are classified with the Moby part-of-speech wordlist compiled by Grady Ward (grady@netcom.com) and hard-coded onto each chip. An example of a modules' dynamically-generated PIC Basic Pro-coded wordlist can be found at *http://stage.itp.tsoa.nyu.edu/~jgr225/nouns.txt*

Word Selection

To provide a subtle introduction to the user's location or destination, each set of words is culled from a digital source that directly relates to the place being visited. For instance, the initial prototype of this installation used the most popular words from the ITP students' electronic mailing list. Similarly, a similar installation at a corporate headquarters could use words from the company's website. The prototype modules presented at the 2003 Ubiquitous Computing conference will feature the most-used words from contributors' presentations.

Networked Modules

Because of the lack of a network connection, the wordlists in the prototype had to be hard-coded onto the chip before installation. In network-enabled environments a connection could be set up to dynamically update the lists in real-time. Additionally, the words selected could be broadcast to a website to reflect the compositions presented in a given place to the world at large.

BEYOND THE ELEVATOR

It became clear to us during the development and installation of these modules that they have broader applications beyond their original context. They can be installed virtually anywhere indoors, and, with slight modifications, outdoors as well.

Thus, they are ideal for "transitory spaces," that is, public areas where people often pass by, allowing for virtual self-expression and subtle, anonymous communication between strangers. In this sense they are best thought of as ephemeral graffiti, although while graffiti is used mainly by gangs to mark territory, these modules are used by everyday people to communicate, however cryptically. In that sense they are not objects of distraction but also true artifacts of interaction that hopefully can serve to relieve the social awkwardness of public spaces.

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The Verse-O-Matic

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ABSTRACT
This paper details the “Verse-O-Matic”, an otherwise ordinary printing calculator re-imagined as an playful way to introduce and distribute verse into everyday life. Instead of a numbered keypad, the device’s keys represent poetic themes, which can be combined to select and print snippets of great poetry. Just as the invention of the electronic calculator made relatively complex mathematics accessible to the masses, a poetry calculator elevates ordinary discourse by making verse more easily accessible to all.

Keywords
Verse-O-Matic, calculators, poetry, digital publishing, handheld devices, literary databases.

CONTEXT
Before the introduction of the portable electronic calculator in the latter half of the twentieth century, solving mathematical equations was a time-consuming activity. Indeed, it was a rare mark of genius to be able to calculate complicated sums quickly.

The same situation exists today with poetry, a discipline that can be as relevant and meaningful to our lives as mathematics. Just as a proliferation of numbers have helped to revolutionize science and finance, a democratization of beautiful verse can add greater meaning and context to our relationships with each other, our lives and our environment by elevating our communication beyond clichés.

Why is poetry largely ignored in today's society? To a large part, it is because it is perceived as inaccessible. One must be highly motivated to begin an exploration of poetry without any previous exposure to verse; as a result, verse is seen as the domain of highly educated and/or pretentious types. (Of course, as many academics know, the two are by no means mutually exclusive.)

Secondly, poetry is sometimes viewed as irrelevant. That may well be a perception borne of ignorance, since, in today's society, poetry garners widespread attention only when it offends us, not when it enlightens us. Witness the recent furor over a controversial poem written by New Jersey poet laureate Amiri Baraka, which led some to call for the abolition of his $10,000-a-year post. [1]

The Verse-O-Matic attepts to remedy this situation by providing a convenient, accessible interface to classic and modern poetry, requiring only a curiosity about life and rudimentary knowledge of a mathematical calculator.

OTHER POETRY PROJECTS
This project is not the only effort to seep poetry to unexpected corners of everyday life. Robert Pinsky’s *Favorite Poem Project* featured dozens of Americans reading their favorite poems on PBS’ *Newshour With Jim Lehrer*. The selections were chosen from over 18,000 submissions. [2] Recently, the Poetry Society of America’s *Poetry in Motion* campaign has enriched the public transportation systems of 11 United States cities with snippets of verse. "We want to surprise people with it, to put it in the very space where it's not supposed to be," executive director Alice Quinn said in 2001. "Everything else on the subway is trying to sell you something. This offers instead a metaphysical moment in the subway." [3] It is in this spirit that the Verse-O-Matic was designed.

CONCEPTION
This project was originally designed to address the question of how to introduce relevant verse into everyday discourse within a simple, usable interface. In other words, we hoped to create a device that was capable of a range of expressive output with only a few simple inputs. The printing calculator presented itself as an interesting model because of its simple interface and the flexibility of the printed output. In addition, the repurposing an ordinary device to provide unexpected results invites an irresistible spirit of playfulness among its users, making the discovery of new poems an exciting, rather than tedious, endeavor.

DEVICE DESIGN

The Verse-O-Matic is designed to look exactly like a regular printing calculator, with one exception: the usual digits are replaced by nine words, each representing a different poetic theme or emotion: LOVE, HAPPINESS, BEAUTY, HUMOR, AGE, NATURE, SEPARATION, SADNESS, and DESPAIR. Despite the transformed key meanings, the universally-recognized calculator format allows new users to easily grasp how the device is meant to be used without special instructions.

INTERACTION

When a key is pressed, the calculator searches its memory to select all of the poems that refer to that theme. Additional themes can be added ("+" = AND) or subtracted ("-" = AND NOT) from the "poetic equation" simply by pressing the appropriate keys. When the user presses "=", the equation is completed and the calculator prints a randomly-selected poem that fulfills all of the thematic boundaries that the user has set.

For instance:

“LOVE”

+

“SEPARATION”

+

“SADNESS”

=

"This bud of love, by summer's ripening breath,
May prove a beauteous flower when next we meet."
WILLIAM SHAKESPEARE [4]

If no poems are found, the device emits a warning. The equation resets and the user is prompted accordingly.

OUTPUT

In the prototype, the poem is printed on a mailing label, rather than a supermarket receipt (as originally conceived). This allows the poem to be easily shared once read; it can be used to seal an envelope or affixed to a personal calendar. The printout also affords a tactile intimacy with the words that cannot be matched in the hulking glare of a computer monitor.

Thus, the project's original purpose of distributing verse is achieved in two levels. First, the user is introduced to a snippet of poetry that touches on the themes he/she has selected. Secondly, the sticker invites the user to share that verse, either personally or anonymously, by either forwarding it along to a friend or displaying it in a public place. Thus the shared verse travels far beyond the original digital database, appearing in a multitude of non-digital spaces. It is no longer a static resident of a digital database but a dynamic, living object to be experienced in our everyday lives.

When this project was first demonstrated at NYU’s Interactive Telecommunications Program, students found a host of novel uses for the poetry stickers. Snippets of verse can now be found in the most unexpected places, from trash can lids in the student lounge to microchip programmers in the physical computing lab. This proliferation of verse in unexpected places represents the best expression of the usefulness of the poetry calculator.

PROTOTYPE

Hardware

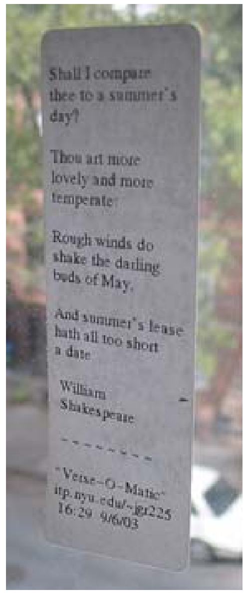
The original prototype for this project was built using a custom-made keypad and a standard commercial label printer interfaced serially with a Toshiba 335CDS laptop running Linux. The laptop and label printers, while bulky, were used so that a preliminary prototype could be easily constructed and tweaked according to user feedback. In later iterations of this project the laptop will be replaced by a microcontroller and the label printer by a custom serial printer, each embedded in the calculator itself, so that the entire device is completely portable for use anywhere. As noted below, future prototypes will also incorporate networked elements.

Software

Poems are stored in a simple database on the host computer, mediated by a Perl program that monitors the input from the keypad and distributes text to the serial printer accordingly. New verse is entered into the database via a web-based CGI form on the local machine’s Apache server, accessible either locally or through a connected LAN. In future prototypes the Verse-O-Matic will be networked to the Internet via an embedded Ethernet controller so that poems can be collected from around the world.

POETRY AND TECHNOLOGY

Despite a generally positive response to this project, several individuals have raised concerns about the implications of trying to represent the intricate, emotional art of poetry through a mechanical, "logical" device. Others have questioned the use of a typically mass-produced device to distribute verse, arguing that it may evoke "the commodification of expression and aesthetics". Another typical response is that the presentation of excerpts, rather than complete poems, abandons the depth and complexity of the author's original intent in favor of a less meaningful soundbite.



These questions are all valid, provocative responses to the project. However, we believe that they are not unique to this device, but will be asked of any effort to distribute verse to a wider audience. Since any attempt to tackle these questions is to tempt participation in a host of broader, more contentious, intellectual debates about poetry and literature in general, we think that within the context of this paper it is best to address them through the original intent of the piece.

"Emotional Art" vs. "Rational Calculator"

One of the largest challenges in designing this project was selecting the nine themes for the calculator's keypad. Of course, the reason this was so difficult is that any attempt to reduce all verse to nine themes is patently ridiculous. How irrational to argue that the calculus of thematic interpretation is in base ten! Rather, the decision to select nine themes was not to make any grand statement about the structure of poetry but rather to simply mirror the familiar structure of a calculator keypad so as make the device as simple as possible for anyone to use.

Just as difficult, for the same reasons, is the classification of submitted verse within the confines of those nine themes. To say a poem is about "love" or "sadness" is an almost meaningless analysis. But, again, some minor form of classification is demanded by the context of the device.

That classification need not be perfect. If we remember that the point is not to create a mathematical structure that allows for the perfect recovery of classified poetry but rather to introduce meaningful verse into everyday life, the question of whether the verse recovered exactly mirrors the user's emotions becomes almost moot. In fact, if the goal is to stimulate the intellect of the user, a snippet of verse that echoes yet challenges the user's original emotions and assumptions is in many ways far more preferable to one that exactly reflects them.

"Commodification of Aesthetics"

Because the calculator can be loaded with any snippet of verse, classified by the contributor, we would argue that it represents the sharing, rather than the commodification, of aesthetics. In this sense, the calculator can be seen less as a static reference and more like a highly-structured, asynchronous instant messenger device. If these devices were to proliferate, our Verse-O-Matic would not be the same as yours; it would contain different poems from a different circle of contributors, from myself, to my friends, family, and classmates. Thus, each calculator would be like a literary iPod -- a highly-individualized representation of a circle of aesthetic expression.

Poetry vs. Soundbite

The small format of the printed sticker meant that in most cases each verse in the Verse-O-Matic is an excerpt of a larger poem, rather than a complete poem. Does an excerpt fully represent the depth and complexity of a poet's complete piece? Of course not. But wonderful ideas can be found in the simplest of sentences, even if they are merely small components of the artist's broader concept.

For this same reason, people often feel comfortable using snippets of poetry in other contexts. If pieces of verse can be used to introduce and enliven essays, prose and speech, why can they not serve as epigraphs for our daily lives?

FUTURE DEVELOPMENT

As noted, the poems on each device need not be standard to each calculator. Just as poetry is a deeply individual and personal means of expression, each calculator could be loaded with diverse collections of verse. A wireless connection could permit users to share their poetry with others anywhere -- on the street, in the subway, or in a workspace. This could be enabled through an infrared connection, as is used on handheld devices, or via an 802.11b wi-fi connection to more remote devices. A user could eventually use his or her cellphone's number keys to "dial up" a poem on a loved one's calculator while away.

CONCLUSION

There is a Chassidic tradition that insists that everything in the world contains a joy that we must continually discover and unlock. The Verse-O-Matic was inspired by that philosophy. Even a humble calculator can be a gateway to revelation; to happiness; to thought and introspection. If anything, it is a challenge not to poetry or literature but rather to the idea that the joy of beautiful verse can only be discovered in the musty halls of libraries. Rather, their ideas should surround, envelop and inspire us wherever possible, freed from the typical boundaries that sequester them in the realm of academia.

ACKNOWLEDGMENTS

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AURA: A Mobile Platform for Object and Location Annotation

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ABSTRACT
In this paper, we describe a system used to link online content to physical objects implemented with commercially available pocket computers using integrated bar code scanners, wireless networks, and web services. We discuss our design goals and technical architecture and describe applications that have been constructed on this architecture. We describe the role of the related web site to create communities around scans collected by the handhelds.

Keywords
Laminated reality, mobile object annotation, communities, mobile devices, bar codes, machine readable object tags, wireless networks

INTRODUCTION

Every object has a story to tell. However, labels and signs can only tell part of this story; there is always an enormous amount more to learn than will fit on a label. Mobile devices are changing this, allowing physical objects to to be linked to associated online content. This dramatically expands the space for commentary and services related to the places, products, and objects that physically surround us.

The technical process of linking physical objects to online content has become increasingly straight-forward. Adding a tag reading device to a network connected portable computer shortens the gap between physical objects and places, and the digital information related to them. This enables wirelessly networked devices to cheaply and accurately recognize a wide range of objects and places, and offer access to information and services pertaining to those objects. It seems reasonable that some form or forms of tag detectors will eventually be common features of most networked information devices. Currently cameras and bar code readers are widely available for cell phones and pocket computers.

We created just such a system that combined widely available wirelessly networked Pocket PC handheld computers with a laser scanner for reading bar codes. Client software was created to integrate these components and connect them with servers available over the public Internet.

The resulting system has applications in many settings. Meta-data about objects with UPC codes, found on almost all consumer products in the United States, can be drawn from publicly accessible online data services. These services often provide the name of the object or product, its size (if it has one) and the name of its manufacturer in exchange for the object's bar coded identifier. Our system uses such a data service to retrieve meta-data that is then used to construct queries for search engines that yield useful and highly relevant results. Scanned objects quickly link back to the web sites for their manufacturers or online commerce sites that offer those objects for sale. Similarly, books often bear an ISBN number in the form of a bar code. These numbers can be used in queries to online book sellers, making the services offered there like book reviews, lists of related books, and, of course, purchasing available with just one scan and a tap.

Figure 1. Mobile device hardware platforms composed of a Toshiba e740 and a Socket Compact Flash Bar Code Scanner.

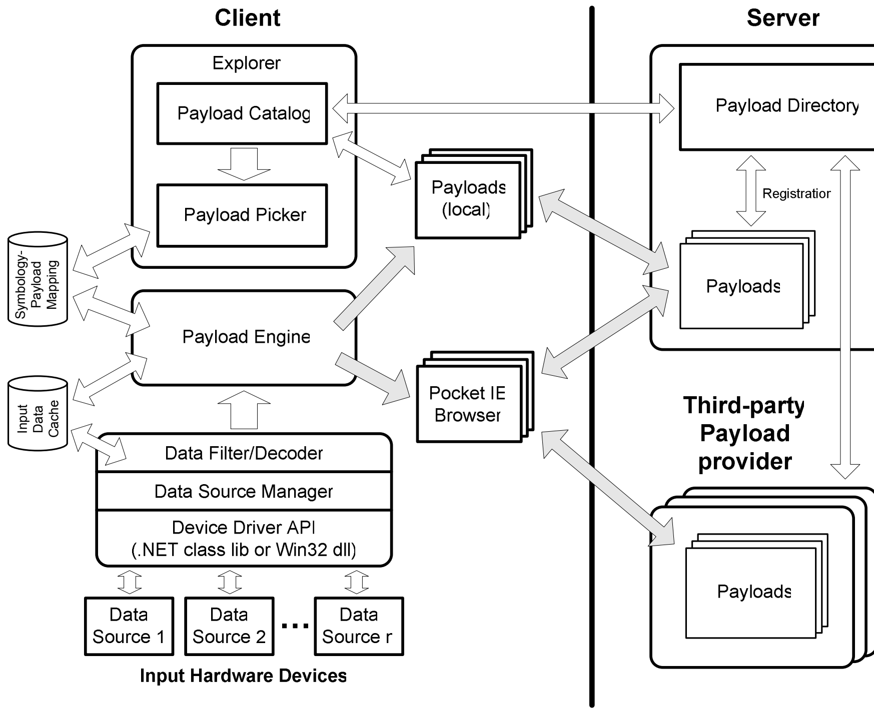

Figure 2. AURA Architecture diagram

RELATED WORK

Several projects have explored the ways objects and places can be linked to online content and services. Ljungstrand, *et al*. (2000) have built the WebSticker system to link barcodes to web pages. This was predominantly a desktop bound system. There is a large body of work on "context-aware" computing (Schilit, *et al.*, 1994). Context-awareness refers to the identification of a user's proximate environment for the delivery of computing content or services. Xerox's PARCTAB system uses custom built infrared transceivers to help palm-sized computers to identify their physical environments (Want, *et al.*, 1995). The Cyberguide uses Palm PDA's to provide map guides to tourists (Abowd, *et al.*, 1997). Positioning in Cyberguide is provided by a combination of custom applications based on infrared sensing (for indoor) and GPS (for outdoor). MIT LCS' Cricket System deploys custom built RF and ultrasound beacons for indoor navigation (Priyantha, *et al.* 2000).

The CoolTown Project at HP is building context-awareness technologies to provide web presences for people, places and things (Kindberg, *et al.*, 2000). Similar to the MIT Project Oxygen (MIT, 2002), CoolTown's main goal is to enable future "nomadic computing" such that computing resources follow the human user and customize the human-computing interaction based on the local human environment.

Our approach is a more modest and potentially more broadly deployable in the short term. Our goal is to enable a light weight way to both access information about physical objects and places and to add annotations to them. This focus is different from, but complementary to, efforts to link physical devices, like printers or projectors to device based user interfaces.

HARDWARE PLATFORM

The mobile component of our system integrates three core hardware features: a laser bar code scanner, a wireless network connection, and a PDA. There are a number of alternative sensors that could be usefully integrated into this system, including GPS and wireless network signal strength detection for location information and readers for the emerging technology of RFID tags. To date we have only made use of bar code readers but the system architecture is extensible, allowing these or other emerging sensor technologies to generate information that can be used to identify objects or places.

SERVER

The server is comprised of three components: a web service, runtime, and local and remote data stores. The Web Service is the channel the client uses to communicate with the backend server. This is accomplished entirely using remote method invocation over HTTP ("web services"). The web service is the interface to the backend runtime for the clients. The Runtime provides the business logic handling event tracing, retrieval, storage, rating calculations, and other tasks. The local database stores contain user profiles, barcodes, ratings, written and speech annotations, which are stored in a SQL2000 database. Information on books and UPC's are provided by multiple remote data stores including the Amazon Web Service for books and music, and the ServiceObjects Web Service for UPC lookup.

MOBILE CLIENT SOFTWARE

The client is a standalone application on the Pocket PC (as opposed to a web front-end) to support improved user interactivity. Network connectivity is not assumed to be continuous for the mobile client. The client application provides queuing and retry services for the storage and retrieval of data to and from the backend servers. These services are not possible for a thin web based client. Caches or local stores on the client can dramatically reduce the demand on network access for content. In addition, a client side application allows for a richer user interface. This is especially true when considering delays and intermittent network connectivity.

CLIENT INTERFACE COMPONENTS

Users can login to the system by creating a unique username and password combination either from the mobile device or through the web portal interface. Without an account the device can be used to scan objects but the device creates an Anonymous User account and all the comments created in that context are by default public.

When a user sees an object that interests them and finds a bar code printed or affixed to it they point the head of the device at the bar code from a distance of about 6-12 inches and press the scan trigger button which we mapped to the thumb button normally used to invoke the voice recorder feature of the Pocket PC. If the device acquires the tag's data and the application gives the user feedback and based on some properties of the bar code data and sends a series of network queries out to appropriate web services.

We have initially created or linked to services to support three types of bar codes: tags created for a local art gallery, UPC (Universal Product Code) codes commonly used to tag consumer products and foods, and ISBN (International Standard Book Number) codes for books. Any number of additional or alternate payloads are possible within this framework to provide services for these or other forms of object identifiers.

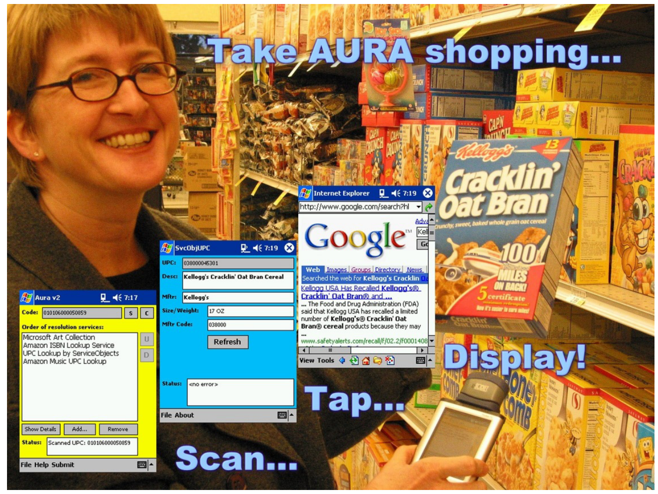

Figure 3. User scenario for grocery and related retail environments. Query highlighted the recall of the breakfast cereal by the FDA.

These payloads are linked to the resolution service registry which contains pairs of pattern matches and pointers to related web resources. When a tag is scanned it is matched to an appropriate payload on the basis of the structure of the identifier string. For example, ISBN codes start with "978" and have a total of 13 digits. All bar codes starting with that series of numbers with that number of digits are assumed to be an ISBN and are submitted to web services that are listed in the client's directory of resolution services that are registered as resolving such codes. We made use of a web service offered by Amazon.com that returns metadata about books and music when passed an ISBN number.

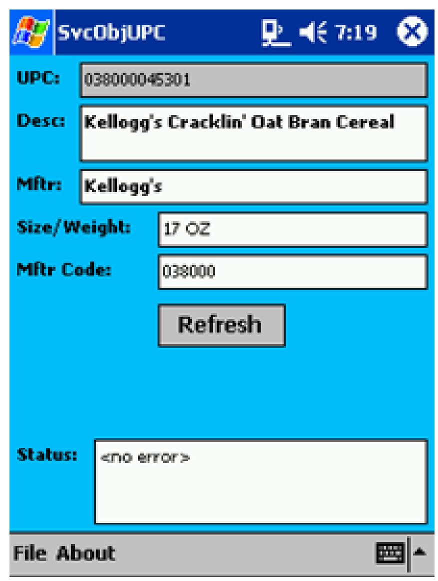

Figure 4. UPC Item Display Screen.

When objects with UPC codes are scanned the system recognizes that the code is not in other classes of codes and submits the identifier to a UPC mapping service. We made use of a UPC metadata service provided to the public by

ServiceObjects.Net, a commercial web service provider. This service returns a set of meta-data about the object and the client presents this data and creates hyperlinks to search engines based on the results. For example, when a box of breakfast cereal is scanned the resulting display provides two tap access to search results, the first of which notes that the product has been recalled due to food safety issues related to undocumented ingredients that might cause fatal allergic reactions for some people (figure 4 and 5).

Figure 5. Search results linked from UPC meta data

WEB PORTAL

Users can access the system through a web portal as well as the mobile device. Users can log into the web site and view their scan history sorted by various properties of the items. Scans can be sorted by time, by product category (books, food stuffs, etc.), or by the ratings or comments of other users or data found in other systems. This creates a simple way to assemble inventories of tagged objects, for example a collection of books, videos or music CDs. Alternatively, it creates a diary-like history of the series of objects scanned while, for example, browsing through a shopping mall or museum gallery.

CONCLUSION

A wave of annotation systems for physical objects is likely to be about to break. Cell phones are already integrating digital cameras and have the processing power needed to natively decode bar codes. As pocket computers merge with cell phones the resulting hybrids will no doubt combine a vision system with network connectivity and computation. The widespread distribution of such devices is likely to have dislocating effects in many sectors of life. Retail environments seem the most likely to change as consumers bring the power of the Internet to bear at the point of sale.

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Anatomy of a Museum Interactive: "Exploring Picasso's 'La Vie' "

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ABSTRACT

"Exploring Picasso's 'La Vie,'" a gallery installation as part of a major exhibition, demonstrates how an interactive display can address various learner styles, foster both social and individual interaction, and seamlessly command a fundamental understanding of the rather complex relationship of artist's methods, artist's life stories and the scientific methods that enable their discovery. The interactive demonstrates the roles of x-radiography and infra-red reflectography as important tools in understanding the artist's processes. The museum found that the interactive gave visitors the information and insight they needed to embrace new ways of looking at art. Its effectiveness may have been enhanced by the use of nearby, static, complementary material. Additionally, by conforming the installation of the interactive to the aesthetic of the exhibition it seemed to be more readily accepted by both museum visitors and staff, which may have added to its effectiveness. Various aspects of intent, design, user experience, and lessons learned are also discussed.

Keywords

interactive, constructivist, learning, art, museum,

INTRODUCTION

In the fall of 2001 the Cleveland Museum of Art presented the exhibition, *Picasso: The Artist's Studio*. . For Pablo Picasso (1881-1973), the studio was the crossroads of all that occurred in his life and contemporary society. Approximately 36 paintings and 9 drawings demonstrated the central place of this theme in Picasso's work and presented the remarkable variety of ways in he explored the artist's studio through portraiture, still lifes, interiors, landscapes, and allegories of artists at work. Picasso developed distinctive methods of creating, destroying, and revising images. Because he derived meaning from the very act of creation, studying his process can be crucial to unlocking the meaning of his art. This understanding is revealed to conservators and art historians in great part through x-radiography, infrared reflectography, and other forms of scientific analysis. Therein lies a tale of art, artist, science, and discovery that the Museum wanted to tell. And Picasso's *La Vie* would help tell it.

This presentation demonstrates and explores how the Cleveland Museum of Art developed and exhibited a large scale interactive display which addresses various learner styles, fosters both social and individual interaction, and seamlessly commands a fundamental understanding of the rather complex relationship of artist's methods, artists' life stories and the scientific methods that enable their discovery. At the same time, this interactive strove to inspire users to return to the real object of delight, the nearby painting itself. As such, it served to augment and enhance the personal experience of the painting, rather than distract from it. The interactive also had to meet the aesthetic rigors of a major art museum exhibition, as well as be easily used by a large number of visitors of diverse age, aggregations, and cultural and technological experience.

THE INTERACTIVE: "EXPLORING PICASSO'S 'LA VIE'"

Exploring Picasso's' La Vie' was presented on a 50" diagonal plasma screen, mounted on a wall in vertical orientation, thereby suggesting the size, orientation and gallery context of the painting as well as echoing the proportions and scale of the actual work. The aim is to give the visitor the sense of 'seeing through' layers of the work and personally uncovering the secrets revealed by the investigative techniques of the conservation department. Forward facing speakers were mounted beneath the screen. A wireless mouse was placed on a small pedestal approximately 10' from the screen. *(See Figure 1.)*

Interface Design

The interface design would only be successful if it were immediately intuitive, if content could be reached in a minimum of steps, if it fostered both group and individual experiences and, if the overall design respected differences in learning styles, responsive to a broad range of visitors. For example, it would have to accommodate constructivist learning methods for the self-directed learner. These would be the visitors who would want to create their own learning experiences from non-linear encounters with

Figure 1. "Exploring Picasso's 'La Vie'" as installed. Other gallery walls (not shown) displayed static, back-lit x-ray and infra-red images of the painting.

various types of rich media, in this case graphics, video, audio, narratives, and interactive tools for exploring the painting. The interactive would also have to respect the needs of the more traditional learner who requires that material be presented in a more sequential, less demanding didactic form. Both of these responses would have to use the same media objects and interface. To achieve this, the following design features were employed*(see Figure 2)*:

- Instantly expanding navigation bars along the themes of "Introduction," "Stories," "Explore," and "Examination Techniques" burst to the left when their iconic representations were rolled over at any time during the interactive's use.
- The *Introduction* bar allowed the user to view an Introduction, Picasso biographical information (Quicktime movies) or Credits.
- The *Stories* bar allowed users to experience illustrated main themes of discoveries about the artist's process through an animated, narrated detailed look at specific areas of the painting. A section of the painting was panned either in normal, x-ray or infrared view, as appropriate. Iconic cues and story names helped users choose stories. At any time during the narrative they could hit an "Interact" button which would switch the image to the area of the painting being discussed. They could then use a slide bar to morph the image between x-ray and/or infrared or normal states, as pertinent. A time bar helped users easily decide whether they wanted to view the whole narrative, or proceed to "Interact," or move to another section entirely. We believed that this information helped the visitor make the most efficient use of his or her time and eliminated the frustration of not knowing how long a narrative will take. Finally, a small representation of the entire painting highlighted the area being discussed. In all of these ways, the visitor experience could range from a sequential and rather passive playing of a series of interesting stories to a non-linear discovery of stories (or parts of stories) and personal explorations.
- The *Explore* bar provided a choice of "magnifying" glasses with which users could examine either a magnified view of the painting, the infra-red image, or the x-ray image If the user passed over a significant area, a pop-up text box would tell its story. A "Reveal Clues" button caused the painting to be overlayed with white circles where the stories could be found. This section of the interactive served two important functions. First, it reinforced the *Story* narratives (or vice versa) through more of a discovery approach. Second, it familiarized the museum public with how to read infra-red and x-ray images, much as a conservator would do. This newly acquired skill could be put to good use as visitors looked at the large static infra-red and x-ray images hung on the walls nearby.
- The *Examination Techniques* bar brought users to six scientific tools of conservation discovery*: x-radiography, infrared-reflectography, optical microscopy, ultraviolet light analysis*, *sampling and cross-sections,* and *scanning microscopy.* These features included animations (e.g. x-ray penetration) and behind-the-scenes videos showing conservators applying these techniques in the Museum's conservation lab on real works of art. We believe that the understanding of process results in a better understanding of result. Also, museum visitors are often intrigued by "behind the scenes" activities, and that some visitors, more interested in science and technology than art, might use this section as an entry point, and be intrigued enough to explore the rest.
- Overall, this interactive provided visitors with ample opportunity to pursue their own approach and interests. The traditional learner could literally "start at the top" and work down through the introductions to stories to explorations to the techniques, with very little demand for interaction --- no content ever requires more than one click. [A second click moved from a story to

"interact," or changed modes of magnifying glass.] On the other hand, more discovery-oriented users could explore all the options, carefully choosing those items that seemed of interest at any moment and in any order, allowing knowledge to built in more personalized way.

Upon opening the exhibition, staff believed that it would be helpful for volunteers to assist visitors with the interactive. This proved counter-productive, as will be described below.

In addition to assuring the interactive's ease of use, the museum recognized that many visitors were unlikely to wait long to use it or spend a lot of time experiencing each feature. These concerns were accommodated in two ways. First, the use of the large screen and distant pedestal with mouse made group viewing feasible and comfortable. Visitors could easily benefit from the stories or other activities that the user was initiating either while waiting their turn, or in lieu of it. Second, large, static, rear-illuminated x-radiography and infra-red reflectography images of *La Vie* were in the same room with the interactive, providing analogous insights from the conservation research. These served as a preparatory resource for those who were waiting to use the interactive, bolstered the information gleaned from the interactive, or provided information in lieu of using the interactive.

Finally, regardless of visitors' learning style or comfort with technology, the goal of this project was to inspire them to return to and look more closely at the art. We also hoped that visitors would internalize this experience and apply their new insights to the way they viewed Picasso's other paintings. We believe we were successful.

FINDINGS AND LESSONS LEARNED

Rather than pursue a formal evaluation, the Museum chose to rely on periodic observation by staff and anecdotal feedback for its overall assessment. Findings and lessons learned follow:

- Because some staff believed that computer experience among museum visitors would be very low, a volunteer was initially present to help use the interactive. However, rather than foster the visitors' personal exploration, the volunteer often became a guide through the content and visitors remained passive and complacent about this. This defeated the purpose of self-directed learning and exploration. We believe this situation occurred for several reasons. Both volunteers (or docents) and museum visitors are accustomed to, and comfortable with, the traditional museum education/lecture/tour model whereby visitors, for the most part, are rather passive receivers of structured information. Therefore it was easy for both groups to fall back into these roles. It is also likely that the seeming appreciation of visitors for the assistance (even among those who might have liked to just give it a go without being observed by a staff member) reinforced the situation. This pointed out the need to reorient the volunteers to the objective of their assistance: the comfort of visitors with a new means of self-directed discovery and education, rather than use the device as a teaching or demonstration tool. It should also be noted that this type of experience did not preclude visitor use. many visitors did try and usually had little problem with the interactive. Nonetheless, between the slight dissuasion of some visitors from use of the interactive, and the apparently higher than expected level of user computer proficiency, the use of volunteers was abandoned.

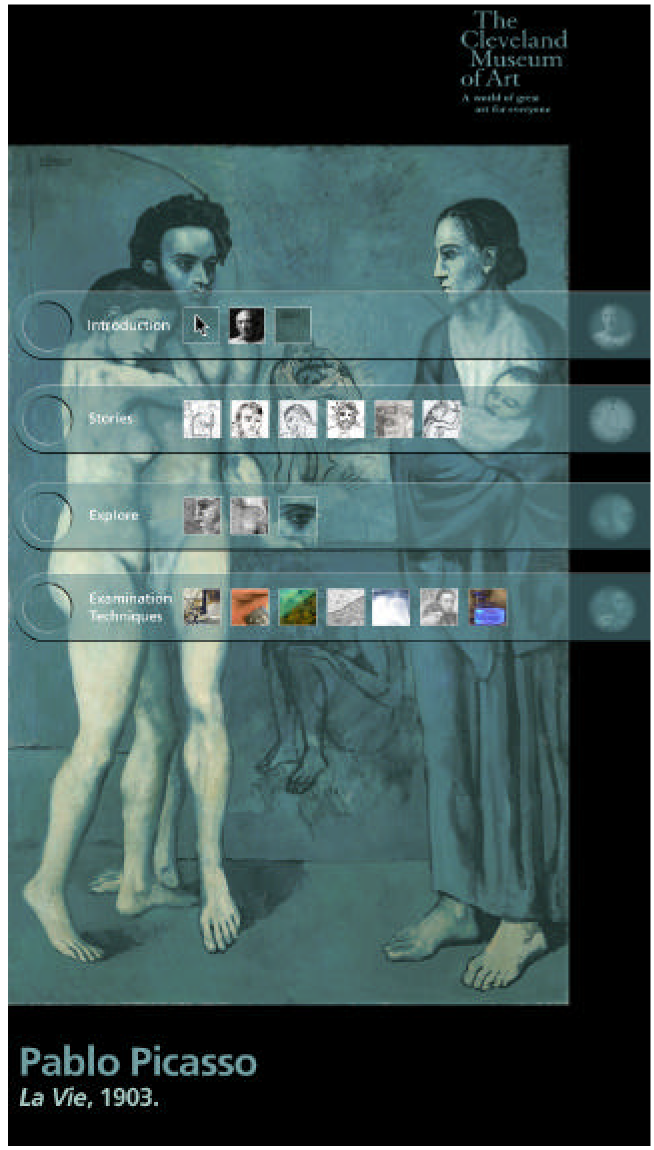

Figure 2. Full screen view of "Exploring Picasso's 'La Vie,'" showing all menu bars "burst" to the left, for illustrative purposes only.

In the absence of volunteers, we observed that users who did not immediately grasp how the interactive worked seemed to work it through and often received help from other members of their party (such as their children) or even other visitors (simply as a polite gesture or because they were waiting to use it themselves). This help was an interesting phenomenon, and we can surmise that it was at least in part borne of the open and shared experience it presented (*more on this below)*. Conversely, if this interactive were constructed as a single-person or small group device, we don't think such unsolicited help would have been forthcoming; if it did occur that it might have been perceived as more of means of hurrying up the hesitant user rather pure benevolent assistance. If we decide in the future that visitors should receive assistance then those providing assistance would have to be trained to focus on the visitors' independent use of the device.

- Clusters of visitors, both users of the interactive and observers, appeared to simultaneously find it engaging. We attribute this to both the quality of content and the comfort and ease with the experience could be shared.
- In family groups, parents seemed pleased to see their children enthusiastically engaged with the interactive; they sometimes had to drag the kids away.
- A gender difference with respect to how the interactive was used has been observed. It seemed that women most often engaged in a random hunt and peck through the menu system and sampled content, while men seemed to engage sections in more depth, were more likely to interact with the content, and would go through more stories sequentially and completely. However, this may be biased by placement of this portion of the exhibition near the Exhibition gift shop; we suspect that the interactive proved a good diversion for men waiting for wives to finish shopping.
- We were surprised at the importance of the static images in the gallery. For many parties, a sort of "teamwork" occurred. While one member was using the interactive, the other(s) would study complementary information in the wall-mounted images; then they sometimes switched roles. In sum, the combination of the two activities appeared to lengthen the overall duration of their experience with this section of the exhibition. The static images also provided more opportunity for visitors to focus on a single aspect of the painting. Additionally, we observed that while some visitors did not use the interactive and only referred to the static images, virtually everyone who used the interactive *also* referred to the static images; virtually no one relied on the interactive alone. This suggests that the effectiveness of interactives which portray rich information and complex concepts might benefit from accompanying complementary and reinforcing material. However, we do not know how effective the interactive alone would have been. It is also possible that the existence of the static images mainly allowed interactive users to pursue an interest that had been piqued, while allowing someone else to try the device. Perhaps in part the interactive acted as a dynamic sampler of the static exhibit. In the future we will give more consideration to the use of supplemental material.
- We believe the resemblance of the installation to a painting hung on a wall, and its accord with the exhibition's overall aesthetic, helped engender its broad acceptance and success. Although the vertical orientation of interactive's image required resolution of some interesting programming issues, it was well worth the effort. The images providing an excellent proxy for the actual painting. The ready association of the interactive's screen image with the art made the "technology" more transparent and brought greater focus to the content. Yet, for the visitor, it did not at all replace the experience of the original object. Rather, viewers went back in search of the actual painting, which was several rooms away. Having learned that there were hidden images within the painting, some of which were were indeed somewhat perceptible if one knew where to look, many visitors sought out the actual painting and took ownership of the ability to discern the heretofore undiscernible. This has significant implications for the potential of museums interactives to teach visitors tools and techniques for their understanding and appreciation of art, beyond factual or contextual information.
- Curators and exhibition designers were not accustomed to technological augmentation of traditional art exhibitions, concerned that an interactive device near an object would distract from the original. Yet, the effort visitors made to compare the information from the interactive to the actual art demonstrates how interactive media can stimulate interest in, rather than supplant the art experience.
- Feedback about the interactive from staff, visitors, the Trustees, the press and others has been overwhelmingly positive, and has helped engender support for continued use of interactives in permanent and temporary exhibitions. In 2002, the Museum the project received an American Association of Museums' *Muse Award.*

CONCLUSION

Far reaching and complex goals were established for the production of *Exploring Picasso's "LaVie,"* and we believe that our goals were substantially met. *T*he number of users who returned to the actual work of art to take a closer look is especially noteworthy. In the future more consideration will be given the role of supplementary materials with interactives as reinforcements or adjuncts; and, the way in which tools and techniques may be taught to visitors, as compared with facts and context.

ACKNOWLEDGEMENT

The authors wish to acknowledge the contribution of Cognitive Applications, Inc., Brighton, England, and Washington, D.C. who created *Exploring Picasso's 'La Vie'* with the Cleveland Museum of Art

Facilitating Argument in Physical Space

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ABSTRACT

We have created a ubiquitous computing application which will facilitate discussion. The system applies radio frequency identification (RFID) and tangible user interfaces (TUIs) to the World Wide Web. It uses TUIs to permit users to explore and construct both sides of a debate. While our initial evaluation focuses on school children, during our demo conference attendees use our interface to participate in the debate of the pertinent Ubicomp topic; "Will ubiquitous computers replace paper?". Our interface moves beyond WIMP to bring argumentation and debate into the tangible realm.

Keywords

Computer Supported Collaborative Argumentation (CSCA), Tangible User Interfaces (TUI)

INTRODUCTION

A regular theme in Human-Computer Interaction research has been the development of systems that help people impose structure on complex interpersonal communication. Systems for Computer Supported Collaborative Argumentation (CSCA) [2], requirements capture [3], discussion thread management [15], and others provide interactive visualisations of human communication, in a way that assists users to address complex topics (such as system design), [5] or work through contentious issues (such as industrial relations disputes) [9]. Typically these systems work by helping users to focus on the structure of discussion, for example noting when new contributions are intended to clarify, support or rebut earlier statements.

One of the challenges in building systems like these is that they are typically implemented to run in a conventional computer environment, as an application under a WIMP operating system [2,3,4,5,9,10,15]. Although many such systems are designed for use by multiple users, each user sits in front of his or her own screen, contributing to the discussion by operating the keyboard and mouse at that screen. It is possible to augment the discussion via video or tele-conferencing (especially if some participants are remotely located), but this introduces many obstacles to effective collaboration. In particular, the introduction of a shared representation is only of value if it then supports *deixis* – semantic reference to a specific component of the discussion (e.g. pointing) [1]. The whole purpose of CSCA systems is to help structure argument through the provision of a shared representation that enables participants to make deictic reference to specific structural components of the argument.

Video and tele-conferencing systems are particularly poor at supporting *deixis*. Although many research attempts have been made, video-conference systems do not yet support gaze inference such that one participant can tell what another participant is looking at. Pointing is a key element of *deixis*, but it is very hard to create multi-user systems that allow participants to communicate by pointing at their screens. If the whole structure fits in a single screen with no zoom or pan, then it is possible to implement multi-cursor pointing systems. Alternatively, one user can be in control of a display that is broadcast to many screens. If each user is allowed to control their own view (i.e. true collaboration), and if the visualisation does not fit within one screen (i.e. truly complex argument rather than toy examples), then it is practically impossible to establish socially appropriate interfaces for collaborative argumentation.

These factors have motivated us to take a ubiquitous computing approach to the support of collaborative argumentation [16,17]. Rather than using conventional screen and keyboard interfaces, we have created a large scale physical interface that can be distributed across a room or over a board table. Participants in an argument can move freely about the room, pointing to, picking up or moving physical objects that represent elements of the argument structure.

While our departure from WIMP interfaces for computer support for argumentation is novel, so is our approach to argumentation. In ancient times the study of rhetoric began with simple forms such as fables and storytelling and progressed through more complex forms to the sophistication of parliamentary debate and legislation[6]. In the field of ubiquitous computing a considerable amount of work has been done on support for narrative creation by children – the beginnings of rhetorical education [7,13]. Meanwhile work in the field of computer-supported cooperative argument has focused on rhetoric in its most accomplished forms of industrial negotiation and legal argument [4,9]. There has however been very little work which has focused on the first exercises in persuasive rhetoric that are used to lead the student step by step to the heights of rhetorical complexity. We have chosen to bridge this gap and focus on the classical rhetorical exercises of encomium and vituperation, where a student praises or criticises a topic or an individual. These exercises break down the construction of an argument into a series of manageable steps that ensure the participants cover all of the necessary ground and organise their knowledge and the fruits of their research as effectively as possible.

Both the rhetorical focus of our system and our approach to ubiquitous computing were designed for use in schools, to facilitate part of the English national curriculum [11] that teaches argumentation and discussion skills to students (see Figure 1). It is particularly useful to see visualisations of

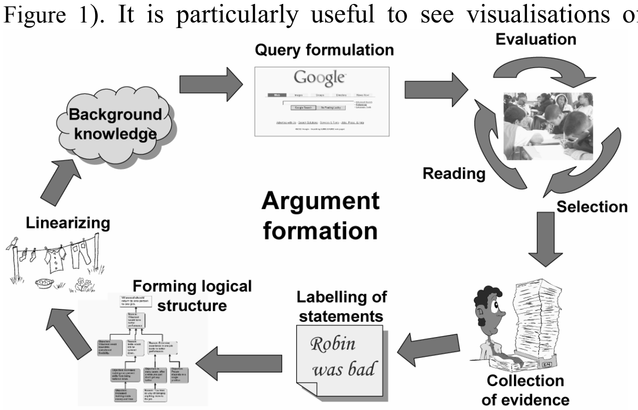

Figure 1. Argument Formation Cycle

argument structure in the classroom. Teaching argument demands that the teacher be able to refer explicitly to the argument structures being developed by the children, in order to provide a relevant critique of a malformed argument, or explain ways the argument could be made more persuasive. In addition to this natural fit to the classroom context, we also believe that it is especially valuable to design ubiquitous computing systems that are constrained by a specific application domain. Many ubiquitous computing research projects have created products, middleware or technical architectures that have no clear application. To avoid this trap, we voluntarily accepted the strict design constraints of the school environment, and of the highly prescriptive English National Curriculum, in order to focus our activities on the creation of a system that addressed a genuine need. We have called this research strategy Curriculum Focused Design [12].

We are however convinced that the classroom is not the only forum that will benefit from computer support for the learning of skills in argument and persuasion. We intend to explore further the possibilities of using our system with older children and adults.

TECHNICAL APPROACH

One of the constraints imposed by the classroom context is that the technology base for the ubiquitous computing system must be extremely robust. The classroom is a physically demanding environment, with little tolerance for equipment failure. We therefore selected a well-established communications and sensing infrastructure, based on radio frequency ID tags and readers (RFID). The physical tokens of argument contributions are augmented with RFID tags, and the argument structure is represented by a series of RFID readers. The RFID readers are networked to a central server, which generates a real-time visualisation of the developing argument for projection onto the wall of the classroom.

Users interact with the application by placing statements which are augmented with RFID tags on the readers. Each reader has a prompt and together they form a trail which takes the user through an argument – either for a position, against it or showing understanding of both sides – in small and easily managed steps. Every time the reader places a statement on a reader this change in state in the TUI is reflected in the GUI. The aim is to use the GUI and TUI in combination to allow the user to do two things: firstly to organise the statements relevant to an argument according to the loose structure provided by the prompts on the readers; and secondly to deliver a speech for the point of view she has set out using both the TUI and GUI as visual aids.

EVALUATION

We have evaluated our design approach over a period of six months, with a range of prototypes exploring the technical approach above. Our iterative prototyping design method commenced with "low fidelity" prototypes that explored the use of the spatial interface within an actual classroom lesson, but only provided limited automated functionality through the use of RFID. Some automated functionality was simulated during these experiments via the "Wizard of Oz" technique [8] where a researcher controlled the computer interface to test alternative designs with minimal development effort. After ten generations of prototypes, we have developed an effective and technically operational system that has been evaluated under lesson conditions [14].

Evidence Selection

Our early prototypes focused on the collection and labelling phases of the Argument Formation Cycle. We had observed that children read source web pages, they then evaluated and selectively highlighted, and then grouped together relevant pieces of *evidence.* These groups were then named (e.g. 'trust', 'sightings', 'evidence and backing up') and claims or *statements* on each theme used to structure the argument. We gave children small stands incorporating a whiteboard on which to write a statement, and a set of clips to attach collected evidence supporting that statement (Figure 2). We intended that RFID tags in the documents would be

Figure 2. Iteration #3 prototypes for grouping selections

recognised by an RFID reader in the stand, so that the logical relationships between statements and collections of documents would be recognised by the system.

Argument Construction

For each stage in the argument an “Activity Square” was produced – a large card stating what the student should do at that stage of the argument – e.g. “Say something good about graffiti” (see Figure 3). Then we used statements produced in

Figure 3. Prototype providing rhetorical structure

earlier stages of the Argument Formation Cycle as counters in a rhetorical board game (see Figure 4). Children placed labels with these statements on suitable activity squares in order to structure their argument using evidence found in their research.

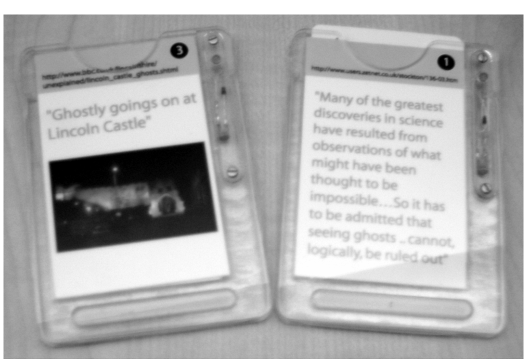

Figure 4. Selection tags each with a RFID & LED

Argument Presentation

The final stage of argument formation is linearization: the argument structure turned into a linear form which can be delivered as a speech. By arranging the TUIs the users have to construct an argument which is also represented on a projected display. Users can use the TUI to trigger the GUI to display content relating to the specific section of the argument they are verbally presenting.

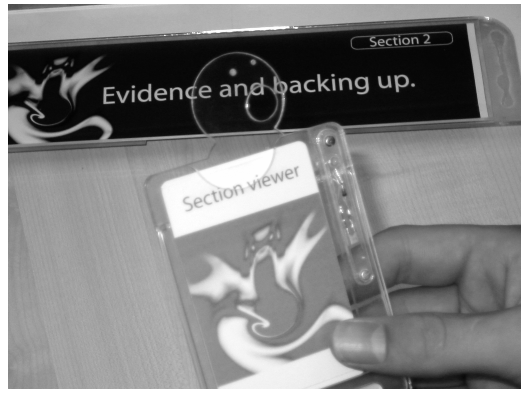

Figure 5. Triggering a transition in the GUI by placing the ‘section viewer’ on the activity square.

Observations

During the course of our evaluations we have spent upwards of twenty hours observing children in schools debating three different topics. All of these children succeeded in using the TUI to construct an argument which satisfied their teacher. The teacher found several of these arguments surprisingly articulate. Students who used the TUI were able to interact better with their audiences while presenting. We have formed a number of preliminary gender-related observations: our female students seem to lead in the coordination and structure of the argument, whereas our male students have focused much of their energies on understanding the relationship between the GUI the TUI.

We learned that making many small changes through multiple iterations allowed us to isolate the effect of the physical affordances vs. the effect of technology. We were forced to switch from low to high frequency RFID tags to allow for clear grouping of multiple statements on an activity square. These trials have dictated our plans for further technological development. We observed how children enjoyed stacking the early box-shaped statements as well as how it helped with argument presentation. This resulted in our plan for a future box-shaped prototype that will permit stacking by containing both a RFID reader and a tag.

CONCLUSION

We have developed an approach to locating conversational argument processes within a physical space through the use of ubiquitous computing. This provides a far richer outcome from ubiquitous computing than previous attempts to integrate video and screen-based visualisation. This argumentation system, while a novel use of technology, also provides a good example of user-centered design. Careful iteration and attention to the needs of users will help ensure a socially appropriate interface for collaborative argumentation which is more likely to be adopted by potential users. Our system will promote natural interaction with evidence, presented via TUIs and paper documents. The demonstration should be of interest both as an illustration of this type of application in use, and as a novel way for delegates to engage with an important question for the future of ubiquitous computing.

ACKNOWLEDGMENTS

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Box. Open System to Design your own Network

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ABSTRACT

Box is a modular architecture that supports distributed, self-regulated networks of information products. The system combines a server application, an on-line visual language and a collection of wireless devices to provide an environment where networks combining these physical objects and digital information can be easily created and maintained. The system allows real-time, collaborative construction of networks of information products across remote locations.

The Box system aims to offer an insight into the basic elements that configure information networks, analising the implications of using ubiquitous wireless devices as nodes of these networks

Keywords

Connected Communities, Wireless Appliances, Visual Languages, Network Visualization, Information Flow.

INTRODUCTION

The architectural spaces we inhabit will become an interface between humans and on-line digital information. Wireless networks are becoming widely available and an increasing number of devices and information appliances are starting to communicate through these networks.

Exploration is needed on computational environments that mix digital media and the physical environment. Tangible interfaces are becoming an increasingly popular design strategy as computational elements hybridize and become smaller and more ubiquitous [1]. The Box system provides a tool-kit to explore physical computation that places information in private or shared social spaces and renders information that can be grasped, literally.

Proposal

A modular system —Box— is proposed to physically couple virtual and actual space, and to network an unlimited number of entities, creating a participatory environment for communication and information exchange. The system adapts the notion and principles of software architectures, to the world of tangible artifacts.

The context of the proposed system will be a connected community: A group of people in local and/or remote locations who often communicate through information networks. The ultimate goal is to create an open platform to facilitate the exchange of knowledge and the interplay of ideas, to create inmersive information experiences, to integrate users into the design process, transforming them from atomised, passive consumers into active interpreters of information [2].

From Content to Structures

Computer networks allow people to dynamically interact with a collection of media, an internal structure, and a diversity of interfaces. The Box system aims to offer an insight into the elements that are part of this internal structure.

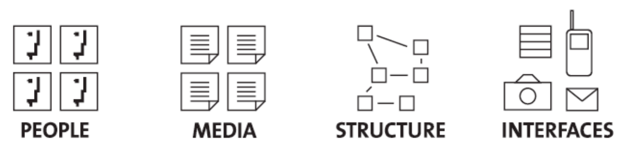

Fig 1: Box focuses on the internal structure of information networks.

This approach will allow the development of new tools and methods for the embedding of computation in everyday things so as to create information containing objects, researching on how new functionality and new use can emerge from collections of interacting artifacts, and ensuring that people's experience of these computational environments is both coherent and engaging in space and time.

SYSTEM ARCHITECTURE

The Box system integrates a server application, an on-line interface and a collection of modular, wireless physical devices, called Boxes.

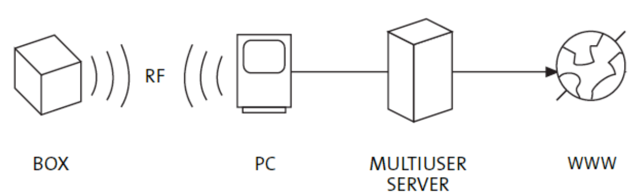

Fig 2: Box system architecture.

Boxes can be distributed around a building or public space. They communicate wirelessly with a PC which routes the data to the multiuser server that holds the internal structure. Every PC acts as a network hub that can communicate with up to 255 boxes.

Server Application

The server application, developed in Lingo (*Macromedia Director* and *Macromedia Shockwave Multiuser Server*) maintains the networks and visualises them through a visual language: Type and location of the boxes, channels for the flow of data, objects that collect information from web databases and other constructs which dictate how the information is transformed and transmitted between each one of the physical devices.

Visual Language

A simple, visual language has been integrated with the system to allow creation and visualization of dynamic information structures. This visual language, based on an model that represents the flow of information, allows the visualization of a variety of information networks: from a web log to an e-mail list, from an ATM machine to a cell-phone voice messaging system.

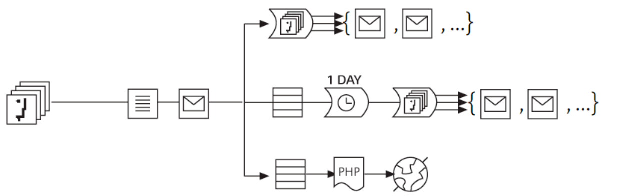

Fig 3: Representation of an e-mail list with the Box visual language.

The visual language is based on 5 different basic types of constructs: Boxes, Containers, Transformers, Transceivers, and Channels.

Physical Devices

The system provides a collection of information devices, embedded into the simple shape of a cardboard box. These objects have just one function and limited affordances: one of these objects presents an antenna that goes up and down, another one detects movement nearby, another one emits sounds, etc. Some of them are able to display information through an embedded screen or a small printer; others are able to gather data through sensors or switches.

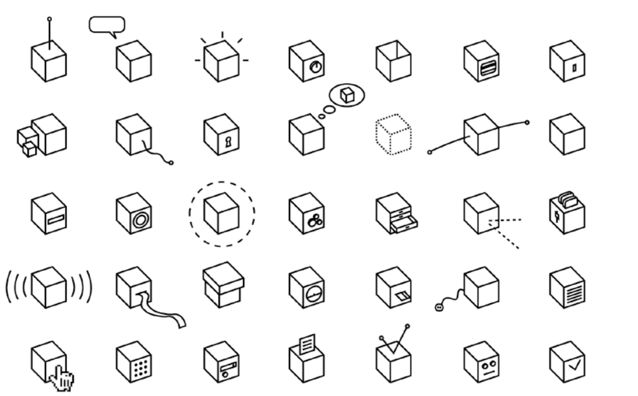

Fig 4: The Box system can combine an unlimited number of information containing objects.

Ignoring the shape of the objects and their affordances, the user can focus on what the boxes do, and not on the way they look.

Their size responds to the need for objects that are portable, objects that you can place in any location but you do not carry around with you. They present a small antenna to indicate they can communicate wirelessly with other entities.

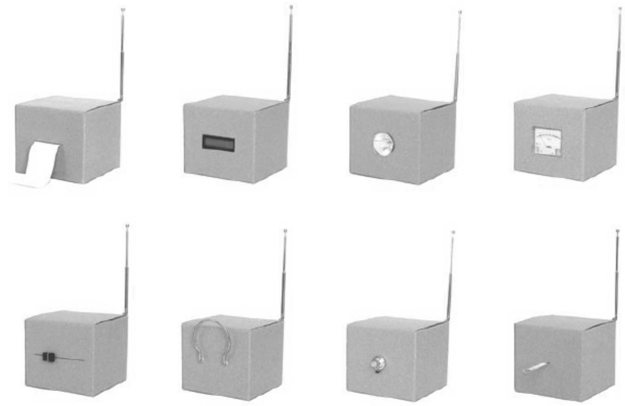

Fig 5: Boxes illustrate information products: wireless devices that can communicate with the network. The first row depicts output boxes, while the second row depicts input boxes.

The modular nature of this objects allows configuration of more complex artifacts by combining them with the virtual structure supported by the on-line interface.

Hardware Kits

Massimo Banzi, Technology Professor at Interaction-Ivrea, has developed a custom PCB (Printed Circuit Board) board to allow simple and cost-effective production of wireless physical devices. The kit is based on the PIC series micro controllers from *Microchip* and uses the BIM2 transceiver from *Radiometrix* to provide RF (Radio Frequency) communication with the hub computer. Wireless communication is controlled with *S.N.A.P*. (Scaleable Node Address Protocol), an open and free protocol developed by *High Tech Horizons*.

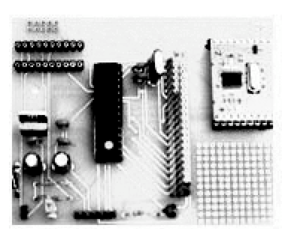

Fig 6: Electronic kits allow easy construction of wireless devices.

The kits allow interaction design students and non-technical people to create their own networked devices by plugging a sensor or actuator into these pre-made kits.

Each device has an identification address embedded into the software of the micro-controller. This address is visible both on the physical device and on its virtual representation on the online interface.

Online Interface

Combining the elements of the visual language and the physical devices in different configurations users can create an unlimited number of information networks. Any numbers of users with an internet connection can collaboratively view and modify this internal structure.

As the structure is stored on-line, boxes can be placed on remote locations, allowing platforms for communication and information exchange combining boxes far away from each other.

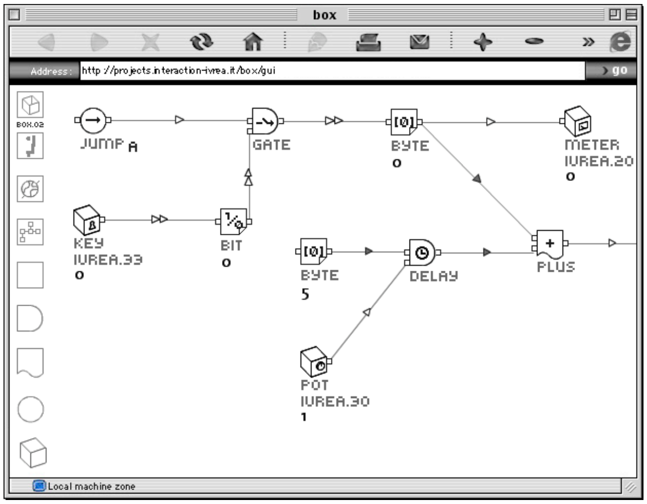

Fig 7: The on-line interface allows collaborative construction of distributed networks of wireless devices.

This separation between tangible objects and virtual structure provides an environment with unlimited potential for expandability, based on the recombination of simple modules.

This concept of information appliances [3] is closely related to the idea of replacing the computer with a number of highly interconnected specialised devices in the ubiquitous computing scenario above. Norman argues that what makes the personal computer so complex and difficult to use is that it aims to do too many things for too many different users. By replacing the universal computer with objects optimised for a single task or activity, we can overcome many (if not most) of the usability problems associated with computers. To get more complex functionality, users should be able to combine the functionality of several objects, hence the need for communication between them.

This solution might not be as simple to implement as it might first seem, nevertheless, if we move beyond usability considerations, the concept of information appliances can be an interesting basis for reconsidering what information containing objects might be like.

INTERACTION

Creating Networks

Every Box has an unique ID number and a visual representation on the online interface. On this on-line environment, participants can combine the elements of the visual language with the boxes, interconnecting modules, gathering data from sensors and switches, transforming and routing data from external sources like web databases to the physical objects.

This provides a collaborative environment where several participants can remotely engage in real time in the construction of platforms for communication and information exchange. As soon as members of the community are able to define a code and agree on the role each box undertakes, they can actively participate on the construction of information networks.

Fig 8: Printer Box archives subject lines of messages sent to the internal e-mail list of Interaction-Ivrea.

A number of different applications have been prototyped at Interaction-Ivrea. Networks to create awareness of the activity on the building, to archive discussions of e-mail lists; networks for personal communication, for continuous visualizations of dynamic data as stock market values, weather forecasts or newspapers headlines; networks to foster social interaction, to provoke debate about academic issues, etc. The applications prototyped do not try to be extensive, but to open up a new design space.

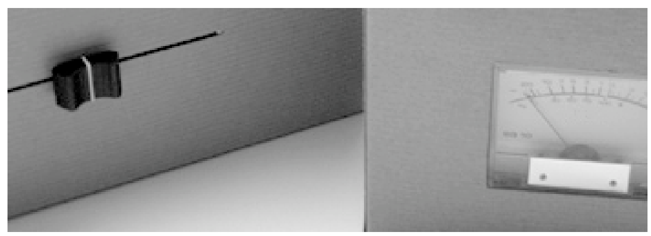

Fig 9: Debate network. Users could rate a particular issue displayed on a Box with and embedded LCD display by moving the slider of another Box. Average results over time are shown on a meter Box.

Distributed Systems

Many small simple independent elements can interact with each other to perform useful outcomes. By examining distributed systems we will change the way we think about design problems. But there is a trade off between efficiency and robust adaptability. Simple machines can be efficient, but complex distributed systems are often not. Looking at complete systems changes the problems for design often in a favorable ways. The emergent complexity of decentralized systems is achieved through the interaction dynamics of multiple simple components all acting in parallel, each with their own set of simple rules.

Decentralized —distributed— models can integrate better with the social dynamics and learning processes found in connected communities. Until recently there have been few alternatives which would allow people to experiment with decentralized systems. Resnick has been building a number of new tools for kids at the MIT Media Lab which allow novices, scientists and designers to explore decentralized thinking [4]. His hope is that these conceptual tools will help people move beyond the centralized mindset.

He contends that best way to develop better intuitions about decentralized systems is to construct and *play with* such systems.

The Box system follows this line of enquiry, proposing an open platform to encourage research and experimentation, allowing new devices to be incorporated into the system and providing an environment where self-regulated networks combining these objects can be created.

PHYSICAL COMPUTING

The Box system has been integrated with the academic program of Interaction Design Institute Ivrea, in order to teach the fundamentals of physical computing and networked appliances. Visiting professor Bill Verplank directed the course. Students were asked to create a network of two devices: one input and one output box.

Fig 10: Luther Thie and Belmer Negrillo's *Whispering to Birds*, an exploration done based on the Box system for the Physical Computing course at Interaction-Ivrea.

Outcomes covered a broad range of interactions, from exploration of physical behaviors representing emotions to a network where the fall of a leaf on the input Box would trigger the sound of a bird on the output Box located on a far away tree.

CONCLUSIONS

When users are allowed to set up and configure their own personal networks based on the recombination of simple modules, emergent platforms will appear that best reflect the social networks that maintain them.

Thus, we, as designers, can create open systems open for interpretation, integrating participants into the design process, encouraging creativity and turning them from passive consumers into active interpreters of information.

With the proliferation of ubiquitous technological devices, the development of a semantic web that will be integrated with these devices and the extensive use of computer networks to play, work and communicate, we, as designers, need to consider the issues, values and opportunities offered by these new technologies.

By abstracting the basic elements of these networks and experimenting with them free from commercial constrains, this program expects to raise up issues about current trends of the information society, which values are being imposed on *information consumers* or simply whether they are desirable.

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LINKS

http://projects.interaction-ivrea.it/box

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Demonstrations of Expressive Softwear and Ambient Media

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ABSTRACT

We set the context for three demonstrations by describing the Topological Media Lab's research agenda. We next describe three concrete applications that bundle together some of our responsive ambient media and augmented clothing instruments in illustrative scenarios.

The first set of scenarios involves performers wearing expressive clothing instruments walking through a conference or exhibition hall. They act according to heuristics drawn from a phenomenological study of greeting dynamics, the social dynamics of engagement and disengagement in public spaces. We use our study of these dynamics to guide our design of expressive clothing using wireless sensors, conductive fabrics and on-the-body circuit logic.

By walking into different spaces prepared with ambient responsive media, we see how some gestures and instruments take on new expressive and social value. These scenarios are studies toward next generation TGarden responsive play spaces [25] based on gesturally parameterized media and body-based or fabric-based expressive technologies.

Keywords

Softwear, augmented clothing, media choreography, real-time media, responsive environments, TGarden, phenomenology of performance.

CONTEXT

The Topological Media Lab is established to study gesture, agency and materiality from both phenomenological and computational perspectives. This motivates an investigation of human embodied experience in solo and social situations, and technologies that can be developed for enlivening or playful applications.

The focus on clothing is part of a general approach to wearable computing that pays attention to the naturalized affordances and the social conditioning that fabrics, furniture and physical architecture already provide to our everyday interaction. We exploit the fusion of physical material and computational media and rely on expert craft from music, fashion, and industrial design in order to make a new class of personal and collective expressive media.

TML'S RESEARCH HEURISTICS

Perhaps the most salient notion and leitmotiv for our research is continuity. Continuous physics in time and media space provides natural affordances which sustain intuitive learning and development of virtuosity in the form of tacit "muscle memory." Continuous models allow *nuance* which provides different expressive opportunities than those selected from a relatively small, discrete set of options. Continuous models also sustain *improvisation*. Rather than disallow or halt on unanticipated user input, our dynamical sound models will always work. However, we leave the *quality* and the *musical meaning* of the sound to the user. We use semantically shallow machine models.

We do "materials science" as opposed to object-centered industrial design. Our work is oriented to the design and prototyping not of new devices but of new species of augmented physical media and gestural topologies. We distribute computational processes into the environment as an augmented physics rather than information tasks located in files, applications and "personal devices."

APPLICATIONS AND DEMONSTRATIONS

We are pursuing these ideas in several lines of work: (1) softwear: clothing augmented with conductive fabrics, wireless sensing and image-bearing materials or lights for expressive purposes; (2) gesture-tracking and mathematical mapping of gesture data to time-based media; (3) physics-based real-time synthesis of video; (4) analogous sound synthesis; (5) media choreography based on statistical physics.

We demonstrate new applications that showcase elements of recent work. Although we describe them as separate elements, the point is that by walking from an unprepared place to a space prepared with our responsive media systems, the same performers in the same instrumented clothing acquire new social valence. Their interactions with co-located less-instrumented or non-instrumented people also take on different effects as we vary the locus of their interaction.

Softwear: Augmented Clothing

Most of the applications for embedding digital devices in clothing have utilitarian design goals such as managing information, or locating or orienting the wearer. Entertainment applications are often oriented around controlling media devices or PDA's, and high-level semantics such as user identity [1, 7] or gesture recognition [28]. Our approach to softwear as *clothing* is informed by earlier work of Berzowska [2] and Orth [19].

We study the expressive uses of augmented clothing but at a more basic level of non-verbal body language, as indicated in the provisional diagram (Fig. 1). The key point is that we are not encoding classes of gesture into our response logic but instead we are using such diagrams as *necessarily* incomplete heuristics to guide human performers.

Performers, i.e. experienced users of our "softwear" instrumented garments will walk through the floor of the public space performing in two modes: (1) as human social probes into the social dynamics of greetings, and (2) as performers generating sound textures based on gestural interactions with their environment. We follow the performance research approach of Grotowski and Sponge [10, 25] that identifies the actor with the spectator. Therefore we evaluate our technology from the first person point of view. To emphasize this perspective, we call the users of our technologies "players" or "performers" (However, our players do not play games, nor do they act in a theatrical manner.) We exhibit fabric-based controllers for expressive gestural control of light and sound on the body. Our softwear instruments must first and foremost be comfortable and aesthetically plausible as clothing or jewelry. Instead of starting with devices, we start with social practices of body ornamentation and corporeal play: solo, parallel, or collective play.

Using switching logic from movements of the body itself and integrating circuits of conductive fiber with light emitting or image bearing material, we push toward the limit of minimal on-the-body processing logic but maximal expressivity and response. In our approach, every contact closure can be thought of and exploited as a sensor. (Fig. 1)

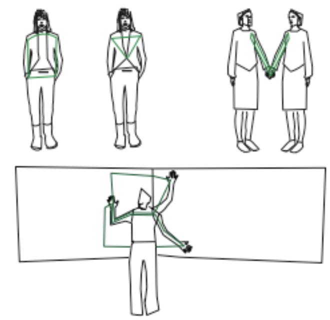

Fig. 1. Solo, group and environmental contact circuits.

Demonstration A: Greeting Dynamics (Fantauzza, Berzowska, Dow, Iachello, Sha)

Performers wearing expressive clothing instruments walk through a conference or exhibition hall. They act according to heuristics drawn from a *provisional* phenomenological schema of greeting dynamics, the social dynamics of engagement and disengagement in public spaces built from a glance, nod, handshake, embrace, parting wave, backward glance. Our demonstration explores how people express themselves to one another as they approach friends, acquaintances and strangers via the medium of their modes of greeting. In particular, we are interested in how people might use their augmented clothing as expressive, gestural instruments in such social dynamics. (Fig. 2)

Fig. 2. Instrumented, augmented greeting.

In addition to instrumented clothing, we are making gestural play objects as conversation totems that can be shared as people greet and interact. The shared object shown in the accompanying video is a small pillow fitted with a TinyOS mote transmitting a stream of accelerometer data. The small pillow is a placeholder for the real-time sound synthesis instruments that we have built in Max/MSP. It suggests how a physics-based synthesis model allows the performer to intuitively develop and nuance her personal continuous sound signature without any buttons, menus, commands or scripts. Our study of these embedded dynamical physics systems guides our design of expressive clothing using wireless sensors, conductive fabrics and on-the-body circuit logic.

Whereas this first demonstration studies the uses of softwear as intersubjective technology, of course we can also make softwear more explicitly designed for solo expressive performance.

Demonstration B: Expressive Softwear Instruments Using Gestural Sound: (Sha, Serita, Dow, Iachello, Fistre, Fantauzza)

Many of experimental gestural electronic instruments cited directly or indirectly in the Introduction have been built for the unique habits and expertises of individual professional performers. A more theatrical example is Die Audio Gruppe [16]. Our approach is to make gestural instruments whose response characteristics support the long-term evolution of everyday and accidental gestures into progressively more virtuosic or symbolically charged gesture.

In the engineering domain, many well-known examples are mimetic of conventional, classical music performance. [15]. Informed by work, for example, at IRCAM but especially associated with STEIM, we are designing sound instruments as idiomatically matched sets of fabric substrates, sensors, statistics and synthesis methods that lie in the intersection between everyday gestures in clothing and musical gesture.

We exhibit prototype instruments that mix composed and natural sound based on ambient movement or ordinary gesture. As one moves, one is surrounded by a corona of physical sounds " generated" immediately at the speed of matter. We fuse such physical sounds with synthetically generated sound parameterized by the swing and movement of the body so that ordinary movements are imbued with extraordinary effect. (Fig. 3)

The performative goal is to study how to bootstrap the performer's consciousness of the sounds by such estranging techniques (estranging is a surprising and undefined word here) to scaffold the improvisation of intentional, symbolic, even theatrical gesture from unintentional gesture. This is a performance research question rather than an engineering question whose study yields insights for designing sound interaction.

Gesturally controlled electronic musical instruments date back to the beginning of the electronics era (see extensive histories such as [13]) .

Our preliminary steps are informed by extensive and expert experience with the community of electronic music performance [25, 31, 32].

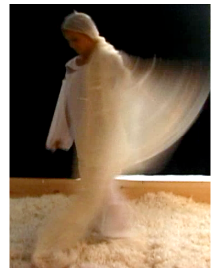

Fig. 3. Gesture mapping to sound and video.

The motto for our approach is "gesture tracking, not gesture recognition." In other words we do not attempt to build models based on a discrete**,** finite and parsimonious taxonomy of gesture. Instead of deep analysis our goal is to perform real-time reduction of sensor data and map it with lowest possible latency to media texture synthesis to provide rich, tangible, and causal feedback to the human.

Other gesture research is mainly predicated on linguistic categories, such as lexicon, syntax and grammar. McNeill [17] explicitly scopes gesture to those movements that are correlated with speech utterances.

However, given the increasing power of portable processors, sophisticated sub-semantic, non-classifying analysis has begun to be exploited (e.g. [30]). We take this approach systematically.

Interaction Scenario

In all cases, performers wearing softwear instruments will interact with other humans in a public common space. But when they pass through a space that has been sensitized with tracking cameras or receivers for the sensors tracking their gesture, then we see that their actions made in response to their social context take on other qualities due to the media that is generated in response to their movement. This prompts us to build responsive media spaces using our media choreography system.

Ambient Media

After Krueger's pioneering work [14] with video, classical VR systems glue inhabitants' attention to a screen, or a display device and leave the body behind. Augmented reality games like Blast Theory's *Can You See Me Now* put some players into the physical city environment, but still pin players' attention to (mobile) screens [4].

Re-projection onto the surrounding walls and bodies of the inhabitants themselves marks an important return to embodied social, play, but mediated by distributed and tangible computation.

The Influencing Machine [12] is a useful contrasting example of a responsive system. The Influencing Machine sketches doodles apparently in loose reaction to slips of colored paper that participants feed it. Like our work, their installation is also not based on explicit language. In fact it is designed ostensibly along “affective” lines. It is interesting to note how published interviews with the participants reveal that they objectify the Influencing Machine as an independent affective agency. They spend more effort puzzling out this machine's behavior than in playing with one another.

In our design, we aim to sustain environments where the inhabitants attend to one another rather than a display. How can we build play environments that reward repeated visits and ad hoc social activity? How can we build environments whose appeal does not become exhausted as soon as the player figures out a set of tasks or facts? We are building responsive media spaces that are *not* predicated on rule-based game logic, puzzle solving or exchange economies [3], but rather on improvisatory yet disciplined behavior. We are interested in building play environments that offer the sort of embodied challenge and pleasure afforded by swimming or by working clay.

This motivates a key technical goal: the construction of responsive systems based on gesture-*tracking* rather than gesture-recognition. This radically shortens the computational path between human gesture and media response. But if we allow a continuous open set of possible gestures as input, however reduced, the question remains how to provide aesthetically interesting, experientially rich, yet legible media responses.

The TGarden environment [25] that inspired our work is designed with rich physicalistic response models that sustain embodied, non-verbal intuition and progressively more virtuosic performance. The field-based models sustain collective as well as solo input and response with equal ease.

By shifting the focus of our design from devices to processes, we demonstrate how ambient responsive media can enhance both decoupled and coordinated forms of playful social interaction in semi-public spaces.

Our design philosophy has two roots: experimental theater transplanted to everyday social space, and theories of public space ranging from urban planners [20, 33] to playground designers [11]. R. Oldenburg calls for a class of so-called “third spaces,” occupying a social region between the private, domestic spaces and the vanished informal public spaces of classical socio-political theory. These are spaces within which an easier version of friendship and congeniality results from casual and informal affiliation in “temporary worlds dedicated to the performance of an act apart.” [18]

Demonstration C: Social Membrane (Serita, Fiano, Reitberger, Varma, Smoak)

How can we induce a bit more of a socially playful ambience in a dead space such as a conference hotel lobby? Although it is practically impossible in an exhibition setting to avoid spectacle with projected sound or light, we can insert our responsive video into non-standard geometry or materials.

We suspend (*pace* T. Erickson [8]) a translucent ribbon onto which we project processed live video that transforms the fabric into a magic membrane. The membrane is suspended in the middle of public space where people will naturally walk on either side of it. People will see a smoothly varying in time and space transformations of people on the other side of the membrane. (Fig. 4) The effects will depend on movement, but will react additionally to passersby who happen to be wearing our softwear augmented clothing.

The challenge will be to tune the dynamic effects so that they remain legible and interesting over the characteristic time that a passerby is likely to be near the membrane, the affect induces play but not puzzle-solving. Sculpturally, the membrane should appear to have a continuous gradient across its width between zero effect (transparency) and full effect. Also it should take about 3-4 seconds for a person walking at normal speed in that public setting to clear the width of the inserted membrane.

Fig. 4. Two players tracked in video, tugging at spring projected onto common fabric.

Above all the membrane should have a social Bernoulli effect that will tend to draw people on the opposite sides to one another. The same effects that transform the other person's image should also make people feel some of the safety of a playful mask. The goal is to allow people to gently and playfully transform their view of the other in a common space with partially re-synthesized graphics.

Artistic Interest and Craft

We do not try to project the spectator's attention into an avatar as in most virtual or some augmented reality systems. Instead, we focus performer-spectator's attention in the same space as all the co-located inhabitants. Moreover, rather than mesmerizing the user with media "objects" projected onto billboards, we try to sustain human-human play, using responsive media such as calligraphic, gesture/location-driven video as the medium of shared expression. In this way, we keep the attention of the human inhabitants on one another rather than having them forget each other distracted by a "spectacular" object [6].

By calligraphic video we mean video synthesized by physicalistic models that can be continuously transformed by continuous gesture much as a calligrapher brushes ink onto silk. Calligraphic video as a particular species of time-based media is part of our research into the preconditions for sense-making in live performance. [10, 5].

ARCHITECTURE

For high quality real-time media synthesis we need to track gesture with sufficiently high data resolution, high sample rate, low end-to-end latency between the gesture and the media effect. We summarize our architecture, which is partly based on TinyOS and Max / Macintosh OS X, and refer to [24, 25] for details.

Our current strategy is to do the minimum on-the-body processing needed to beam sensor data out to fixed computers on which aesthetically and socially plausible and rich effects can be synthesized. We have modified the TinyOS environment on CrossBow Technologies Mica and Rene boards to provide time series data of sufficient resolution and sample frequency to measure continuous gesture using a wide variety of sensory modalities. This platform allows us to piggy-back on the miniaturization curve of the Smart Dust initiative [13], and preserves the possibility of relatively easily migrating some low level statistical filtering and processing to the body. Practically this frees us to design augmented clothing where the form factors compare favorably with jewelry and body ornaments, while at the same time retaining the power of the TGarden media choreography and synthesis apparatus. (Some details of our custom work are reported in [24].)

Now we have built a wireless sensor platform based on Crossbow's TinyOS boards. This allows us to explore shifting the locus of computation in a graded and principled way between the body, multiple bodies, and the room.

Currently, our TinyOS platform is smaller but more general than our LINUX platform since it can read and transmit data from photocell, accelerometer, magnetometer and custom sensors such as, in our case, customized bend and pressure sensors. However, its sample frequency is limited to about 30 Hz / channel.

Our customized TinyOS platform gives us an interesting domain of intermediate data rate time series to analyze. We cannot directly apply many of the DSP techniques for speech and audio feature extraction because to accumulate enough sensor samples the time window becomes too long, yielding sluggish response. But we can rely on some basic principles to do interesting analysis. For example we can usefully track steps and beats for onsets and energy. (This contrasts with musical input analysis methods that require much more data at higher, audio rates. [21])

The rest of the system is based on the Max real-time media control system with instruments written in MSP sound synthesis, and Jitter video graphics synthesis, communicating via OSC on Ethernet. (Fig. 5)

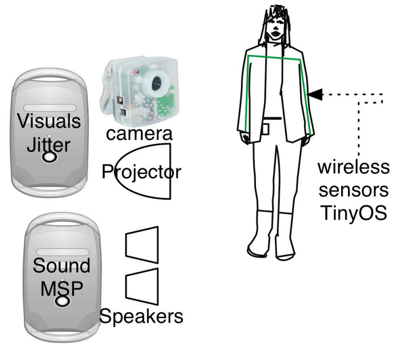

Fig. 5. Architecture comprises clothing; sensing: TinyOS, IR camera; logic and physical synthesis in OSC network: Max, MSP, Jitter; projectors, speakers.

Technical Comment on Lattice Computation

Our research aims to achieve a much greater degree of expressivity and tangibility in time-based visual, audio, and now fabric media. In the video domain, we use lattice methods as a powerful way to harness models that already simulate tangible natural phenomena. Such models possess the shallow semantics we desire based on our heuristics for technologies of performance. A significant technical consequence is that such methods allow us to scale efficiently (nearly constant time-space) to accommodate multiple players.

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Mobile Capture and Access for Assessing Language and Social Development in Children with Autism

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ABSTRACT

We present a mobile device that supports expert practices for assessing the development of language and social skills in children with autism (CWAs). Our Tablet PC–based system combines aspects of existing paper- and video-based data-recording activities at a preschool for CWAs. We created in Macromedia Director a prototype that supported automated capture and access of multiple data streams, addressing the information needs of researchers, teachers, and parents. Video of natural classroom behaviors is synchronized with researchers' assessments of behavioral variables. We obtained user feedback on our prototype and on the resulting Java-based system, which we will deploy and evaluate.

Keywords

Ubiquitous and mobile computing, computer-supported cooperative work, ethnography, capture and access, autism

INTRODUCTION

Early behavioral intervention — begun when children with autism (CWAs) are approximately ages 2 to 5 — is reported to improve the language and social skills of "virtually all children, and in some cases it leads to complete eradication of any sign of the disorder" [4]. At the Walden Early Childhood Center at Emory University, early intervention is administered in the context of typical preschool education activities. Treatment plans are individualized for each child, because CWAs "are often characterized by idiosyncratic learning styles" [5]. Assessments of CWAs' ongoing, naturally occurring social behaviors in the classroom help determine both the effectiveness of interventions and the appropriate goals to be targeted. Observers must be both "very sensitive to the child's needs and reactions, and scrupulously *objective* in the measurement and analysis of those reactions" [5].

Treatment plans are developed collaboratively by members of three stakeholder groups: researchers, teachers, and parents. Data must be collected, analyzed, and reported to meet the needs of all these groups. It is crucial that proposed technological innovations support established practices. Mackay et al. suggest that designers who follow this guideline, taking "evolutionary path[s] to … new methods," may encounter less resistance to technological change [3]. Our goal is to understand better these practices from the perspectives of the stakeholders, and to meet their needs by developing technological solutions based on automated capture and access. We studied the environment and designed a prototype, then obtained user reactions that influenced the development of a system that we will deploy and evaluate.

CASE STUDY

Walden is the early-childhood model demonstration program of the Emory Autism Center, which is a component of the Department of Psychiatry and Behavioral Sciences at the Emory University School of Medicine. Walden has three classes — toddler (ages two and three), preschool (ages three and four), and pre-kindergarten (ages four and five) — of approximately eighteen children each. One-third of the students in each class are CWAs, and two-thirds are typically developing children who serve as role models for CWAs as they develop language and social skills.

For ten weeks, we spent six hours a week observing classrooms and interviewing stakeholders (two teachers, two researchers, and three sets of parents). We interviewed many more researchers and teachers as they worked.

Treatment plans for CWAs are written at the beginning of each child's tenure at Walden. The plans are reviewed quarterly and updated annually to meet each child's changing needs. Plans are divided into goals — such as improved language development, social interactions and engagement, and independent-living and school-readiness skills — which are then broken into measurable objectives set progressively over the school year. Data on these objectives are collected daily, in quantitative experiments incorporated into classroom routines. Research assistants also observe CWAs unobtrusively and capture data on video or on a paper spreadsheet known as a Pla-Chek (pronounced "PLAY-check"; Figure 1(a)), on which these variables are recorded:

- proximity to adult (within three feet)
- adult interacting with CWA
- proximity to typical child
- typical child interacting with CWA
- proximity to another CWA
- other CWA interacting with target CWA
- verbalization (words listed in dictionary)
- engagement
- focus on an adult (if the child is engaged)
- focus on another child (if the child is engaged)
- focus on a toy (if the child is engaged)
- autistic behaviors

Video data are coded later but for the same variables, except proximity to other CWAs, interactions with other CWAs, and autistic behaviors. This difference exists because research assistants may not know which children in videos are CWAs. Because of this similarity, we chose the Pla-Chek for our prototype.

Pla-Cheks place cognitive burdens on research assistants. They observe children for intervals of ten seconds, which are counted mentally, then record values in a line of cells. Each line is followed by ten more seconds of observation. The next line is filled and the process repeated until twenty intervals are done. Counting time complicates the recording, which requires strict objectivity.

Pla-Cheks for each CWA are recorded on ten consecutive days each calendar quarter. Classroom coordinators tabulate the data quarterly. Because sessions are not videotaped, they cannot be reviewed for accuracy, or be used for demonstrating visually to parents that progress is being made. The assistant director uses the tabulated data to prepare reports that indicate progress on each objective and can easily be fifteen pages long.

Parents receive these reports quarterly, and discuss them with classroom coordinators. However, parents can obtain visual evidence of their children's progress only by observing classroom activities through one-way mirrors or by watching videotapes. There is no artifact that combines visual evidence with expert assessment. We believe our system will do this effectively.

RELATED WORK

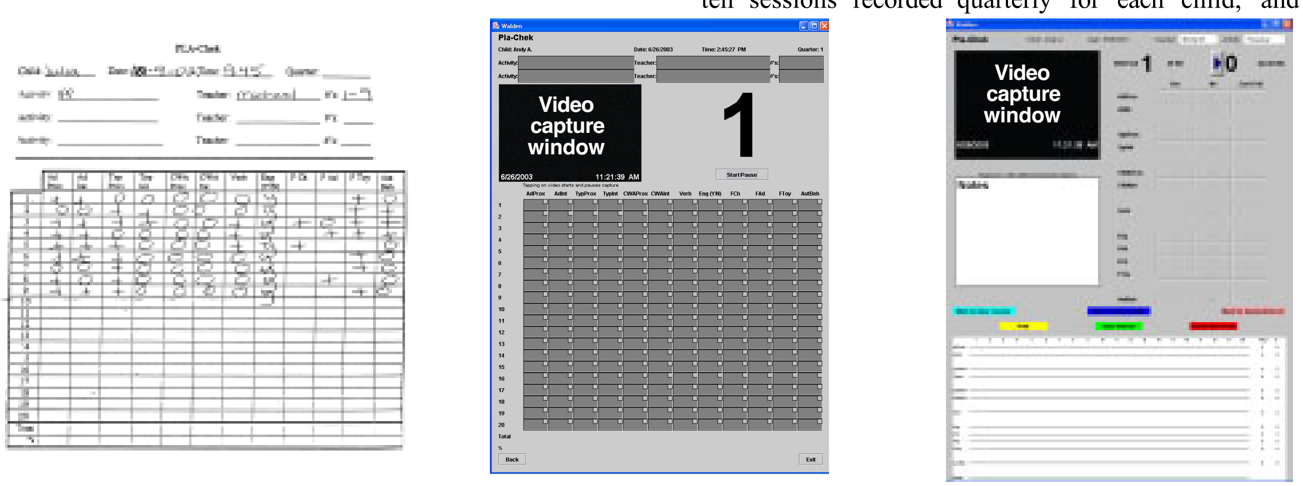
Our prototype follows the principle of "voluntary, explicit, task-appropriate interaction" that Arnstein et al. support in the second version of Labscape [1]. The cell-biology lab for which Labscape was designed is similar to Walden in that data must be recorded with scientific rigor. The first version of Labscape relied on sensors that could not "provide the detail, completeness, and reliability sufficient to the task."

Steurer et al. have chosen a sensor-based approach for another education environment, the Smart Kindergarten [6]. The authors suggest that data collected by sensors in a classroom can help teachers identify and address the learning problems of individual children.

DESIGN OF PROTOTYPE

With our prototype — designed in Macromedia Director and later implemented in Java — we transferred the Pla-Chek to a Tablet PC (Figure 1(b)). The prototype captured handwritten data as well as video from a webcam worn at the research assistant's beltline. The system tabulated the data as they are collected rather than requiring a teacher to do so later. The interface reduced the research assistants' cognitive load by providing a timer that counted two ten-second intervals for each line of data: an observation interval, then a handwriting interval.

The access interface (Figure 2(a)) contained the video and two visualizations of the data: a "macro" timeline of the ten sessions recorded quarterly for each child, and a



(a) (b) (c)

Figure 1: The paper Pla-Chek (a) was the template for our initial capture interface (b), in which we maintained, as much as possible, the look and feel of the original. User feedback led to the second iteration of the interface (c).

“micro” timeline of the session being viewed. Data were represented on these timelines by dots. Variable names were displayed on the Y-axis and grouped by dot colors: red for proximity to and interaction from adults, gray for proximity to and interaction from typical children, green for proximity to and interaction from other CWAs, black for verbalization, blue for engagement and focus, and pink for autistic behaviors. Graphed on the X-axis of the macro timeline were the ten quarterly sessions; on the X-axis of the micro timeline, numbers indicated the progression of time, measured in minutes, through the video.

Dots in the micro timeline were uniform in size, and represented single positive recorded occurrences of variables; dot sizes in the macro timeline varied to indicate the percentage of positive results recorded in each session. There were five sizes of dots, representing values in 20-percent increments. We considered using more sizes for finer granularity, but we believed that constraints of screen real estate would prevent clear distinctions in sizes.

When the user rolled over a dot in the macro timeline, the interface displayed the percentage represented. In both timelines, the percentages and number of occurrences of each variable were displayed at the end of the line. The user selected a session for review by clicking on its column in the macro timeline. That session’s micro timeline and video then appeared. A vertical line moved along the micro timeline to help viewers relate variables to the actions displayed in the video. The access interface does not necessarily have to be viewed on the Tablet PC, although doing so would allow access in many settings.

SYSTEM IMPLEMENTATION

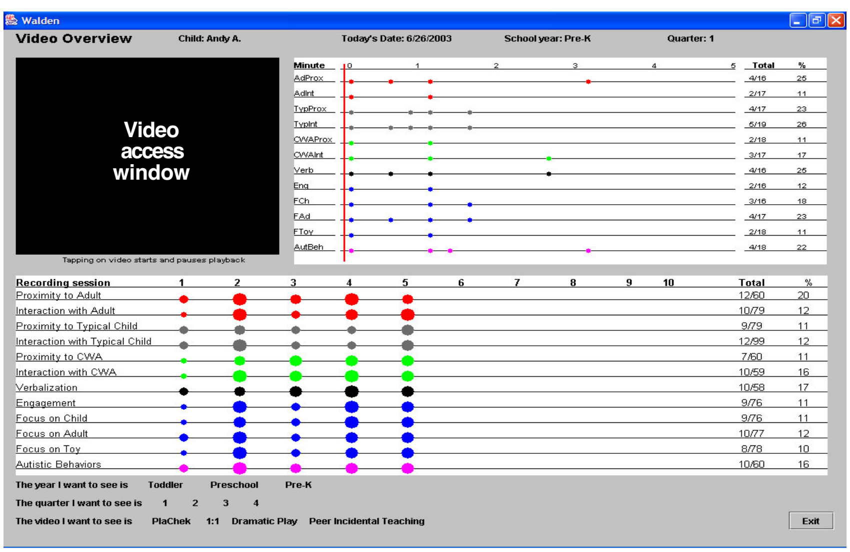
The Walden system was developed on top of the INfrastructure for Capture and Access Applications (INCA) toolkit [7]. INCA provides abstractions and reusable components that address capture-and-access concerns and facilitate application development.

The system has three INCA modules: a capture module to record annotations and video; a storage module to hold that information for later access; and an access module to provide synchronous access to multiple integrated streams of information gathered from context-based queries.

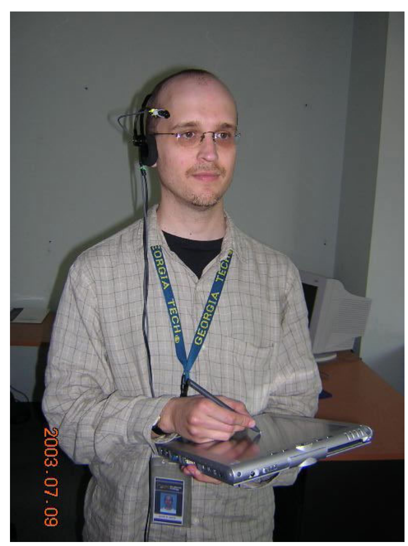
The capture interface is built on INCA’s capture module, which supports the recording of video data and behavioral variables (Figure 3(a)). The video and handwritten annotations captured — with metadata describing when, what, and for which child information is being captured — are stored in a relational database using the storage module (Figure 3(b)). The access module draws on this database to compose the access interface (Figure 3(c)). In this interface, each marked behavior is an index into the video (Figure 3(d)).

The first capture interface used the Quill toolkit as a gesture recognizer, with a few changes that allowed for automatic interpretation and tabulation of the observers’ data [2]. While this design supported a familiar method of data input, its deployment on a Tablet PC failed. Writing on a tablet was different from writing on paper in two important ways: calibration and resolution. Annotating boxes in the electronic form that were the same size as those on a paper version proved to be noticeably difficult, and the imperfect handwriting recognition resulted in a significant amount of time and effort being spent correcting the data. The research manager also found it difficult to keep children in the video frame while observing and annotating behaviors.

We redesigned the prototype to simplify capture. We used screen real estate more economically by replacing the spreadsheet with click boxes for “yes,” “no,” and “can’t tell” (Figure 1(c)). The same set of boxes is used for each recording interval, with the number of the interval noted at the top. We replaced the cells for writing the names of teachers and classroom activities with drop-down menus from which the names can be selected. We added buttons



(a)



(b)

Figure 2: The access interface (a) has at the bottom a “macro” timeline that shows an overview of a child’s ten quarterly Pla-Chek sessions. The micro timeline at the top right shows the results of the selected session, and the video for that session appears at the top left. A researcher performs capture during naturally occurring classroom activities, using a Tablet PC with a head-mounted camera attached (b).

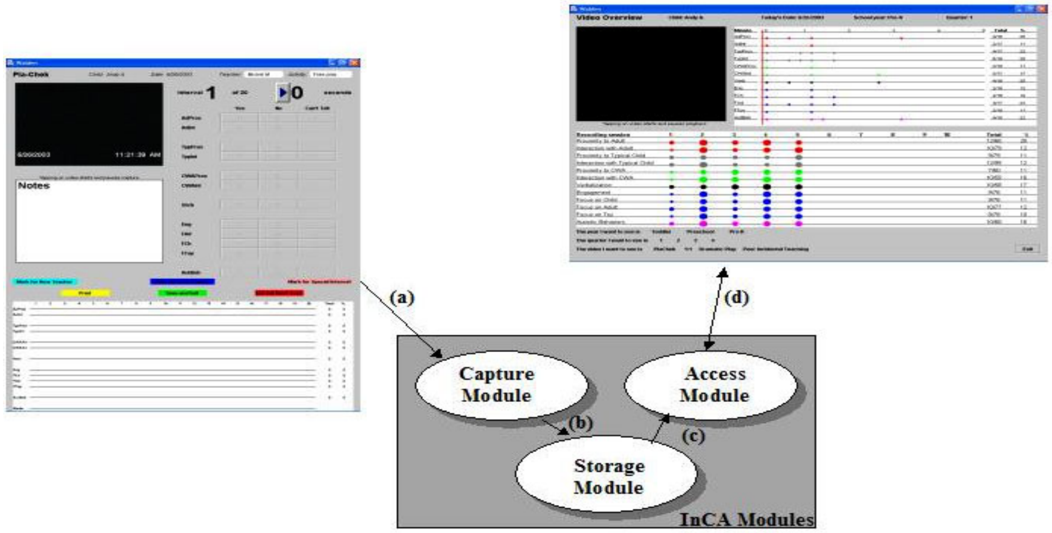


Figure 3 : The capture interface (a) is built on the capture module of INCA, which supports the recording of video data and behavioral variables. The storage module (b) saves the data for use by the access module (c) in composing the access interface (d).

that can be used to place marks in the timeline when teachers or activities change; these marks remind the research assistants to make the changes using the drop-down menus after the session, avoiding interruptions.

Handwriting and gesture recognition are no longer issues. Each ten-second interval is added to a canvas that renders a quick review of the CWA's behavior throughout the session. A head-mounted bullet camera — which ensures all data are recorded during the heads-up observation interval — replaced the beltline webcam (Figure 2(b)). A notepad was also added, allowing the research assistants to associate handwritten notes with each recorded interval.

FUTURE WORK

We will add a harness to support the weight of the Tablet PC, as well as a belt-worn pack to hold the battery and controller for the bullet camera. We will develop a plan for deploying the capture and access modules, recording and reviewing quarterly data for several children, and evaluating the usefulness and usability of the system.

ACKNOWLEDGMENTS

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The Narrator : A Daily Activity Summarizer Using Simple Sensors in an Instrumented Environment

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ABSTRACT

People tracking provides the basis for automatic monitoring. This service can help people with disabilities or the elderly live independently by providing day-to-day information to physicians and family. The Narrator system uses information generated by a tracker to generate concise, scalable summaries of daily movement activity. We demonstrate output from the Narrator as well as the workings of an underlying tracker in an instrumented home environment. We show that in a system made up almost entirely of sensors that do not report identity information, we can maintain identity information and recover from identification errors.

Keywords

Ubiquitous Computing, People Tracking, Simple Sensors

INTRODUCTION

Knowledge of the identity and position of occupants in an instrumented environment is a basic element of automatic monitoring. Automatically generated summaries of daily activities for people with cognitive disabilities can be used to improve the accuracy of pharmacological interventions, track illness progression, and lower caregiver stress levels [7]. Additionally, [15] has shown that movement patterns alone are an important indicator of cognitive function, depression, and social involvement among people with Alzheimer's disease.

In this paper we describe a people tracker and a derivative service -- the Narrator. The Narrator is a finite state machine that parses movement information provided by a tracker and generates a concise, readable summary. Our tracker consists of a discrete state Bayes filter and associated models that use information gathered from binary sensors to provide low-cost automatic tracking in a home environment. We demonstrate results from an off-line smoothing algorithm, although online filtering techniques are possible. We instrumented a permanently occupied home and conducted a series of experiments to validate our approach.

RELATED WORK

People tracking has been approached via a variety of sensors, including cameras, laser range finders, wireless networks, RFID (Radio frequency identification) badges, and infrared or ultrasound badges [1, 2, 3, 6, 9, 11, 13, 14]. Cost of sensors and sensor acceptance are pivotal issues, especially in the home. Many people are uncomfortable living with cameras and microphones. Laser scanning devices are anonymous, but costly and have limited range. We find that people are often unwilling, forget, change clothes too often, or are not sufficiently clothed when at home to wear a badge, beacon, set of markers, or RF tag. Elderly individuals are often very sensitive to small changes in environment [4], and a target population, institutionalized Alzheimer's patients, frequently strip themselves of clothing, including any wearable sensors [5]. We have chosen to explore a set of sensors that are already present in many homes as part of security systems (motion detectors, contact switches, and other simple binary sensors). These sensors are cheap, computationally inexpensive, and do not have to be continuously worn or carried. We aim for room level tracking, as our sensors do not provide the higher spatial resolution of other types of tracking systems.

Combining anonymous sensors and sensors that provide identification information for people or object tracking is an open problem. Our tracking problem is similar to *object identification*. The goal is to determine if a newly observed object is the same as a previously observed object. The solution offered by [12] has been applied to tracking automobile traffic using cameras, extending the technique introduced by [8] to accommodate many sensors. In a recent experiment [13], laser range finders and infrared badges were used to track six people simultaneously in an office environment for 10 minutes. The range finders provide anonymous x,y coordinates while the badge system identified occupants. Our system uses a single RFID-sensor with many anonymous sensors to provide room-level tracking. We collect data over long periods to provide an ever-improving model of the unique motion patterns of each occupant. These models can be used later for occupant identification in lieu of additional ID-sensors.

NARRATOR

The purpose of the Narrator system is to provide a summary of daily movements, using information generated automatically by a tracker in an instrumented environment. This summary represents important daily events in a compact, readable format, although the tracker provides many thousands of second-by-second location predictions.

On the most basic level, the Narrator could produce an English account of the second by second location predictions. In our instrumented environment there were an average of 2000 readings per day. This scheme would produce volumes of not very useful information. Instead, we make a few simplifying assumptions and provide user-scalable levels of abstraction.

We make two assumptions. First, although we track several occupants simultaneously, we choose to create summaries for one occupant at a time. We also report only movement information and do not attempt activity recognition, except for sleeping. For sleeping we use a simple rule – if an occupant spends more than four hours in the bedroom, that time is tagged as sleeping. Second, the Narrator directly uses the maximum likelihood predictions of the tracker. Each of these predictions has an associated posterior probability, which we ignore for now. In future work we plan to incorporate this confidence measure into the Narrator's output.

We identify two areas in which reporting may be abstracted. First, we use duration of time spent in a location to scale the amount of information reported on that movement. Second, we use sensor granularity to scale reporting from room level up to house level.

Transient Locations

Some locations are less interesting than others, because they are traversed constantly and quickly in order to reach end locations. Usually, transient locations are stairways and hallways. These locations demonstrate a marked decrease in the average amount of time spent compared to other locations. For example, in our experiments the staircases had mean durations of 5.5 seconds and hallways had mean durations of 10.3 seconds. On the other hand, the living room and study had a mean of 8.2 minutes.

The transience property of a location determines what detail to report travel through that location. We use a threshold on mean duration spent in a room to identify transient spaces. We fit a Gaussian to the amount of time spent in these rooms to obtain an overall measure of transience. The Narrator tags travel through any room as transient if the amount of time spent there is within the transient mean and variance. In this way we simplify the summary without restrictive rules that completely ignore certain areas. With this information the user may choose to fully or partially ignore transient locations, and focus instead upon end locations where the occupant spends the most time. The below sentences were generated by the Narrator and demonstrate the three scales.

- `Daniel entered the first floor hallway and stayed for 2 seconds. Daniel entered the kitchen and stayed for 10 minutes.`
- `Daniel passed through the first floor hallway, entered the kitchen and stayed for 10 minutes.`
- `Daniel walked to the kitchen and stayed for 10 minutes.`

Sensor Granularity

The tracker can predict location at the granularity of individual sensors, although the current implementation reports at room level. The Narrator allows the user to scale the granularity from room level to floor level and to the entire house. The sentences below demonstrate room level, floor level, and house level granularity, respectively.

- `Daniel woke at 8am. He walked to the bathroom and stayed for 15 minutes. He walked downstairs to the kitchen and stayed for 10 minutes. He passed through the foyer to the front porch and left the house.`
- `Daniel woke at 8am. He stayed on the second floor for 15 minutes. He went to the first floor and stayed for 10 minutes. He left the house.`
- `Daniel woke at 8am. He stayed home for 25 minutes. He left the house.`

Algorithm

The Narrator algorithm is a conceptually simple deterministic finite state machine. It is composed of a set of states, an input alphabet, and a transition function that maps symbols and states to the next state. The set of states represent English words and phrases, while the input alphabet is composed of sensor readings and times. To add some variety to the language, some states have more than one transition for a given symbol. A lookup table maps the room and occupant ids reported by the tracker to room and occupant names.

TRACKER

We wish to estimate the state of a dynamic system from sensor measurements. In our case, the dynamical system is one or more occupants and the instrumented environment. For this paper we track people at the room level, so a person's state, x, indicates which of N rooms they are in. Measurements include data from motion detectors, pressure mats, drawer and door switches, and radio frequency identification (RFID) systems. We solve the tracking problem off-line with a technique commonly known as *smoothing* which uses information from both past and future time steps, providing higher accuracy for off-line purposes, such as a daily summary of movement activity.

Technological Infrastructure

We instrumented a house in order to conduct experiments using real data. The three story house is home to two males, one female, a dog, and a cat. Our environment contains forty-nine sensors and twenty different rooms.

- Radio Frequency Identification (RFID): We use low frequency RFID to identify occupants entering and leaving the environment. Each occupant and guest is given a unique transponder, or 'tag'. When the credit card sized tag nears the RFID antenna it emits a unique identification number. Upon recognition of a tag the tracker places a high initial belief that the occupant is at the antenna location. Note that using this tag is no different than using a house key; it is not necessary to carry the tag throughout the environment.

- Motion detectors: We use wireless X10 Hawkeye ™ motion detectors. Upon sensing motion a radio signal is sent to a receiver, which transmits a unique signal over the power line. This signal is collected by a CM11A device attached to a computer. The detectors are pet-resistant, require both heat and movement to trigger, and run on battery power for over one year. There are twenty four motion detectors installed.
- Contact switches: Inexpensive magnetic contact switches indicate a closed or open status. They are installed on every interior and exterior door, selected cabinet drawers, and refrigerator doors. There are twenty four contact switches.

The sensors are monitored by a single Intel Pentium IV 1.8 GHz desktop computer with 512MB ram. We use an expanded parallel port interface to monitor contact switches, a serial interface to a CM11A device to monitor motion detector activity, and a serial interface to the RFID reader. All activity is logged in real-time to a MySQL database.

Tracking Formulation

Our goal is to estimate the probability distribution for each person's location, conditioned on sensor measurements. This probability distribution, the tracking system's "belief" or "information" state, is encoded as a length N vector, whose elements give the probability of being in the respective rooms. We use a discrete state Bayes filter to maintain the belief state *B*el. Our belief that a person u is in room i at time t is:

$$Bel_t^u[i] = p_t^u(x = i \mid y_1,..., y_t).$$

Here $p()$ indicates probability and $y_1,..., y_t$ denotes the data from time 1 up to time t. Given a new sensor value, we can update the beliefs for all rooms. For room i :

$$Bel_{t+1}^u[i] =$$

$$\eta \cdot p_{t+1}^u(y \mid x = i) \cdot \sum_{j=1...N} p^u(x_{t+1} = i \mid x_t = j) \cdot Bel_t^u[j].$$

The variable, η, is a normalizing constant, so that the elements of any *Bel* vector sum to 1. In using a Bayes filter, we assume that our room-level states are Markov. This is an approximation, and one research question is whether we can accurately track people after making this approximation. We assume that each person u has a different motion model $p^u(x_{t+1} = i \mid x_t = j)$ and sensor model $p^u(y \mid x)$.

Data Association

Each sensor reading must be assigned to at least one occupant or to a noise process. This is the *data association* step. Our solution is to use an EM process to iteratively 1) estimate the likelihood of each occupant independently generating a given sensor sequence, and then 2) maximize by re-assigning ownership of sensor values [10]. We use the forward-backward algorithm to estimate the posterior beliefs, and then maximize the following quantity:

$$\sum_x p_t^u(y \mid x) \cdot Bel_t^u(x).$$

Occupant Independence

Currently, we assume that occupants behave independently, an obvious approximation. In reality occupant movements are highly correlated. Conditioning on the presence of several other occupants increases the computational complexity of the problem, while including guests causes further growth in the number of required models. For this paper we were interested in testing the performance of a simpler model.

Motion model

The equation, $p^u(x_t \mid x_{t-1})$, represents the motion model for a specific occupant. This model takes into account where the occupant was at the previous time step and predicts how likely the current room is now. Our data is a time series of sensor measurements. All occupants are constantly generating streams of data that are combined in the database. For this reason, we learn motion models for each occupant using the entire database of sensor readings in which that occupant is home alone. We map each sensor to a state that represents a room and counted to generate an [N x N] table of transition probabilities.

EXPERIMENTS

We performed an uncontrolled experiment on a single occupant using 1288 sensor readings from when that occupant was home alone, collected over a two-day period. During this time one person moved through the house, visiting every sensor and moving with varying speed and direction. The occupant conducted several common tasks, such as making a sandwich and using the computer. The system was not running while the occupant slept. The tracker used a motion model trained for the occupant being tracked. Accuracy is measured as the fraction of time that the room location was predicted correctly. We performed 10 trials, training motion and sensor models on 90% and testing on a rolling 10%. Using smoothing we found an accuracy of 99.6% ± 0.4.

We also report results from five days of continuous, unplanned, everyday movement of one to three people in the house. We measured tracker performance over a continuous five-day period. The tracker used individual motion models for the three occupants. There were no guests during this period. To evaluate performance we had to hand-label the data. To make hand labeling feasible we gathered additional information from eight wireless keypads. The keypads have one button for each of the three occupants and one for guests. During that week when anyone entered a room with a keypad, they pushed the button corresponding to their name. This information acted as road signs to help the human labeler disambiguate the data stream and correctly label the movements and identity of each occupant.

There were approximately 2000 sensor readings each day for a total of 10441 readings. When the house was occupied on average there was one occupant at home 13% of the time, two occupants home 22% of the time, and all three occupants home for 65% of the time. Note that each night every occupant slept in the house. On the whole, the tracker correctly classified 74.5% sensor readings corresponding to 84.3% of the time. There was no significant difference in accuracy between occupants. The tracker was accurate 84.2% of the time for one occupant, 81.4% for two occupants, and 87.3% for three occupants. Accuracy for three occupants drops to 74.5% when sleeping periods are removed.

CONCLUSION

We described the Narrator, a service that uses information from a tracker to provide daily movement summaries. We described algorithms that exploit information from binary sensors to perform tracking of several occupants simultaneously. We validated our algorithms using information gathered from an instrumented environment in a series of experiments and provided example output of the Narrator.

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Part III

Interactive Posters

Device-Spanning Multimodal User Interfaces

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ABSTRACT

Despite the large variety of mobile devices available today, none of them is without flaws: small devices like cell phones are very limited regarding interaction, while larger devices like laptops lack true mobility. We are investigating how both mobility and rich interaction can be achieved by federating small mobile devices with other interactive devices on demand. However, this raises the question how user interfaces can be authored if the target device is not static and known, but rather a changing set depending on user context. We approach this using device independent widgets, which are mapped to device specific widgets at runtime.

1. INTRODUCTION

Mobile devices have continuously become more powerful and cheaper over the last years. However, they still lack flexibility as most of them are designed to be used stand-alone, and offer only limited interaction means. We present an architecture which integrates the multitude of mobile devices with each other to augment the users' experience with them.

While we expect most of such mobile devices can be shared and accessed as needed, we also think that there still will be a personally owned device in such a world for security and privacy reasons. Such a device should be unobtrusive and as small as possible. Our group has designed a headset with voice based interaction and communication abilities. Other devices may be associated to this *Talking Assistant* (TA) [2] as needed, and may also bring in other means of interaction such as graphical user interfaces.

1.1 Example Scenario

What is the benefit of a voice based assistant, and of associating other interactive devices with it on the fly? We show this in a scenario which describes how a user named Alice orders a pizza online while hurrying out of her office. Alice notices that she is hungry exactly as she locks her office behind her. She considers turning back and ordering from her desktop PC, but she is wearing her TA and decides to access the pizza order application by voice menu instead. Alice instructs the TA to access this application and orders a bottle of soft drink. The next step is choosing a pizza topping. Before making a choice, Alice would like to see the menu. But how should the menu be presented to her? Speech synthesis is unsuitable for reading such a long list. Luckily, the building has public displays installed in the hallways. Rather than turning back and restarting the order on a better suited device with a larger display, Alice simply stops in front of one of the displays. The TA notes that it is able to associate with a screen, and relays this information to the order application, which decides to show its menu there. After scanning the menu, Alice simply says "sixty-five, large" into her TA, and resumes walking. The remaining steps of the order are presented to her as a pure voice menu again.

2. AUTHORING ADAPTIVE APPLICATIONS

For authoring applications that make use of the TA and its associated devices, we are going to enhance the idea of widgets as simple elements of interaction [1]. Widgets currently are considered merely as graphical elements; there is no such high-level approach for other modalities. In our broader approach we think of them as objects that represent a generalized, general purpose solution towards interaction between users and applications.

The framework for programming the TA will provide basic device independent *logical widgets* which developers may use to create their multimodal applications. These are comparable to the *atomic interactors* of XWeb [3]. XWeb features a browser-like approach to data exchange, whereas we provide an event system like traditional GUI widget toolkits. Our widget system is extensible: It is possible to extend existing widgets, to create entirely new ones or to combine widgets to more powerful ones. While further research will be done in this area, we have so far identified the following as some of the basic widget classes to be provided by the system:

- free form text input; output of simple and structured text
- yes/no input for boolean elements
- select one of several mutually exclusive elements
- input and output of date and time
- a grouping element combining several widgets

3. MAPPING WIDGETS TO A DEVICE

Application developers define the user interface of their applications by creating a tree of logical widgets. These logical widgets are purely abstract representations of the user interface with no association to a specific device. In a two step process, these logical widgets are mapped to a device.

First, the mapping subsystem creates *physical widgets* out of logical widgets. Logical widgets are mere data objects representing only the kind of interaction. Their physical counterparts contain methods to render themselves onto a specific modality and/or device. As a result, physical widgets are device dependent. The mapping subsystem utilizes context metadata such as the device used, its primary interaction method (graphics based or voice based) and additional information about the capabilities of the interface (e.g. the voice recognizer used, window metrics, etc.).

Physical widgets are registered to the mapping subsystem with the information what logical widget they map to, what modality they implement, and what constraints they have. Several physical widgets may be registered for one logical widget, e.g. for different modalities or for different implementations of one modality. At runtime, the mapping subsystem searches for the physical widget which best fits the device and chooses it to substitute the logical widget.

In the second step, the physical widgets render themselves onto the user interface. How this is done is modality specific. For voice based interaction, this could involve using text-to-speech for doing the output and generating context free grammars for specifying the input. The equivalent physical widget for GUIs may just call the appropriate element of the operating system's widget toolkit.

4. ASSOCIATION AND MULTIPLE DEVICES

A user interface can obviously not exceed the limitations of the device it runs on. When mapping an interface to a small mobile target device, it may allow basic interaction in the absence of a better terminal. However, mobile devices are not always used in isolation. Often, the surrounding infrastructure could provide additional means of interaction. We intend to dynamically associate mobile devices with devices from the infrastructure in order to overcome their limitations regarding interaction. Since the number of possible combinations of devices is rather large, hand-coding a specialized UI for each combination is infeasible. The mapping subsystem will provide a scheme to render an interface on a *federation* of multiple devices. This concept has so far only been considered for playback of multimedia content [4].

Before such a federation can be established, one must detect that a device is within the user's range and that the device can be associated. We currently use two methods for detecting possible association between users and devices. One is the TA, which determines its wearer's head position (using two cameras tracking an infrared beacon on the TA) and gaze direction. The other consists of tags on each device, which transmit their ID using short range infrared, and badges on each user, which receive a tags' ID if the user is standing in front of the tagged device, and relay them to the network. The advantage of the latter solution is the low cost.

Mapping a user interface to span multiple devices introduces a number of novel problems:

- When adapting for a single device, there is no choice regarding which device to present a widget on. If several devices are available, the mapping needs decide how to distribute widgets to devices, factoring in usability and device characteristics.
- While there are some dynamic device characteristics (e.g. battery status), most characteristics of a single device are fixed. If users move in and out of range of associated devices at runtime, the virtual target device of the mapping changes drastically at runtime, making mapping the UI for multiple devices a much more dynamic process.
- Despite constantly changing context, the mapping should not present the user with a constantly changing interface. This would inhibit usability since the user would have no chance to become accustomed to the UI. Therefore a history of how a UI was presented to a user before needs to be considered as an additional form of context.
- In the case of a single device, each widget is rendered exactly once. When using a federation of devices, it can make sense to render an element more than once, e.g. in different modalities to achieve multimodality, or on different devices to create some form of remote control.

We are investigating several mapping methods that take these criteria into account. Currently we are building a test bed that allows us to create distributed UIs, and to automatically send components of these to different devices in the room infrastructure. This allows us to experiment with distributed UIs, and to try out mapping algorithms for the distributed case. In future work it will be used for user studies.

5. CONCLUSION

We have presented a way to create multimodal applications whose user interface may span across several devices. The approach is based on a generalized concept of widgets as interaction elements. We have developed a mapping subsystem that determines the appropriate mapping of a logical widget at runtime based on the target device. By mapping at runtime we can support several modalities concurrently.

We have shown how several devices may be integrated into federations in order to define the target for device-spanning user interfaces. While the mapping subsystem is designed to cope with several modalities, distributed user interfaces pose additional challenges to the mapping which we have identified and are currently working on.

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On the Adoption of Groupware for Large Displays: Factors for Design and Deployment

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ABSTRACT
Groupware systems on large displays are becoming increasingly ubiquitous in the workplace. While these applications face many of the same challenges to adoption as conventional desktop-based groupware, the public and shared nature of these systems heighten these challenges as well as present additional difficulties that can affect adoption and success. Our field study of seven large display groupware applications (LDGAs) uncovered several factors of their design and deployment that influenced their adoption and usage within the workplace.

Keywords
Large displays, groupware, collaboration, adoption patterns

INTRODUCTION
In his seminal CSCW article, Grudin outlined a number of challenges for the successful creation of groupware applications [1]. In the realm of LDGAs, we have found that common characteristics of these systems that distinguish them from desktop applications heighten the existing challenges and present new ones. Four of these characteristics are:

- *Form factor* – The size and visual impact of large displays cause users to perceive and interact differently.
- *Public audience and location* – The location in shared space affects the amount of attention users direct at LDGAs as well as the visibility and privacy of interactions.
- *Not in personal workspace* – The location outside of users' personal workspaces affects the amount and type of interaction and exploration in which users engage.
- *Not individually owned*—The lack of personal ownership of LDGAs affects the extent to which people use them or interact with the content.

We conducted a study involving three different groups: a) researchers working on LDGAs b) members of workgroups in which LDGAs were deployed, and c) salespeople for a corporation that produces large displays and LDGAs. Our goal was to identify common factors affecting the success of adoption of these applications. Our study entailed face-to-face interviews, telephone interviews, and observations of seven systems that had had varying success in being adopted into normal workgroup tasks.

FACTORS AFFECTING THE ADOPTION OF LDGAs
Our research uncovered five important factors that were common across many of the systems we studied. Each stemmed from the four common characteristics of LDGAs that we identified. The factors are a combination of technical and social issues that influence system design as well as techniques for deployment that affect adoption and usage.

1. Task specificity and integration
The value and usefulness must be more evident than for conventional groupware because users may spend less time exploring and experimenting with LDGAs.

In many LDGAs, the specificity of the tasks involved was crucial to the adoption of a tool that seemingly supported general collaboration practices. Systems introduced for the sake of promoting specific collaboration or information sharing tasks generally were more successfully adopted than those introduced for general collaboration purposes. Tools designed or deployed to support specific tasks were more likely to be successful if they either deployed for a task for which their use was critical or a task whose content itself was critical to the user. In one example, professors teaching certain classes chose to make use of a collaborative display for teaching and class discussions. The use and interaction with the technology was critical for the tasks of taking or teaching the class; students taking the class used the display not because they were required or told to do so, but because it was deeply integrated into critical tasks involved with being a part of the class. In another case, an LDGA was introduced and adopted for space exploration planning, a critical task whose inherently collaborative nature increased scientists' ability to carry out the task efficiently.

2. Tool flexibility and generality
LDGAs that support general collaborative practices may be adopted by new user groups or for novel tasks because of their high exposure and public and shared nature.

Although LDGAs introduced for specific tasks or tightly integrated with important tasks have had good success in being adopted, we have also observed the value of broad and flexible collaboration support in their design. Most successful systems we observed provided support for a breadth of different practices that people employ to collaborate, even though the systems were deployed to support specific tasks. In short, tools that offer a variety of interaction methods that users can select as needed have been more widely adopted than those that lock users into very specific interactions.

A flexible tool that is deployed to support a specific task may be also appropriated for other tasks as people realize the tool's potential. A system that supports a broad set of collaborative practices may be used beyond its intended purpose. In one case, a tool designed to help visiting scientists collaborate was appropriated by teams of resident engineers because it provided them with general tools for creating shared digital artifacts as well as an easy method of distributing documents among users.

3. Visibility and exposure to others' interactions

The interactions of others demonstrate usage and value because the form factor and public nature of these applications can make user behaviors highly visible.

Although certain features existed of which users were aware, they were exposed to the potential value of the features after observing others making use of them. In one particular instance, the item forwarding feature of an information sharing application in an LDGA existed in the interface for approximately three months before it received use. Though the feature was highly visible and people were aware of it, users did not perceive it as useful until they saw others using it. Through seeing people forwarding items and possibly from receiving forwarded items, users began to use that feature and it became widely adopted. Because large displays are perceived as more public than desktop systems [2], the value of exposure to others' interactions on LDGAs can influence usage and the perception of value.

4. Low barriers to use

Barriers must be low so users can quickly discover value because LDGAs may be less amenable to exploration and have a lower frequency of use than desktop groupware.

It is important that users be able to interact successfully and easily with the system early in their usage in order for the system to be adopted into normal tasks. Systems that require significant time to install or configure, have time-consuming steps to initiate use, or have functionality that is not visible tend to find small audiences or a drop in usage after the initial deployment. In one application that requires user-submitted content, users have the option of posting information via a web form or an email address. Because email is perceived as quicker and easier than going to a form and filling it out, it is often used to post, while the web form is not. Another system that requires users to install and configure an application on their desktop machines in order to use the LDGA is used by only a small portion of its workgroup, despite a steady, long-term deployment. The researchers attributed this to the lack of an easy installation process.

5. Dedicated core group of users

Advocates and a core set of users early on help others to perceive usefulness and reduce hesitancy to use the system stemming from their form factor and location.

With all groupware applications, achieving critical mass is crucial to adoption [1]. Because LDGAs are generally less amenable to exploration and experimentation than desktop groupware, they are more likely to fall into disuse soon after deployment. Researchers who developed systems that were not very task specific found that adoption was aided by having a dedicated core group of users early in the deployment. This group, which often included the researchers, used the system regularly and encouraged usage by others after the initial burst of "novelty use" died down. Continued use by the core group ensured that displays remained dynamic and content fresh rather than stale. The perception that displays were being used and viewed encouraged further adoption into everyday use by a wider audience. Additionally, the core group advocated others' use by directly encouraging others to use the applications. For one application designed to share user-submitted items, core users encouraged coworkers to post information onto the displays that they had previously emailed to others. This encouragement was positive feedback to the senders of the information and helped lower initial hesitancy they felt about interacting with a new system, both technically and culturally.

FUTURE WORK AND CONCLUSIONS

The shared and public nature of LDGAs poses unique challenges for their design and deployment in addition to the challenges faced by conventional groupware. By surveying several systems, we identified some common factors affecting their success of adoption. Future work includes applying these lessons to our own LDGAs and refining our findings to better understand the dimensions, roles, and usage of these systems within workgroups.

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Super - Compact Keypad

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ABSTRACT

A compact design for a sensitive keypad construction is presented here that includes a touch-sensitive keypad with a single pushbutton mechanical key. While the user's finger seeks the desired key, a few small keys could be touched and then pressed by that finger at the same time. The desired character can be defined and shown before pressing as the centroidal point of the sensors that are touched simultaneously. Only a modicum of accuracy is required to operate such a compact keypad. The user does not need to push a small-targeted key precisely because all keys have been pushed jointly. The keypad may be made so small as to allow the tactile sensibility and the stable positioning of fingers to fit a design of ultra-portable devices.

Keywords

Touch-sensitive keypad, haptic interface, tactile feedback, pre-typing visual feedback.

INTRODUCTION

Touch-sensitive keyboard technology is based on the use of sensors, incorporated in the keypad. The identity of the touched key is tracked and monitored on a display before the key is pressed, so that the operator can see when the finger is over the correct key. Data entry will be made simpler without looking at the keyboard [1]. A visual map is represented by a keypad layout diagram to monitor finger motion. This visual feedback assists the user in locating keys before or after the keystroke without looking at the keyboard. To combine visual feedback with tactile feedback, the common surface of the sensors must be shaped so that convex or concave sections will mimic the corresponding keys. The user can keep his attention on the screen and does not need to shift focus between display content and keyboard layout. Since the system can display what will happen when a given key is touched, the user can predict the effect of the action [2].

Motion detection sensors, including any types of object sensing, field responsive devices, or a camera may be

applied to the keyboard for providing information of the hand motion.

The electrical detection signal for identification of hand motions on top of the key caps is generated by the sensor detection circuit and provided through an accessory interface or multiplexed with the keystroke data interface to the computer.

When key <A> is touched, then sensor <A> sends “A” to the application for preview, afterwards if key <A> is pressed then the mechanical key sends the same “A” and “A” has been entered. The same thing happens when <B>, <C>, or other keys have been touched and pressed. A visual map is produced and displayed with the location of the operator’s finger plus a keypad layout diagram for assisting the operator to locate keys before manual actuation.

The main observation is that a sensitive keyboard and interface provide reduced action by the users to move their focus between the keypad and the screen. The possibility of easily changing from one- to two-handed operation and the fact that there is no need for a particular hand position to find the necessary keys reduces fatigue and allows extended use.

COMPACT TOUCH-SENSITIVE KEYPAD

If the keyboard size is too small one problem needs to be solved. While the user’s finger seeks the desired key, a few small keys could be touched (and then pressed) by that finger at the same time (Fig.1).

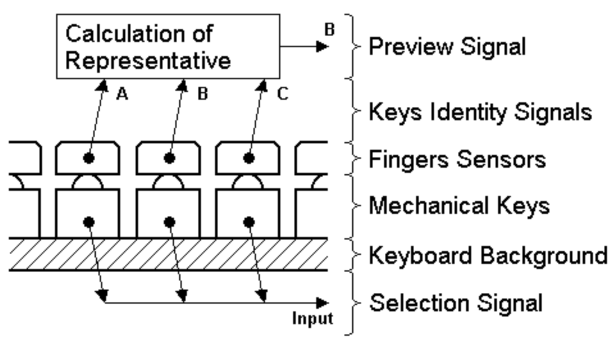

Fig. 1. Partial construction of the sensitive keyboard, when keys <A>, <B> and <C> are touched at the same time.

The desired character can be defined (and shown before pressing) as the single representative of the keys that are touched simultaneously [3]. In accordance with a present technology, a conventional mechanical pushbutton keypad, such as one for a computer, a handheld, a phone, a remote control or any other kind of data entry device, is covered by a touch-sensitive and shaped cover, includes the fingers position sensors. If any key is touched, its sensor sends a corresponding identity to the application for preview. If any key is pressed, then a mechanical key sends a common input signal, because the application already knows which key identity needs to be entered. Each mechanical pushbutton key does not need to send the key's identity signal to the application – only the input command needs to be sent.

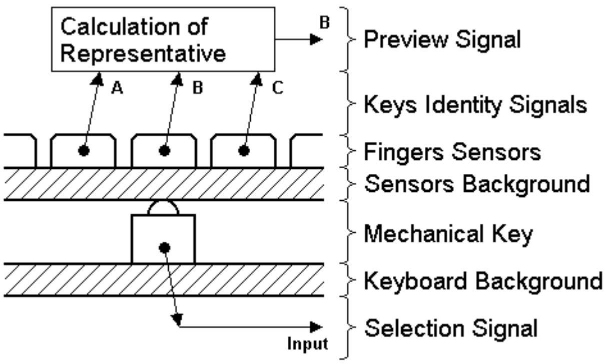

Fig. 2. Partial construction of the sensitive keyboard with a single mechanical pushbutton key.

All sensors can be placed on the common background for joint pushing (Fig.2). Only one or a few parallel pushbutton keys can be used, because all of them send the same input command. If the user's finger touches a few sensors simultaneously, then the central point of the touched figure represents the targeted key. The user does not need to push a small-targeted key separately, because all keys have been pushed jointly.

Using various predefined algorithms can provide a calculation of the representative. For example, the centroid or "center-of-mass" coordinates can be a valid representative characteristic. The use of pressure-sensitive sensors allows the calculation of the centroid of the finger pattern with more accuracy. For more accuracy other characteristics (Extent, Solidity, Eccentricity etc.) can be added to the algorithm. Each key's sensor can also be implemented as a multi-sensor element. The use of a surface with multiple mini-sensors allows the calculation of the centroid of the finger pattern with more accuracy.

THE PROTOTYPE

The sensitive linear keypad (Fig.3) was implemented as elastic, plastic bar with touch-sensitive stripes. Twelve-keys pad actual size is 8 x 32 mm ($^3/_8$ x $1^1/_4$ in.).

The virtual keyboard image can show a full set of keys or only part of the keyboard, which is touch-activated at a given time. Before pressing the key, the position of the operator's fingertip is tracked and monitored on a display, so that the operator can see when his/her finger is over the correct keyboard indicia.

Simple detectors' topology incorporates a code that uniquely represents the keys to determine a location of the fingertip of the user. Such a thin and elastic cover surface can be used for speed typing and is versatile enough to be made in different sizes and shapes to fit a design of ultra-portable devices.

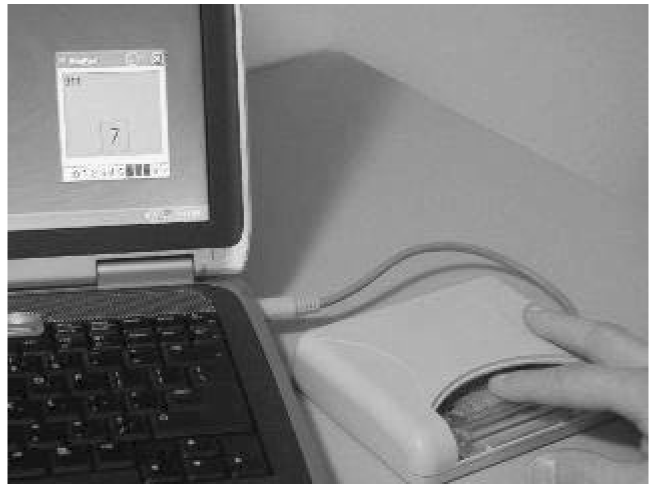

Fig. 3. Linear keypad prototype.

CONCLUSION

The following benefits could be stated after the experimental use of the prototype:

- The user is not required to push a small targeted key precisely as all keys are pushed jointly.
- The shaped, sensitive surface offers tactile feedback for the finger location that provides comfortable control.
- The keypad could be made as small as the tactile sensibility and the stable positioning of fingers allow.
- The keyboard exterior design is not limited by the parameters of mechanical keys, but by sensors only.
- The design flexibility provides the use of a mobile device in a naturally comfortable hand and wrist posture.

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EnhancedMovie: Movie Editing on an Augmented Desk

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ABSTRACT
In this paper, we describe our prototype system for movie editing on an augmented desk. We aim to enable a user to edit a movie in an intuitive operation using both hands. In the current prototype system, a user can make a movie by editing a sequence of pictures. We introduce some hand gestures in the current system and then propose other hand gestures which would be implemented in the future.

Keywords
Augmented reality, computer vision, gesture recognition, movie editing.

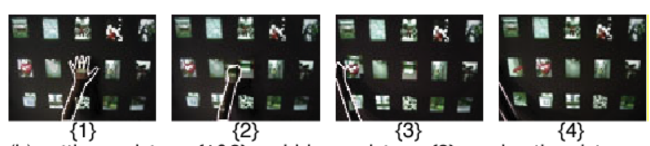
1. INTRODUCTION
With the wide spread of digital videos and digital cameras, PCs with an IEEE1394 port have become general, and it has become popular to edit and make a personal movie by oneself. Because movie editing requires a large workspace, it would be convenient to use a large display, and persons who like a large-scale display will increase more. PDH using a large display as a round augmented table for sharing a story that contains many pictures [4]. Editing a movie, requires such operations: cutting movies by setting a starting point and a ending point; changing the sequence of movies or pictures; inserting another movie or another picture. However, having such operations in a GUI application with a large display requires that people select a command and then move a cursor a lot, and several times actions would be required for completing such operations.

We have developed an augmented desk interface system called the "EnhancedDesk." By using an infrared camera and advanced computer vision techniques, the system provides users intuitive interaction by allowing them to use their own hands or fingers for direct manipulation of both physical and projected objects. We have developed some applications, including an X window system that can be operated by fingers [2], as well as a system that links a drawing tool using gesture recognition by HMM [3]. In these applications, the merits seem to be that such an operation needs setting a length or a size after selecting a command like making a circle or a rectangle. For example, in making a rectangle, users in a GUI system have to select a command and then specify two corners (or a center point and one corner); these tasks require three actions. In our system, the user can make a rectangle by drawing a vague one with a finger, an action which is realized by gesture recognition. The user also puts both hands on EnhancedDesk while making a right angle with a thumb and a first finger, which is equal to selecting a command and specifying two corners. A two-handed system [1] allows users to perform certain tasks which are usually done one-by-one with one mouse simultaneously.

Movie editing might be one application which can make use of this aspect, because the operations in movie editing described above need users to specify a command, a length or a location. We are developing a system with which users can edit a movie on our augmented desk interface system; this new system is called "EnhancedMovie". This paper describes the prototype system that we have developed, and introduces gestures that should be integrated into our system.

2. EnhancedMovie
2.1 Prototype system
In this section, we introduce our prototype system, which makes a movie from a sequence of pictures. It loads pictures in the specified directory and displays them on the desk using a flow layout.

(a) moving a picture: {1&2} grabbing a picture. {3} moving the picture. {4} releasing the picture.



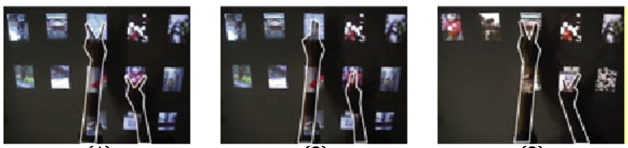
(b) cutting a picture: {1&2} grabbing a picture. {3} moving the picture. {4} cutting the picture

Figure 1: gestures with one hand

The system recognizes closing all fingers as the "grabbing" gesture and opening all fingers as the "releasing" gesture. When a user makes the grabbing gesture on a picture with one hand, the picture is selected and is specified as a target for subsequent operation. The selected picture is highlighted in red, which will let the user know that the picture has been selected. When the user moves the fist by closing the hand and then performs the releasing gesture, the selected picture is moved to a location between the two pictures where the releasing gesture was done (Fig. 1a). When the place is not between two pictures, moving the picture is not done. When the user moves the fist outside of the desk keeping the hand closed, the picture is cut (Fig. 1b).

{1} {2} {3} {4}

(a) moving some pictures at once: {1&2} grabbing pictures with both hands. {3} moving the pictures. {4} releasing the pictures.



{1} {2} {3}

(b) cutting some pictures at once: {1} two fingers are opening. {2} these are closing. {3} these are opening again.

Figure 2 : gestures with both-hands

When the user makes the grabbing gesture on two pictures with both hands, pictures between the two pictures are selected and are specified as the start and end points for the subsequent operation. The selected pictures are highlighted in green. When the user moves the fists and then does the releasing gesture, the pictures are moved to a location between which the two pictures where the gesture was done (Fig. 2a). This intermediate point is shown as a white square. While the user moves the fists with hands closing, the square moves together, so that the user will know the inserting point. In order to cut some pictures, the system recognizes another gesture. When the user puts both hands on two pictures while opening only the index finger and the middle finger and gathers the two fingers, the pictures between the two specified pictures are cut (Fig. 2b). The user puts both hands on two pictures while opening the index finger for two seconds; then the system makes a movie composed of pictures between the two, and starts to play the movie in another window (Fig. 3). When the gesture is completed, the pictures are highlighted in blue. While the system is making a movie, the color changes into white gradually. In this process, we utilize JMF (Java Media Framework) 2.1.1 and QuickTime for Java.

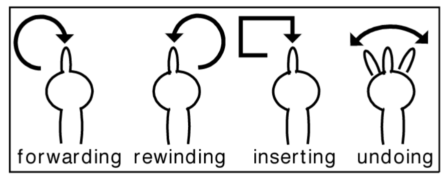
{1} {2}

{1} A start point and an end point are specified. {2} The made movie starts to play in another window.

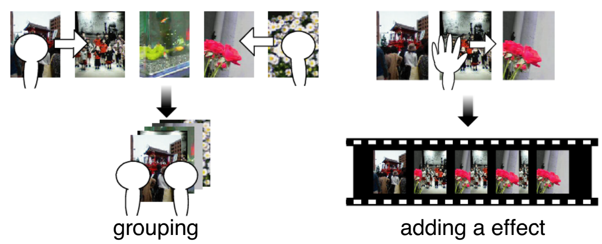
Figure 3 : making a movie

2.2 Gestures planned to integrate

The gestures implemented in the current system utilize only the numbers of fingers and the locations of fingers. We will integrate our system's capability for recognizing various hand gestures [3]; those gestures include: drawing a circle; drawing a rectangle; and waving a finger. We will make the following functions correspond to these gestures: forwarding and rewinding a movie; inserting a frame for texts; and undoing an operation (Fig. 4a). We will implement other gestures which utilize directions of moving-hands, and those that join both hands, and sliding a hand. The gestures will correspond to the following functions: grouping pictures or movies; and adding a animation effect to the movie (Fig. 4b). When the user joins both hands on two pictures, pictures between the two will be grouped together. An animation effect will be added according to the direction of the moving-hand. For example, when the user moves a hand on a picture to the right, the system will add a slide-out effect to the right direction.



gestures with finger-trace



(b) gestures with direction of moving-hand

Figure 4 : gestures to implement

3. DISCUSSIONS

We introduced the prototype of the movie editing system on our augmented desk interface and the gestures which we will implement. The current system loads only pictures; in the next system, users will be able to load some movies and to edit them. We will also evaluate it by comparing it to a GUI application using a mouse.

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Instructions Immersed into the Real World– How Your Furniture Can Teach You

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ABSTRACT

In this paper we show a simple way to immerse instructions into the real-world. In particular, we propose to enhance static affordances of objects by using LED's attached to the objects. Using the example of a flat-pack furniture demonstrates how to guide and teach the user during the assembly .

KEYWORDS

instructive interaction, physical interaction, dynamic affordance

INTRODUCTION

In previous work [1] we introduced the notion of proactive instructions that service users specifically to their needs in the current situation. Using a piece of a flat-pack furniture we showed how to determine the assembly actions the user is performing: sensors attached to unassembled furniture parts can recognize the user's actions and send the data to a separate computer. This computer holds an assembly plan, which contains all possible states of assembly similar to a finite state machine. In the first state all items are unassembled, subsequent states are reached based on the user's physical actions. The final built up state becomes valid if all assembly steps have been performed properly. The underlying principle is that the system can track, by deploying sensors, the user's assembly actions and give recommendations specifically to the user's needs in the current situation.

Presenting these recommendations to the user in a proper way is crucial. Augmented Reality (AR) is very established to visually integrate virtual knowledge into a user's physical environment. However, AR is cumbersome and typically computationally expensive. Audible instructions offer a cheaper way of immersion but have to tackle with the problem of addressing the appropriate parts by a vocabulary the user is familiar with or has to learn before. There is the possibility of presenting information on a screen, as in our prior work [1]. However, the integration of instructions with the task remains unsolved.

This paper studies how affordances of physical object can be exploited and enhanced by dynamic cues: LED's attached to the parts draw the user attention to and signal the next action.

SELF-DESCRIPTION OF PHYSICAL OBJECTS

An ideal design should not require any instructions at all: by simply looking at the physical objects the user can guess and understand the functionality. For this phenomenon Gibson coined the term affordance [2] and it was widely spread in HCI by Norman: "Affordances are perceived properties of an artifact that indicate how it can be used" [3]. Affordances are static properties of physical objects that can be perceived by a user. Furthermore, these properties can invoke a user's mental model explaining functionality of the object and possible actions. Depending on the properties of the object and the experience of the user, affordances cannot always be easily perceived and may require additional signs: instructions.

Instructions change over time as they depend on the current state in the task. Consequently, this paper proposes to enhance static affordances of objects by dynamic signs that give additional hints to the user adapted to his situation: instructions should mediate the dialog between the user and the physical objects. This introduces dynamic affordances as proposed in [4].

DESIGNING LEARNING-BY-DOING

People learn to do things by hearing, being told or instructed, seeing, being shown, or by doing. Despite of individual differences for one mode or another, learning by doing is often very important. A user recognizes something novel ("I see two screws and two boards…") guesses the next appropriate action ("…perhaps the screws fit in here..."), executes the action ("…let's put in the screws…") and is immediately rewarded by discovering if the guess was correct (or wrong). Ideally, instructions provide hints that subtly but infallibly guide users toward correct conclusions. This requires three principles that support learning by doing [5]: *explorability, predictability,* and *intrinsic guidance*.

Explorability enables users to explore, experiment, and discover functionality without penalization of unintentional or mistaken actions. In particular, this requires infinite-level undo and redo operations in a coherent and consistent manner. *Predictability* builds upon intuition: a user can draw conclusions based on first impressions without extensive thought or chains of reasoning. Accordingly, familiar things must behave as expected and novel or unfamiliar things must behave in ways that are reasonable and immediately understandable. *Intrinsic guidance* provides help as needed without requiring any special action or initiative on the part of the user.

FURNITURE INSTRUCTIONS

For the furniture application we identified five types of feedback the user should receive:

1. direction of attention
2. positive feedback for right action
3. negative feedback for wrong action
4. fine grain direction
5. notification of finished task

This enables users to explore how the furniture has to be assembled. Users unwrap the flat-pack and their attention gets directed immediately (1) to the parts they are supposed to start with. User's actions, such as turning and moving boards are sensed and blinking green light patterns indicate which edges have to be connected in which manner. If boards are aligned in the proper way, a synchronized green light pattern (Fig. 1) indicates a well performed action (2).

Fig. 1: Flash patterns: right/wrong action

If the user takes a wrong action, a red light pattern appears (Fig. 1) reporting a mistake (3). Additionally, a green flash pattern shows the right alternative (2). After boards have been aligned together in the right way, individual green lights direct user's attention to the holes where the screws have to be inserted and tightened (4). Once the final assembly state is reached, synchronous flash patterns on all LED's indicate that the task is finished (5).

These light patterns extend an parts' static affordances and can teach the user in a learning-by-doing manner how parts fit together: As a physical notion of undo and redo, attached boards can be continuously detached and rearranged, which fosters *explorability*. Furthermore, the LED's also contribute *predictability* to the assembly as red (green) light immediately indicates a right (wrong) action. *Intrinsic guidance* is provided by dynamic instructions that adapt to the current assembly state. This allows the user to take any sequence of actions without being constrained to a certain predefined linear sequence.

SYSTEM ARCHITECTURE & FUNCTIONALITY

We have developed a first prototype to display the instructions dynamically for a flat-pack furniture [6]. For sensing functionality accelerometers reveal orientation, force sensors measure screw tightening, and IR sensors measure co-location of boards, see [1] for details. Sensor data processing and wireless communication is established by the Smart-Its platform [7].

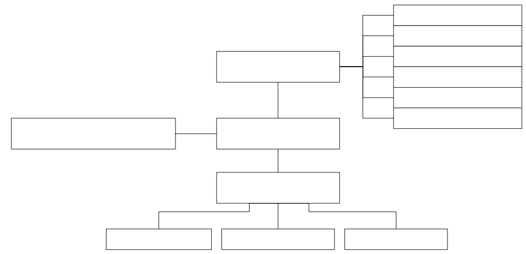

Fig. 2: Architecture Diagram

For the output functionality we have developed a custom layout board carrying eight dual green/red LEDs. Those boards are attached to the connecting edges of each furniture part (Fig. 3).

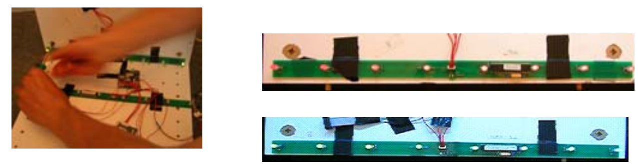

Fig. 3: Prototype: Guidance through LED's

CONCLUSIONS

This paper demonstrates how static affordances can be enhanced by dynamic cues mediating the interaction between users and physical objects. By augmenting parts of a flat-pack furniture with sensing capabilities and LED's we demonstrated the feasibility of this approach This augmentation of objects allows to integrate instructions directly into the objects, gives the user the flexibility to draw own conclusions and provides intrinsic guidance if appropriate.

ACKNOWLEDGEMENTS

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i-wall: Personalizing a Wall as an Information Environment with a Cellular Phone Device

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ABSTRACT
The authors' aim in this paper is to attach information environments in streets in a natural way. We utilize walls in places where people pass by as an attempt to the aim, and have implemented *i-wall* (intelligent/information/interactive wall). i-wall is normally an ordinal wall, but when a user comes, it provides an information environment to him/her. The services of i-wall are not only a conventional information terminal but also a location-specific information (e.g. events which occurred in front of the i-wall system) service. i-wall employs web-accessible cellular phone devices for its interface and aims for an easy-to-use environment using users' accustomed devices which they take along.

Keywords
Information environment, Wall, Cellular phone device, User interface

INTRODUCTION
Amazing progress in mobile infrastructure has enabled us to access information anytime and anywhere. And, augmented reality and interface technologies have enabled us to build information environments in the real world (daily life space). We can see the stream toward the "ubiquitous computing" [4] era. Considering the background, we aim to build easy-to-use information environments in public space where people pass by. To achieve this concept, we pick up various existing objects and enhance them. In this paper, the object is a wall, since there are walls that could be utilized efficiently everywhere. We name the enhanced wall for an information environment *i-wall*.

Suppose that a person coming in front of the wall can occupy a part of it as an information environment for him/her. To put it concretely, an information window will open in front of him/her and he/she can interact with it. The interface for interaction is a cellular phone device, which is used like a remote controller. Cellular phone devices are very common and each user knows how to use his/her own one. Thus, they would be useful for clear interface of systems a lot of people use.

The remarkable point of services of i-wall is location-specificity. For example, i-wall records events in front of the wall in its memory and users can play it back. Through these services, i-wall creates a value-added space as well as an information-accessible environment.

EXPERIMENTAL SYSTEM
Implementation
The overview of the experimental system is shown in Fig. 1. The system consists of: (1) a video projector to give a function of a display to the wall, (2) a camera to capture the scene in front of i-wall, (3) a position sensor, (4) PCs.

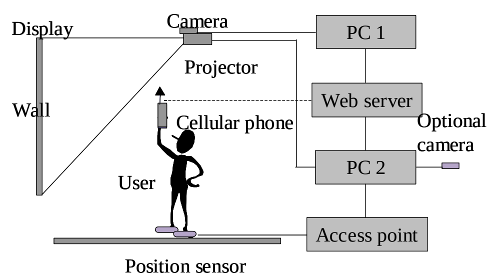

Fig. 1: Overview of the experimental system

For ease of attaching it to an existing wall, we attach a video projector on the ceiling (Video projectors are popular devices for displaying information to existing environments, e.g. [1]). The white wall is suitable for projecting images. A camera is placed on the projector to capture and record the scenes. Capturing interval is 30 seconds in today's implementation. As a position sensor, the authors used infoFloor [5], which is an RFID-based system.

When the user comes in front of the i-wall system, the user's position is detected (shoes with RFID reader are needed in the current implementation) and a window appears on the wall (Fig. 2). The window follows the user and its size becomes larger when he/she gets closer to (occupies more space of) the wall. When two users come by, individual window appears in front of each user and they can share the wall.

Fig. 2: An information window appears in front of the user

Windows can be operated with the users' web-accessible cellular phones. They access the web page for operation (Fig. 3) and submit data through CGI. Available operations are: window operation (size, position and on/off), application switching and specifying the time to playback (as we mention below). The page is designed with symbols for intuitive operation and configured to fit in the display size of cellular phones.

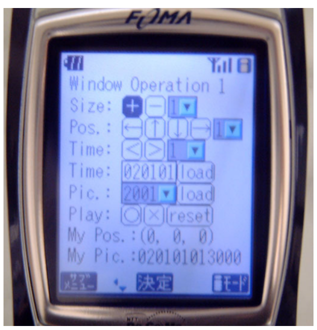

Fig. 3: The web page for operation

Information Services

The distinguished service of i-wall is its ability to playback the events which took place in front of it at the very spot where they happened. The reproduction achieved this way has a reality brought from the situation/location.

As explained above, i-wall records scenes in front of the wall. Users can playback the scene by specifying the time when they want to see or flipping scenes like a slide show (the operation is done with their cellular phones). The reproduced scene is displayed in each information window.

This service evokes an application as follows; As seen in Fig. 4 left, a person was waiting in front of i-wall, another person comes later and playbacks the past scene (Fig. 4 right), he finds out his friend had waited and has gone.

Or, you can stamp your activity on the place, which makes the place special for you. You can reproduce your stamped trace at the very spot anytime you want.

Of course, the i-wall system can be used as a conventional information terminal. By application switching, you can view information stored in the system or from the network, and watch the remote view from the optional camera (or over the network). Note that these images are basically displayed in the user's window, not on the whole wall. To see the whole image, he/she has to move along the wall, which gives a feeling to the user as if he/she is seeking treasures on the wall.

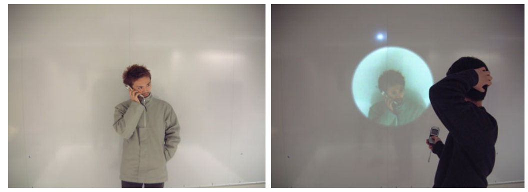

Fig. 4: The past scene is reproduced on the very spot

CONCLUSION AND FUTURE WORK

The concept and a prototype system of i-wall (an enhanced wall for information environment) are described here. We are planning to improve the implementation (hardware and software) and install the i-wall system in public space for further evaluation. Cellular phone devices are getting more and more sophisticated and groping for new interface with them is also an interesting topic.

RELATED WORK

"i-wall" is an attempt to information environments in streets. Ubiquitous Display [2] and ActivePoster [3] are similar especially because they use mobile terminals.

In Ubiquitous Display, users can control large displays connected to the broadband network to get services that mobile terminal cannot handle because of lack of its capacity. In contrast, i-wall's services deal with the real world and people's activity there, rather than information on the network.

ActivePoster obtains personal information from users' mobile terminals and displays personalized information (advertisement) actively. i-wall does not necessarily perform actively because it is a part of the environment and activated only when users want to use it.

ACKNOWLEDGMENTS

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Healthy Cities Ambient Displays

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ABSTRACT

The Healthy Cities project addresses the lack of publicly-available information about city health. Through interviews and surveys of Berkeley residents, we have found that city health includes a wide variety of economic, environmental, and social indicators. We are building public ambient displays that make city health more visible and encourage change by highlighting the value of individual contributions.

Keywords: ambient displays, peripheral displays, city health, sustainability indicators

INTRODUCTION

City datasets such as air quality, crime rates, energy usage, or recycling amounts can be powerful indicators of city health; however, it is often difficult for city residents to access this information or interpret it. Despite the wealth of information collected about various aspects of city health, residents know little about this information or how they can make a noticeable contribution, leading to feelings of frustration or helplessness. The Healthy Cities project aims to make city health information more publicly visible by displaying easily interpretable health indicators in public places such as transit hubs, shopping districts, or public buildings. We hypothesize that this information will empower residents to improve city health by giving them a better sense of what they can do and by making them feel like their actions are visible.

Healthy Cities

We have chosen to display city health information in the form of an ambient display, which provides a continuous stream of information in a simple format that can be interpreted at a glance. Because our target locations are places where people will be passing through and will have only peripheral awareness of their surroundings, the easily-readable nature of ambient displays lends itself well to these locations. We have also noted that few ambient displays have been built for the general public, and were interested in exploring this design space.

Ambient Displays

Ambient displays are devices that peripherally provide a continuous stream of information. Ambient displays show non-critical information in a simple, intuitive, and aesthetic way, reducing the cognitive load of users. Researchers at PARC, M.I.T. Media Lab, Carnegie Mellon University, Georgia Tech., Viktoria Institute, and elsewhere have designed various displays, including a "dangling string" that twitches with network activity [1], a water lamp that casts rippling shadows, pinwheels that provide awareness through sound and air flow [2], a pixellated ambient display [3], a "Digital Family Portrait" that gives peripheral awareness of remote family members [4], and informative art pieces [5].

METHOD

We began our investigation of city health by conducting in-depth, exploratory interviews of six East Bay residents. Participants were recruited from flyers in grocery stores and posts on Craigslist (an online community forum). We followed up the interviews with a culture probe [6], consisting of four postcards that encouraged our six participants to provide additional details on their day-to-day perceptions of city health.

Responses were categorized into broad topics, which were used to create a follow-up survey. The survey included 33 yes-no and Likert-scale questions and ten written-response questions, asking about the importance of various indicators of city health. Questions were divided into ten groups: neighbors and safety, diversity, environment and conservation, public events, city history, volunteerism, shopping and economics, schools, transportation, and individual health. Surveys were distributed to over 300 people in post offices and farmers' markets in Berkeley, and a link to an online survey was published on Craigslist.

RESULTS

The interviews and surveys showed us that city health includes myriad indicators such as public school conditions, air quality, effective minimum wage, maintenance of houses and streets, unemployment, individual health, racial diversity, pedestrians, public events, and more. Of these indicators, the ones that are quantitative and are updated often are more suitable for public ambient displays.

Interviews

The interviews and culture probe postcards gave us a qualitative sense of city health. The participants were two women and four men, with ages ranging from 25-55 years. Three were Caucasian, and the three others were Lebanese, Asian and Latina, respectively. Although our participants had diverse definitions of city health, most or all mentioned certain indicators: the number of locally-based businesses in the community (all 6 participants), the number of parks or amount of green space (5), diversity (5), uniqueness (5), safety and poverty (4), pedestrians (4), and public events (4). These gave us a sense of areas to cover in our survey.

Surveys

145 residents of Berkeley and nearby Oakland, El Cerrito, and Richmond completed the survey, 95 from in-person recruiting and 50 online. Of these, 90 were female and 52 male, and the ethnic and income distribution was very similar to Berkeley's 2000 census data, suggesting that we succeeded in getting a uniform sample by ethnicity and income, though not by gender.

In our analysis of the survey, we found that thirteen indicators received average ratings 4.0 or above out of 5, in terms of their importance to city health (5 being "very important"). All of these had modes of 5. These indicators are summarized in Table 1.

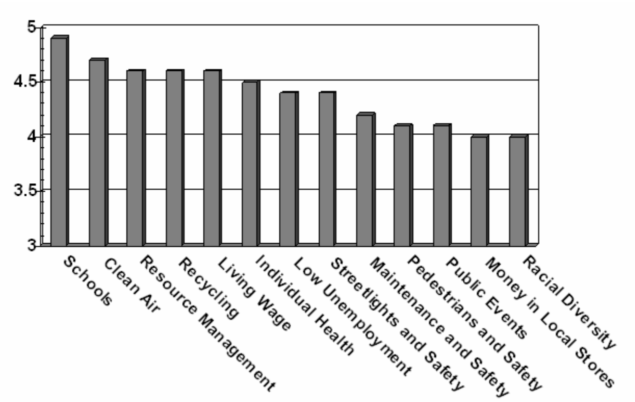

Table 1. Indicators that received average ratings of at least 4 out of 5 in importance to city health.

Displays

While all of these indicators could be used to develop interesting displays, the two indicators we chose to focus on first are electricity usage, as part of resource management, and recycling. Although these were not brought up in our interviews, we chose them because they were important to our survey takers (which had a much larger sample size than our interview pool) and are quantitative, measurable, constrained, and frequently updated, and have accessible data sources. These characteristics are important because the display should be credible and should noticeably change for people who will see it on a daily basis.

Unfortunately, we could not gain access to citywide data for either source, so we have focused on the activity in one recycling bin as a microcosm of city recycling, and light pollution levels at night as an estimate of electricity usage.

We have designed a preliminary recycling display, which will use load cells to sense a can thrown into a particular recycling bin. A visual meter rises when the weight in the bin changes to give users a sense of what their contribution was worth. The interface runs on a Sony Clio, and currently has been made to work in a simulated environment where the addition of a can is simulated with the clicking of a button on the touch-screen.

We have also designed a preliminary electricity display, which uses computer vision to sense the amount of light pollution given off by lights in the city of Berkeley at night. Multiple cameras are used to collect aerial views of the city every few minutes. These images are analyzed for brightness characteristics and aggregated across cameras. The resulting brightness information is overlaid on a map of Berkeley and presented on a screen to users.

FUTURE WORK

We plan to continue design on our two display prototypes, and possibly design more displays on other city health indicators such as air quality or public events. These displays should be evaluated for their effects on public awareness and action. If successful, Healthy Cities displays could be extended to other cities to raise awareness of city health.

ACKNOWLEDGMENTS

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LaughingLily: Using a Flower as a Real World Information Display

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ABSTRACT
Ambient displays and calm technology as termed by Weiser and Brown [5] are key techniques to help ubiquitous computing applications enter our everyday life. Here we present an ambient display in the form of a physical object that can be moved around in physical space, thus being highly adaptive to the users needs. LaughingLily is an artificial Lily enhanced with an electromechanical system that enables the flower to let its petals hang or open them up to full bloom. Using the flower as a meeting mediator we show how well it can be integrated into the real world and how easily it is accepted by potential users.

Keywords
Calm Technology, Ambient Display, Real World Display

INTRODUCTION

Many ubiquitous computing applications exist, which use elaborate sensing of their environment to adapt to local context. But they mostly still rely on classic output methods such as computer displays or projection screens. Many researchers have worked on integrating output into the physical world by using classic displays in different ways [1,2,3]. Experience however shows that classic displays often become the main focus of attention, which can distract the user from his activity. Oppositely displays hanging on the wall as in [1] can seemingly vanish into the periphery if someone is looking the opposite way.

Weiser and Brown [5] proposed the concept of *Calm Technology*. Their goal is to design technology so it is equally *encalming* and informative. To do so they propose presenting information in the user's periphery. This makes it possible for the information to move out of the user's focus when it is not important, and to move to the center as soon as an important event occurs. Calm Technology aims to manage this transition easily. In the AmbientROOM project [6] the presence of distant people is represented with different peripheral displays. As soon as someone enters the distant but connected space light reflections appear on the wall and water ripples start moving. By presenting information in the periphery and only moving to the user's center of attention at specific events these Ambient Displays represent a form of Calm Technology.

Besides having the ability of moving between the periphery and the center of attention Calm Technology also can enhance the user's *peripheral reach* by bringing more details into the periphery. Informative Art as presented by Holmquist et al. [1] refers to a set of paintings, which display different kind of information in a subtle way. The information displayed ranges from weather forecasts of distant cities, to recent earthquake activity around the globe. By slowly adapting to information changes the art pieces don't attract the user's attention. However, the user can bring the art piece to the center of his attention if he or she wants to extract some information.

Let's regard the example of a meeting, where information needs to be displayed unobtrusively. In order to be visible for all participants the ambient display should be close if not in the center of the physical space of the people and their activity. We propose to integrate the display into the physical world by actually using a real physical object as the display itself. This enables a display to be omni-directional in order to be visible for all meeting participants. It should display peripheral information without distracting from the actual task. Finally the aim should be for a visually appealing object since it is more likely to be accepted and even enjoyed by people.

This paper proposes such a display, named LaughingLily, where a physical object - here an artificial flower - becomes the ambient display itself. Depending on the information to be displayed the flower can let its petals hang, or open them up to full bloom (see Figure 1). By nature a flower is omni-directional and can be perceived by all participants. By careful design of the movements and blooming behavior of the flower LaughingLily can display information without distracting.

MEDIATING BETWEEN MEETING PARTICIPANTS `

Team meetings with a handful of participants can sometimes be very cumbersome. Do you remember your last meeting that got out of hand? When your colleagues kept arguing about the same thing over and over again? Oppositely there can be brainstorming sessions where nobody has any ideas and a laming silence fills the room.

To mediate between meeting participants we built a flower

Figure 1: LaughingLily opening her petals to full bloom.

that can droop its petals or show its bud in full bloom; thus representing a sad or a happy state. The flower stands on the middle of the meeting table and changes its stature depending on the surrounding sound. If nobody is talking the flower lets its petals droop. If a conversation at an intermediate volume is going on the flower moves towards full bloom. If an argument breaks out the flower starts drooping again.

To be able to react on the audio activity of the participants the flower is connected to a microphone. Using multiple directed microphones each connected to an individual flower the display can show which participants in the meeting are dominating the discussions and which have not spoken for some time. A similar effect can be achieved by placing two or three flowers on the table at different positions. This way, the meeting participants are not directly exposed as too loud or too silent, but the one side of the table is accused as a whole.

LaughingLily - Implementation

LaughingLily is an artificial Lily extended with a electro-mechanical system. The microphone on a Smart-Its [4] sensor board was used to capture an audio signal. The onboard processor (PIC microcontroller) calculates the energy level of the signal, representing the loudness of the people speaking. To make the flower move a servo motor was controlled directly from the sensor board. A shaft connecting the servo motor with a cup-shaped plastic part actuates the flowers petals. The whole system can either be powered by batteries (working for several days using 4xAA batteries) or directly from the mains.

First Impressions and Discussion

The first afternoon LaughingLily was standing on the coffee table in our hall many comments from office colleagues were made about how sad or how pretty the flower looked. They soon learnt that when someone is talking in the environment the flower starts lifting up her petals. After the novelty wore off everybody continued with their everyday business. LaughingLily had become integrated into the physical space and became a peripheral display.

We believe the quick integration of LaughingLily resulted mainly from having a physical object as a display itself. An object can be moved around in space and be placed amidst people. In this way the display is adapted to the situation instead of having the people adapt to the display.

As expected due to the natural association between LaughingLily and a real flower, first experiments showed how people's emotions can be invoked. A drooping flower is naturally associated with sadness, whereas a flower in full bloom can trigger happiness to a certain extent. Exploiting these associations people have with physical objects could be a powerful tool in interface design.

OTHER APPLICATIONS

Beyond the meeting application presented in the previous section many more applications are imaginable. In office environments LaughingLily could be used to warn computer users from repetitive strain injuries by letting the petals droop if someone hasn't had a break for a long time. Further LaughingLily could display to co-workers how interruptible one is depending on approaching deadlines, calendar information or e-mail load.

In the domestic environment LaughingLily could act as a progress bar for simple procedures. For example, the flower could show how far the washing machine is by slowly elevating its petals. It could show how long the cake has been in the oven. The petals would then simply start to droop again if the cake was is in for too long.

Finally, LaughingLily can display the interaction level between conference participators and the poster presenter at a conference such as UbiComp 2003.

CONCLUSIONS AND FUTURE WORK

In this paper we have presented LaughingLily – an ambient display embodied by a flower. Although we have yet to conduct a comprehensive user study, we have shown how well such an ambient display - in the form of a flower - can integrate into the environment. We believe that displaying feedback to the user in a physical object is the key to making ubiquitous computing applications calmer and more suitable to human needs.

Besides exploring LaughingLily's effects on meeting participants in a larger user study we want to continue developing further physical feedback devices.

ACKNOLEDGEMENTS

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Habitat: Awareness of Life Rhythms over a Distance Using Networked Furniture

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ABSTRACT

The demands of modern working life increasingly lead people to be separated from loved ones for prolonged periods of time. Habitat is a range of connected furniture for background awareness between distant partners in just such a situation. The project particularly focuses on conveying the patterns of daily routines and biorhythms that underlie our well-being, in order to provide a sense of reassurance and a context for communication between people in relationships.

Keywords

Awareness, biorhythms, limbic regulation, connectedness, networked furniture

INTRODUCTION

Intuition leads us to believe people have an innate desire to have an up-to-date understanding of the emotional and physiological state of loved ones. When two people form a close bond, awareness of each other is essential to convey feelings and needs to one another and ensures that the relationship can survive and flourish.

Awareness of a partner's activities and biorhythms, such as sleeping, eating, socialising and working, is useful as these rhythms can be indicators of well-being - providing feelings of reassurance and connectedness, stimulating comparison and synchronisation between the pair-bond. The knowledge of any deviation from regular patterns and cycles is of equal significance.

Today our lives are enriched by pervasive technology that conquers distance to such an extent that the anxiety of being apart is minimal. But a corollary to technology mediated relationships is that people can still feel disconnected or not attuned with their partner, especially if they happen to be in different time-zones. Old-fashioned methods of keeping in-touch such as letter-writing are accepted as conveying a greater sense of intimacy but lack the instantaneity we are now used to. The majority of modern communications technology such as telephones, text messaging and e-mail, cause untimely interruptions, can be in-contiguous or can require a significant amount of effort to use while doing other tasks.

Habitat explores the potential of addressing these issues by using household furniture as a network of distributed ambient display appliances that centre on the capture and visualisation of daily rhythms to convey a sense of awareness between partners separated by distance.

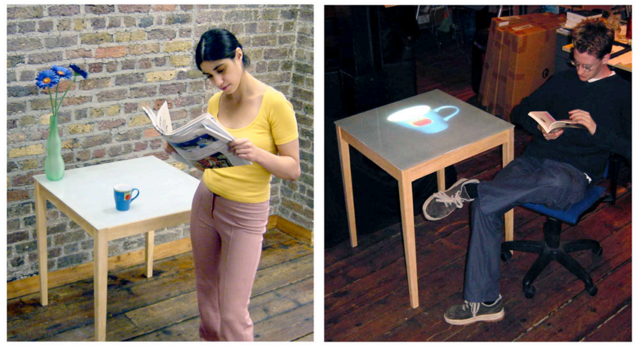

Fig. 1 - Habitat being used to link two distant partners.

BACKGROUND AND RELATED WORK

Research into the physiology of the brain is now starting to unravel some of the issues on why humans have such an affinity to one another [3]. The limbic brain, which was once believed to only co-ordinate sensations from the external world to internal organs, is now thought to be responsible for regulating our emotions. This mechanism for the mutual exchange and internal adaptation between two mammals, whereby they become attuned to each other's internal states is known as limbic resonance. This theory is developed further, proposing that the human nervous system is not autonomous or self-contained but an open-loop system that is continually rewired through intimacy with nearby attachment figures - a process of interactive stabilisation, known as limbic regulation.

The field of psychobiology provides us with a body of experimental evidence on biorhythms and their impact on our well-being [2]. Our biorhythms and internal body clocks are affected by a number of external factors, most importantly people we are bonded to.

Habitat also draws upon ideas from previous projects in ubiquitous computing that employ furniture and architecture as display devices, such as Ambient Displays [6], Roomware [5], Peek-a-Drawer [4] and The RemoteHome (exhibition - London/Berlin 2003).

TECHNOLOGY AND DESIGN GOALS

The initial range of Habitat appliances are in the form of two geographically separate, networked coffee tables.

Each station consists of a networked Linux computer, a RFID tag reader and a video projector.

Two people having a long distance relationship (Figure 1), use the Habitat system as follows: When objects (with a RFID tags embedded inside) are placed on the coffee table, they are sensed by the tag reader, which uniquely identifies each object. The tag reader is polled regularly by the computer to check if any items have been added or removed. Such events cause messages to be sent to the coffee table in the remote partner's living space. The remote coffee table displays a corresponding representation of the opposite person's activity (Figure 2) and their overall daily cycle on the surface of the table, using an appropriately mounted video projector. When items are removed, the displaying coffee table gradually fades away that representation.

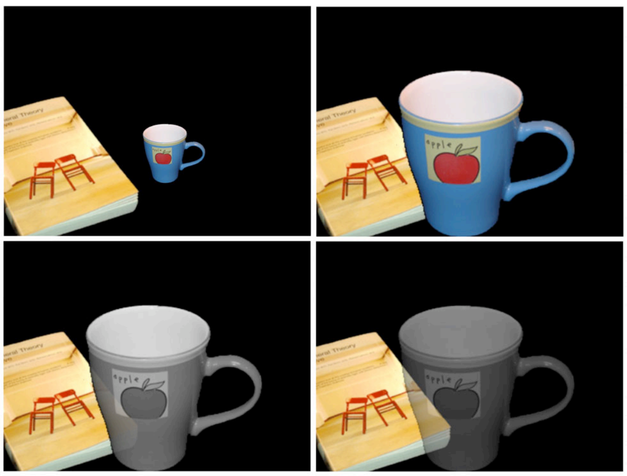

Fig. 2 - A typical sequence within a visualisation

Habitat takes into consideration several design guidelines in creating connectedness applications [1]: -

- The system should behave like an appliance that is always on and connected, to foster sense of continuity - an open link between the users.
- Participating with Habitat should require no change in the user's normal behavior and not alter the furniture's original use.
- The visualisations should be non-distracting, so they can be viewed across the room and in the periphery of vision without distraction. The visualisations are designed to indicate presence of the remote partner over a duration of time, so that observers are free to move around the living space and not have to constantly watch the display.
- The system should express the notion of a digital wake. A digital wake is a visual construct that allows the users to ascertain the history of previous interactions. When an activity ends, its representation gradually fades out but is never completely removed from the display. This gives users who return to their living space a mechanism to interpret what took place while they were absent.

Privacy and trust issues are dealt with implicitly as the furniture only connects into the personal space of a loved one, a person that a high level of trust is already shared with. Users are also made well aware of the specific artifacts that trigger the communication between Habitat stations. Reciprocity is important for limbic regulation, since each station is a duplicate, awareness flows in both directions in a continual feedback loop.

CURRENT STATUS AND FUTURE DIRECTION

The first phase of Habitat is complete, a proof of concept demonstrator system which acts as a platform for conducting experiments and extending ideas. A range of visualisations that describe remote activities have been created. A forthcoming trial will be used to determine the effectiveness and appeal of these different visualisations to potential users.

Future versions of Habitat will concentrate on the capture of more complex routines and activities. We plan to use biomedical technologies in concert with the connected furniture platform, to monitor users' body temperatures, heart rates and other well known metrics for tracking biorhythms with additional accuracy. Humans have several bodily rhythms that affect how we feel in addition to circadian rhythms, such as ultradian (~90 minutes), infradian (many days) and circannual (~1 year). There are also several environmental factors that alter or reset body clocks (known as zeitgebers) that could be accounted for within visualisations.

The aim of this research is to determine if we can successfully convey awareness of rhythms over a distance and if doing so can provide similar levels of reassurance and intimacy as physical proximity of partners in a domestic setting.

The eventual goal would be to install suitably evolved iterations of the technology with many groups of people outside of the laboratory environment and assess their use in a study - prime candidates being people who endure separation from family and partners for prolonged periods of time, such as off-shore workers or military personnel.

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Smart Home in Your Pocket

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ABSTRACT
In this poster we present HYP, an application that enables a mobile phone user to create his own context-aware services for his smart home. By setting criteria tailored for the individual user, HYP can for example warn the inhabitants of a house if the TV is on when no one is watching. We developed HYP in J2ME, making it possible to run on any java enabled handheld device. Future work includes attaching it to a real smart home, in order to test the actual employment of the application.

Keywords
Context-aware computing, smart homes, handheld devices

INTRODUCTION
The seamless interaction between a house and its inhabitants that context-aware homes strive for is shown to be difficult to achieve [6]. The advantages of a home with functions that adapt and assist according to sensor measures seem numerous; however, people have very different habits and ways of leading everyday life, and applications that are developed for one lifestyle therefore might not work for another. For example routing phone calls to the room where the receiver is present might work in a busy nuclear family, but for the elderly couple, who both enjoy getting calls from their grown children (meaning the call in not directed at one person, but both), the function might not be optimal or even relevant.

In this project we approach the problem by suggesting a new application, which enables people to create their own context-aware applications for a sensor saturated home. The user defines the sensor measures (criteria) that should be taken into account when performing a specific action; the action then depends on user specified criteria, making the applications more flexible and tailored, rather than having a programmer specify each application. We have developed a prototype of the system that runs on a handheld device, but it is still not attached to a real smart home or any sensors. We first present the HYP application and examples of functions the user can develop, second, we review related work. Finally, we discuss the implications, conclude and suggest future research.

THE HYP APPLICATION
The HYP application is developed in Java, using its micro-edition API [3] in order to make it run on a handheld device with limited processing power and memory. It is in its development phase and therefore still only a prototype with no back-end so far; eventually the goal is to connect it to a sensor equipped (test) home in order to make further user testing. The core concepts of HYP are the *actions* and the *conditions* as seen in figure 1. An action is a single action, for example 'turn on coffee maker' or 'turn off TV'. The conditions are the more complex user specified criteria that make up one action. Conditions can for example be 'light on in bedroom' or 'motion detected in bathroom'. The conditions for each action are all defined in an 'and'-aggregation. The conditions can be wrapped in a timer, so the user can specify a specific time frame for the condition, e.g. 'for at least 10 minutes', however, a condition can be a time interval in itself, meaning that all conditions are restricted to a specified time frame, for example 6-9 PM. In order to provide more insight into the use of HYP we provide three examples of sub-applications.

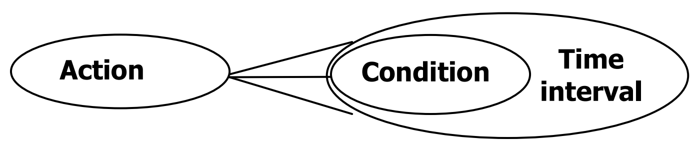

Figure 1: HYP model of concepts

Examples of Tailored Functions
The first example function alerts the user when the next bus will leave from the closest bus stop. The user models this from the criteria that the fridge door opens between 7 and 9 in the morning, while the light in the bathroom has been on for more than 10 minutes. This particular user knows that he drinks a glass of milk in the morning after showering, which always takes more than ten minutes; therefore the bus schedule is relevant at this point in his schedule, as opposed to a fixed time.

In another function, the user defines the action of turning on the record button on the VCR. The user defines the five criteria as there are no lights on in the living room and the cell phone is not in its cradle; the front door has not been opened the last 10 minutes and the TV is not on. If it is Sunday night, 9pm, the VCR turns on and tapes the latest episode of the user's favorite show: Sex and the City.

The final example alerts the user if he is about to forget his cell phone in the morning. If he opens the front door between 7 and 9 in the morning and the cell phone is still located in its cradle, the cell phone alerts the user with a loud beep that he has not taken it with him.

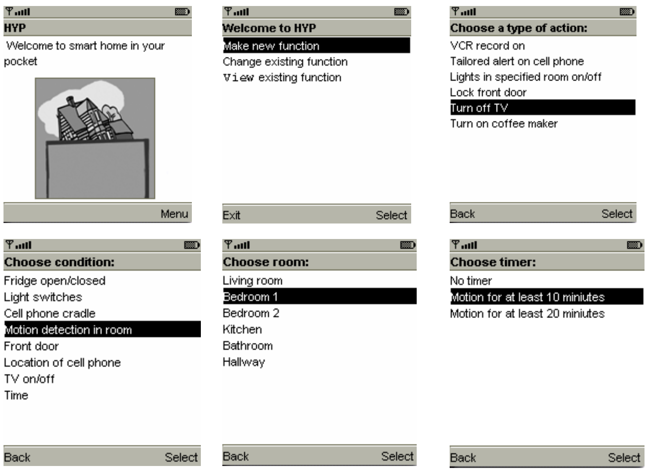

Figure 2: Screen shots from HYP: actions and conditions

RELATED WORK

A fair amount of research has focused on developing smart homes; one example is The Aware Home at Georgia Institute of Technology [5]. Here, the purpose was to make the sensors learn about the users' habits to facilitate the development of human-centered applications for a rich sensor infrastructure. MIT's House_n is build with another goal: to teach and motivate the user to take control in a sensor augmented house instead of having the smart house overriding the user's actions with inappropriate behavior[4]. In our view, the goal of a smart home is to assist individual inhabitants with everyday tasks by tailoring functions to their habits and behavior.

Other relevant work includes context-aware applications for handheld units such as the Tour Guide and the Cyber Guide[2,1]. These applications change their content according to the surrounding context, for example location, time and identity of the user. Finally, iCAP is a system that enables users to create context-aware applications [7]. But where iCAP focuses on end-user programming on a desktop computer, HYP goes all the way and enables mobile users to define their own criteria 'on the go'.

IMPLICATIONS OF THE HYP APPROACH

While HYP is in essence still an outer layer of the prototype, it illustrates a new way of specifying a smart home. It is our goal to empower the users by giving them simple options for dynamic functions. By making it easy to revise existing sub-applications, the chance that users will reject context-aware functions is diminished, because the user can change it to better fit his needs. However, in order to keep HYP simple, the options provided are limited. When creating a timer for example, the user is left with few selections (see figure 2), which in some cases might not satisfy the user's needs. It is likely that the user wishes to create applications that are not possible and finds that it is difficult to define the right criteria for a specific action. Most people lead irregular lives, resulting in exceptions that might initiate the action at the wrong time. However, the HYP approach makes users understand why the system acts like it does, because they specify the conditions themselves.

CONCLUSIONS AND FUTURE WORK

We have presented our prototype application HYP that illustrates how users can create their own smart home functions on a handheld device. The concept of HYP emphasizes the user's individual and unique lifestyle by letting him define his own criteria. This approach lets the user stay in control of the technology and thereby prevents the user from not using the application due to irrelevance. It is our belief that this type of context-aware applications will, in many environments, be preferred over the more autonomous ones, which, in their effort to work smooth and transparent, leaves little free choice to the users.

Since we have not performed any formal user evaluation on HYP, this is the next step. Testing how users interact with it and see if they are able to create desirable applications, are essential for further deployment. Our second goal is to connect the HYP prototype to a sensor equipped smart home in order to develop the application further and get real user feed back. Finally, it should be considered which other environments will likely benefit from a similar approach.

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SiteView: Tangibly Programming Active Environments with Predictive Visualization

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ABSTRACT
Active environments – those with sensing and actuation capabilities – are often difficult for end users to control. We describe SiteView, a system for creating and viewing automation control rules. SiteView has an intuitive tangible interaction method for creating control rules and enhances user understanding of the system by appropriately exposing internal state. SiteView also supports users' visualization of the active environment through a photographic display keyed to control rule conditions.

Keywords
Tangible interaction, end-user programming

INTRODUCTION
Research in *active environments* – those with sensing and actuation capabilities – usually involves sophisticated technology, but usable active environments need not be complicated for end users. Much automation can be achieved with simple sensing and actuation, and, indeed, commodity toolkits and protocols such as X10 exist for this purpose [7]. However, use of everyday automation tools is generally limited to hobbyists and those comfortable with traditional programming techniques. We argue that this can be seen as chiefly *a problem of user interface*. Specifically, commodity automation toolkits do not correspond spatially to how users interact with their environments and do not offer feedback about the internal state of the control system [7,8]. Furthermore, these toolkits lack *situated visualization* – they do not show the user the future effects of her rules at the time she is programming them.

SiteView addresses these issues by lowering the learning curve for environment automation, while maintaining enough logical expressiveness to remain useful. SiteView programs consist of rules with a simple conjunctive predicate and one or more consequent actions. Users create rules by manipulating tangible interactors representing sensed conditions and automated actions within a world-in-miniature (WIM) model representing the active environment. To enhance transparency, our interface offers explicit user feedback during programming. It shows what control rules are applicable given the user's conditions and it provides an image of what the environment will look like under those conditions and actions specified by the user.

Our project draws inspiration from a broad base of previous work. While Mozer's neural network house investigated making home automation usable, the behavior and internal state of his machine learning system is essentially opaque to the user [5]. The Accord toolkit also supports home automation, and encourages explicit programming by direct manipulation, but it reverts to a simplified GUI as a programming environment [1]. To ease programming in SiteView, we built tangible interactors, drawing upon previous tangible programming work in Gorbet et al's Triangles and Blackwell's Media Cubes [4,3]. The world-in-miniature ties our tangible interactors to the physical environment, and originated as a technique by Stoakley et al. for navigation of virtual reality spaces [6]. Here, we describe the design and implementation of a system for intuitive end-user programming of active environments, and motivate the design with a use scenario.

SYSTEM DESIGN
Our tangible interaction interface makes end-user programming of automated environments simpler by leveraging spatial and visual correspondences between the control interface and the automated environment, and by enabling seamless visualization of the active environment and the automation rules. As a proof of concept, we implemented our interface design to provide control for a new laboratory space used by our research group. There are five main components of the interface's physical design. The first three support the act of rule creation and the last two support feedback about those rules:

Interactors are physical objects that logically correspond to rule conditions, such as *afternoon*, and automated actions, such as *light on*. Tangible interfaces allow for collaborative and two-handed interaction, require less dexterity than traditional input, and better preserve spatial relationships between virtual objects and their real-world counterparts [4].

The **world-in-miniature** is a small-scale representation of the environment, used as an interaction space for the user to spatially specify automation actions. The WIM is a physical artifact with a spatial and logical correspondence to the user's view of the environment, unlike GUIS and scripting languages, enhancing intuition about programming actions. The **condition composer** is an area that senses and structures the user's specification of rule conditions. Conditions are represented as discrete tokens.

The **environment display** shows what the environment will look like when a rule is activated. The environment display shows photographs of what the active environment will look like for a given set of user-specified conditions

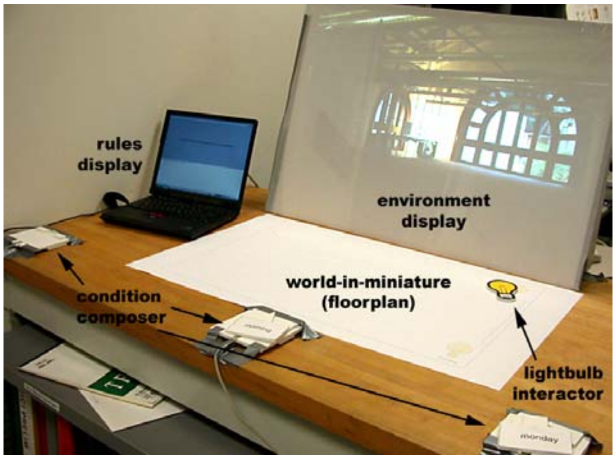

Figure 1: The condition composer is at front; the large screen is the environment display. The laptop is the rules display, and there is a lightbulb interactor on the WIM floorplan. The configuration shown creates a rule to turn on the north lamp on rainy Monday mornings.

(weather, day, and time). The user can also use the environment display to simply check automation settings for a particular set of conditions, including the current ones.

The **rules display** shows the rule as it is created and shows other rules applicable for the given set of conditions. The rules display provides the user with explicit feedback about the internal state of the control system, which supports a more transparent user understanding of system behavior. As rules are being created, SiteView displays them as English-like sentences. SiteView also displays the relevant set of existing rules as the user specifies predicate conditions.

USE SCENARIO

As an illustration, consider the following scenario. On a rainy morning, Dana finds her workspace too dark and too cold and wants to adjust the lighting and room temperature. She consults the SiteView rules display, which, by default, shows the rules active in the current situation. She notes that the active control rule handles weekday mornings in general, but not rainy weekday mornings in particular. Rather than manually changing the temperature and light conditions using the available thermostat and light switches, Dana uses SiteView to add a new rule, so the active environment will behave appropriately now and in the future. First, she places the interactors signifying rain, morning and weekdays in the appropriate slots on the condition composer (left, center and right, respectively, in Figure 1). The rules display (far left of Figure 1) shows all applicable control rules for those conditions, including (the currently active) one for a more general condition, weekday mornings, and the visualization display shows an image of the office similar to the office's current appearance. Next, she places the *light on* interactor on the portion of the WIM signifying her floor lamp. Now that Dana has specified a valid rule – both a condition and an action – the rules display shows it as an English-like sentence: if it is raining and a weekday and morning, then turn on the north lamp. She sets the thermostat interactor to a warmer temperature and places it in the WIM. The rules display now shows the new rule, which handles light and temperature on rainy mornings, along with the original set of rules. The environment display reflects her new rule, and shows her office lit by her floor lamp on rainy mornings. SiteView then turns on the floor lamp and adjusts the temperature.

EVALUATION

An initial user study of SiteView demonstrated that end users could create rules that control their environment. The tangible interface appears to be intuitive and the environmental display and rules display are useful for helping users create rules and view the effects of these rules. Overall, the system was usable for generating a variety of rules, each using one to three rule conditions, and each triggering one or both of the lights and the thermostat settings. The system also made the effects of composing multiple active rules transparent. For example, a rule that turned on the lights in the evenings was understood to be combined with another rule that set the temperature at 55 degrees on overcast weekends to turn on the lights and set the temperature to 55 on a Saturday evening. One confusion that arose during the study was the duration of time-based rule conditions. While the use of natural words for time-of-day appeared transparent, one user was unsure if a rule that specified turning down the heat at 8 PM would still be in effect at 8:15 PM or later.

Our future work includes further user evaluation of SiteView to determine the types of tasks it is appropriate for, providing support for disjunctive relationships, and exploring how the tangible nature of SiteView can be used to constrain user input for novices.

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Towards Ubiquitous End-User Programming

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INTRODUCTION

We believe that end-user programming capabilities are an essential part of any flexible ubiquitous computing system. When these are well designed, and tightly integrated with the system as a whole, they allow users to add functionality that was not, and in many cases, could not have been, anticipated by the system's designers. This enables users to benefit fully from the possibilities ubiquitous computing offers. However, End-User Programming in a ubiquitous computing context faces several novel issues, in particular the communication channels available and the diversity of the user population.

We have taken as the domain for our research the domestic environment. There are already a range of programmable microprocessor controlled devices that are routinely found in the home, ranging from alarm clocks, security systems and boiler controls to VCRs and personal video recorders such as TiVo™. Several of these devices already pose a notorious usability problem for large segments of the population [1]. As home appliances start to interact with each other, the complexities of end user programming and customisation will become far more severe. Home networking systems are already becoming a widespread site of ubiquitous computing, both in research prototypes [2], and (in more limited form) in existing systems such as X10.

Is it possible that home-owners will ever be able to configure and customise interaction between the appliances in their homes? This is a critical question for the acceptance of ubiquitous computing. If the combined functionality of many appliances is no more powerful than that of the individual appliances purchased separately, then ubiquitous computing will not have any significant impact on regular lifestyles.

We have applied recent theoretical approaches in end-user programming [3] to the problem of domestic automation. Unlike end-user programming in the business context, where programming is done by "power-users" with respectable (if incomplete) technical knowledge, programming in the home can be done by people with a very wide range of abilities. The end user programming languages in products such as Excel already present a serious design challenge in supporting both casual users and serious developers [5]. In the domestic environment, we recommend an approach in which a range of programming paradigms are made available via a common programming architecture to support different modes of interaction with the underlying ubiquitous computing architecture. Not only will this support a range of user abilities, but also different programming tasks, as psychology of programming research has demonstrated that no language can be best for all applications - different notations give better support for different programmer activities (for example, creating a new program, modifying an existing program [4]). Hence, the system should allow a single program to be represented in a variety of notations for different users and different tasks.

LINGUA FRANCA - SCRIPTING IN MANY LANGUAGES

In order to create a system in which a user may manipulate a single program via multiple notations, we have designed *Lingua Franca*, a common XML-based intermediate form for scripting languages. Using this intermediate form has several advantages. For example, automated enforcement of policies that limit the action of scripts is of particular importance for end-user programming in domestic ubiquitous computing. Both home owners and authorities are likely to be concerned that end-user programs should not inadvertently or maliciously bypass fire alarms, security systems, or payment mechanisms. In order to achieve these safety provisions, the system must be able to reason about the behaviour of new programs as they are created, in order to assess whether they conflict with existing policies. The common representation allows a common enforcement mechanism across languages.

Lingua Franca goes beyond conventional multiple-language systems in it's support for translations *between* source languages (as opposed to simply translating multiple source languages into the same form of object code). Various source languages in *Lingua Franca* are supported via "language environments" that translate between the source language and *Lingua Franca*. Note that not all environments allow translation in both directions; some language environments only translate from the source notation to *Lingua Franca* (and may only be used to create script), whereas other only translate from *Lingua Franca* to some other notation (and may only be used to display script). The most general class of language environments perform translation in both directions; these may be used to edit a script, by first translating from *Lingua Franca* to a "source" notation, modifying that representation, then finally translating it back to *Lingua Franca*. To allow this bidirectional transformation, language environments must conserve all information in the *Lingua Franca* representation, regardless of whether it is meaningful in the present language or not. (Contrast this to traditional compilers, where information and structure not relevant to the result is usually discarded.)

The two types of information that are most commonly discarded when translating a script from one form to another are *secondary notation*, such as comments, and *higher level structure*, such as loops. Both of these may vary greatly from language to language. *Lingua Franca* allows multiple secondary notation elements to be associated with a part of a script; each such element is tagged with a notation type, to allow language environments to determine which (if any) to display. Higher level structure is represented by grouping; again, each group is tagged with a type (such as "while loop"), which may imply a particular structure, and language environments may use this to determine how to display the group's members. Unlike secondary notation, any environment that can display *Lingua Franca* can display any group, as in the worst case it can simply display it as a grouped collection of primitive operations.

We have implemented a interpreter that stores the "corpus" of scripts that have been entered into the system. Language environments communicate with this interpreter via HTTP, allowing them to read, add to and update the *Lingua Franca* code (represented as XML) that makes up the corpus. In addition, the interpreter is responsible for executing *Lingua Franca* code, and interfacing the *Lingua Franca* environment with the rest of the ubiquitous computing system.

A MENAGERIE OF PROGRAMMING LANGUAGES

A wide variety of scripting languages are being developed in order to demonstrate the flexibility and range of the *Lingua Franca* architecture. These languages are designed to complement each other, in that they may be used to perform different manipulations on the same script with ease. Each language is embodied in a *language environment* that provides an interface via which the user can view and/or manipulate a particular notation, translates between the notation and *Lingua Franca*, and communicates with the *Lingua Franca* interpreter via HTTP.

A *textual language* provides an interface familiar to those with experience of conventional scripting languages. It is envisioned that this will be primarily used for editing substantial scripts, a task most likely to be undertaken by someone with at least some programming background. (It is of course possible to manipulate *Lingua Franca* directly in XML form, but this is needlessly difficult and carries the risk of introducing malformed code into the database, or accidentally removing or modifying data associated with another language environment.)

Two forms of *visual language* are in development, serving slightly different needs. The first is a purely *presentational* diagram that cannot be used to create or edit scripts, but only to display them. This allows it to be specialized in order to facilitate searching, navigation and comprehension of scripts. The second, a *mutable* diagram, allows scripts to be edited, and is likely to be the main environment for the manipulation of mid-sized scripts.

Perhaps the most unusual of the language environments being developed for use with *Lingua Franca* is the *Media Cubes* language. This is a "tactile" programming language, in other words, a language where programs are constructed by manipulating physical objects—in this case, cubes augmented such that they can determine when they are close to one another. The faces of the cube signify a variety of concepts, and the user creates a script by placing appropriate faces together; for example, to construct a simple radio alarm clock, the "Do" face of a cube representing a conditional expression would be placed against a representation of the act of switching on a radio, and the "When" face against a representation of the desired time. In an appropriately instrumented house, the representation can often be an existing, familiar item, or even the object itself. In the above example, a time could be represented using an instrumented clock face, and turning the radio on could be represented by the radio or its on switch.

The *Media Cubes* language is intended to be easy for those unfamiliar to programming, and as such would provide a low-impact path from direct manipulation to programming. However, the language as it stands is unusual in one very significant respect—scripts do not have any external representation. This means that it is only feasible to construct small scripts, and that, once created, scripts may not be viewed, and hence may not be modified. However, as the language exists within the *Lingua Franca* framework, we do not need to abandon the language, with its substantial advantages. *Lingua Franca* makes it feasible to include niche languages such as the Media Cubes in a system without sacrificing functionality.

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TunA: A Mobile Music Experience to Foster Local Interactions

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ABSTRACT
Can the Walkman become a social experience? Can anyone become a mobile radio station? With the TunA project we are investigating a way to use music in order to connect people at a local scale, through the use of handheld devices and the creation of dynamic and ad hoc wireless networks. TunA gives the opportunity to listen to what other people around are listening to, synchronized to enable the feeling of a shared experience. Finally, TunA allows users to share their songs in many situations, while moving around, fostering a sense of awareness of the surrounding physical environment.

Keywords
802.11, music, synchronisation, local networks, shared experience, ad hoc networks

INTRODUCTION
R. D. Putnam claimed a few years ago: "Social networks based on computer-mediated communication can be organised by shared interests rather than by shared space"[1]. As the market of PDAs spreads and new wireless technologies are being improved, we research instead a way to create and support social networks of people who share the same physical space. In the application we are currently developing music constitutes the main interest around which communities, virtual and real, can be formed.

We wish, in general, to contribute to the understanding of how wireless networks, so far mainly considered for their "globalising" potential, could also make people more aware of their local reality. By connecting PDAs in an ad hoc way with 802.11b, we focus on the creation of dynamic local networks in which users are able to share information and resources with others who are in range.

In order to find a subtle and non-intrusive way to connect people who are nearby through mobile devices, we decided to explore the concept of a "shared music experience." Music is commonly used as a form of mobile entertainment, through personal devices such as Walkman or digital players. While so far listening to music when moving around has been mostly an individual and quite isolating process, we are here suggesting making it a fun and socialising experience.

MOTIVATION
The TunA project is about being able to access the playlists of other users who are near, and to listen synchronously to what someone else is listening to. This application has been developed following a recent social study that we conducted for a project called WAND (Wireless Ad hoc Network for Dublin)[2]. WAND is an infrastructure, based on 802.11b and in the process of being installed in the city centre of Dublin. It is designed to support and run applications that exploit an ad hoc, decentralised, and peer-to-peer type of communication. An ethnographic study was organised in order to understand the socio-cultural dynamics of the area covered by the network, to involve users in the project development, and to inform and inspire content and service providers for the design of new applications. In this framework, we see TunA as targeted to some of the communities identified during this study, in particular students, skaters, and commuters. The goal of the project is not only to create new social links but also to strengthen existing ones; established communities like the skaters could in fact use TunA to reinforce their identity, and to express themselves in new creative ways.

Fig. 1: Example scenario of TunA usage—people on a bus

TECHNOLOGY
Tuna is ideally meant to work on any handheld device that supports 802.11 technologies. We are now working on a prototype for iPaqs, running the GPE 0.7 version of Linux Familiar, connected in ad hoc mode through 802.11b. TunA can be used as a standard mp3 player for personal music; at the same time it visualises, in one single screen, all the other TunA users who are in range, and gives options to access their playlists, their profiles, and the songs they are listening to. The user has an option to "tune

in" and start listening to what another person is listening to. An important aspect of this work is the synchronisation of the listening experience. The "tune in" option gives in fact only access to the song another user is currently listening to, and this is what we refer to as a "shared music experience". Finally, in order to keep track of the songs and the users encountered TunA gives the possibility to have a record of "favourites".

Fig 2: TunA interface in development

SCENARIOS

TunA can accommodate a number of occasions in which people gather during the course of the day. While conducting the ethnographic study for WAND, previously mentioned, we ran across some recurring situations happening in the city centre of Dublin, where TunA could play an active role in connecting people who are nearby.

- *Queuing for the Bank*. On Thursdays most of the employees receive their salary. A wide number of people gather in the main branch of AIB (Allied Irish Banks) to collect the money to spend over the weekend. To make the action of queuing more interesting and engaging, music enthusiasts could use TunA to feed their curiosity about what other people in the queue are listening to.
- *Commuters*. The 123 bus is one of the main links between opposite sides of the city. Many commuters spend part of their daily routine on this bus, sometimes getting curious about each other's presence. TunA could provide a platform for light-weight interactions, in which people can discover who else commutes during the same hours, find out if they have music tastes in common, and finally listen to what others are listening to.
- *Skaters of the Central Bank Square*. A well-established community of teenagers gathers everyday in front of one of the main buildings of the city centre. They have in common their passion for skating along with a specific set of rules and behaviours. TunA could help this community to reinforce their identity through music. Instead of bringing their stereo and listening to their songs loudly, which would cause problems for the surrounding environment, they could use TunA to have a shared music experience, while still keeping their privacy and an individual listening process. At the same time they could provide a source of music, a sort of "skaters' radio station", for other people around.

RELATED WORK

The recent success of the new version of Apple iTunes, which uses the Rendezvous technology to share music playlists over the same local network, has proven the potential of wireless peer-to-peer applications that count on the physical proximity of the users. iTunes is mostly suitable for office spaces or in general "static" settings, while TunA focuses on a mobile fruition of music, and on the social dynamics fostered by an ad hoc shared music experience. It is moreover based on handheld devices instead of desktop computers, and this makes it a very flexible application.

Along the same lines as TunA, the SoundPryer project [3] is about a peer-to-peer wireless exchange of music files through devices, especially designed for car travellers. TunA, targeted mainly to people moving around in an urban environment, translates the profiling process that SoundPryer uses to identify vehicles into a more personal one. With TunA the identity of each source of music is linked to the information users want to give about themselves. Moreover, the shared experience TunA wishes to provide is connected to the concept of synchronisation, which is for us at this stage one of the main technical issues to face.

FUTURE WORK

In order to make TunA progressively more flexible and engaging, we plan to implement, in future versions, ad hoc networking protocols, to allow search options. We also see TunA as ideally integrated with an Instant Messaging application; messages exchanged among users could in fact become the result of the shared music experience.

ACKNOWLEDGMENTS

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AudioBored: a Publicly Accessible Networked Answering Machine

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ABSTRACT
AudioBored is a publicly accessible networked answering machine with two components: an online audio message board and a physical device used to access voice messages and topics of discussion. The project focuses on adding networking capabilities to the familiar household interface of the answering machine, a widespread device that maintains social ties in an asynchronous manner. The project also incorporates an online voice messaging website that allows for people to post messages with their telephones and listen to the posts online. Usage scenarios for AudioBored include voice-based online forums, situated voice posting from live events, and accumulated public voice message histories.

Keywords
Audio messaging, bulletin board, answering machine, telephone interface, online discussion list, community messaging

INTRODUCTION
AudioBored is a framework for a shared public audio messaging system where anyone can record a message and share it with the world. AudioBored augments the traditional telephone answering machine by adding a networked component to its everyday use and situating it in public space. Since answering machines are devices that have reached ubiquitous penetration in many areas of the world, they are already familiar interfaces to people of varying computer literacy. The project aims to extend the possibilities of public communicative spaces away from pictorial and written interaction and opens them to the potentially richer and more human-centered medium of voice-based messaging. The system allows for dynamic threading of incoming messages by sender and can store messages over time to build a personal or public archive of ongoing communications within an organization, individual relationship, or community. AudioBored adds a voice component to the previously text-only platform of online message boards by integrating network access and flexible architecture into an easily navigable physical device. AudioBored extends on existing voice-based online messaging applications by focusing on being a publicly accessible, always-connected physical answering machine that allows for numerous message threads and archiving of shared conversations collected over time.

RELATED WORK
AudioBored's focus on augmented networked appliances and shared audio messaging systems invokes references to considerable past research. In appliances, projects range from the 3COM's *Kerbango* [1] radio that brought Internet radio streams to a standalone radio, to Tobi Schneidler's *RemoteHome* [2] which features a collection of networked household appliances and furniture. *VoiceMonkey* [3] and *AudioBlog* [4] demonstrate uses of live phone-based posting to the internet where people can add messages to their personal websites. Finally, Lakshmipathy's *TalkBack* [5], describes adding a networked component in the form of a screen that displays pictures of the caller along with their message.

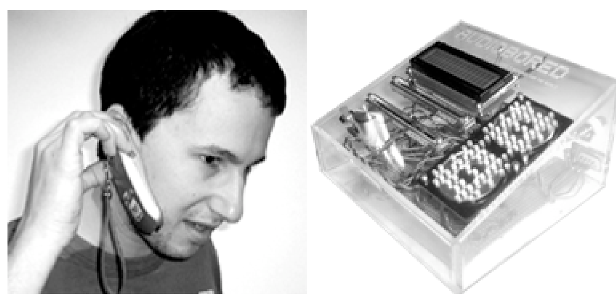

Figure 1. Caller leaving message on AudioBored answering machine

TECHNOLOGY
The AudioBored prototype incorporates a server-side voice-based technology to allow people to call in and record messages and a hardware component for the answering machine. Over the phone, a VoiceXML script prompts users to record a candid message. [Fig.1] Once recorded through a PHP script, their message is saved according to topic and caller in a threaded database and posted online. The answering machine communicates serially with a PC via a microcontroller to access the database for recent messages and updates the device when a new message is available. Users can see a display of topics and total messages on an embedded LCD display. [Fig.2] There are two sliders – one to navigate "topics" of messages and one for selecting individual messages within threads. The slider ranges expand dynamically according to the number of incoming messages available online.

Figure 2. Close up of LCD display and slider

SCENARIOS

Below are a few specific examples of possible applications of the system.

1. **Voice-based Online Forums**: AudioBored allows for people to contribute to a shared online public space without a computer. Since standard telephones (including mobile and fixed lines) are ubiquitous and exist in far greater numbers than computers, they provide an alternative entry point to the Internet. Using VXML as the voice input system, the project opens up the landscape for public contribution to distributed online audio forums where a greater number of people can potentially contribute to the discussion. Since most online bulletin boards exist in text format, identity and authenticity of users can be concealed. Voice message posting can still maintain anonymity, but it potentially adds a more personal touch to messaging applications. For instance, users who communicated on a text-based web board could use AudioBored as a means of "hearing" each other's voices for the first time, which may ultimately bring their community closer together by adding a more human element to their previous interactions.
2. **Situated Voice Posting**: AudioBored provides a shared public outlet for people to post candid voice messages on the Internet from any phone. This becomes especially interesting in the midst of events where Internet access is not easily available. For example, people in the midst of a crowded protest march could voice their opinions from the center of the action. These candid comments might better reflect the electric atmosphere and excitement of such a live event, adding a sense of immediacy to the collected messages. Each voice message is immediately recorded, stored in a database and made public for people to listen to on the device or online. Since all messages are sorted by topic, this would allow for an ongoing protest to take place through contributors experiencing the event online.
3. **Public Voice Histories**: With most physical answering machines and voice-mail systems, there is a limited amount of message storage and lack of a way to sort incoming messages into separate storage mailboxes. AudioBored addresses this by storing all threaded messages on a server that can be instantly accessed through the physical interface. The device gains importance in public spaces where PC access to messages might be awkward or prohibitive, and it exists as a shared community resource. Over time, personal voice histories of messages left by community members can accumulate while the hardware architecture can scale to adjust for the new messages. This database of public voice messages could possibly provide an invaluable historical resource for future generations.

FUTURE RESEARCH

Future versions of AudioBored will allow for more customized message information that will be catalogued along with individual clips and made into a directory searchable by contributor and subject matter. We plan additional work on interactive visualizations of information collected by the system, such as the geographic origin of messages. The device could also gain Internet access through public wireless hotspots, allowing for it to be placed in a wider variety of public spaces in order to maximize its user base. A detailed study is also planned on uses of the system along with an analysis of message content to gain inspiration for potential deployment locations and future refinements.

ACKNOWLEDGMENTS

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Dimensions of Identity in Open Educational Settings

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ABSTRACT
Based on our deployments of Livenotes, a Tablet-based application for collaborative note-taking in open educational settings, we observe that communication breakdowns, potentially affecting learning, arise from imperfect knowledge about other users' identities. This leads us to argue that user identity is an under-explored topic in ubicomp. We show that the concept of identity needs to be expanded to include digital, social, and physical features. We conclude with preliminary design implications.

Keywords
identity, education, tablet computing, proximity, familiarity

INTRODUCTION
We study how people learn via distributed dialogue. Livenotes (LN) [1] is an application for collaborative note-taking and drawing in classrooms. Using LN, groups of 3-7 students are wirelessly connected to one another via their handheld tablets, such that students may exchange notes synchronously on a multi-user, multi-page whiteboard with peers from the same group. LN users are currently identified by being assigned unique ink colors and through logging in, with login names defaulting to machine names.

The most prevalent method for users to identify themselves to a computer is through logins, an explicit form of input. Nonetheless, traditional logins center heavily on the desktop model, assuming a single user who is bound to a given computer terminal for a substantial period of time. In contrast, Livenotes uses the "common pool" model, in which Tablet PCs do not have fixed users and can be easily swapped between users in a session. Pea and Rochelle [2] argued for device mobility in the education context. In this model, however, users can lose track of who is engaged in communication at a specific moment.

Ubicomp therefore becomes important as a way to address this problem. Abowd et al. [3] highlight the relevance of context, such as identity, to ubicomp, where applications accurately keep track of their users through implicit sensing, instead of relying on logins. We argue, however, that ubicomp needs not only to focus on digital identity, but also on social and physical identities where educational and collaborative work settings are concerned.

OBSERVATIONS
We made observations while analyzing five multi-session deployments of LN in educational settings (at UC Berkeley and the University of Washington). The deployments were not in controlled settings [1], but in open contexts including a graduate seminar (STS), reading group (TSD), design studio (DMG1, DMG2) (Figure 1), and undergraduate lecture (CS). The data includes transcripts of the written conversations (~500 pages) and, in some cases (~12 hours), video and audio recordings.

Figure 1. Livenotes deployed in an architectural studio review session DMG1. Graduate students and faculty swapped, picked up, and set aside tablets at will.

In the deployments, we discovered a number of disruptions to small group dialogue, and we then explored the mechanisms that people develop to resolve these problems. In each deployment, groups were confused over who was making what inputs on the whiteboard at different points because users would drop out of the dialogue, swap Tablets, or come and go from the classroom. Group dialogue improved over time with greater familiarity with technology and user identity, provided that groups remained stable and did not swap Tablets freely. Still, break-downs occurred from time to time because of user identity issues. In a computer science lecture in April 2003, for example, group dialogue stopped when the group realized that a member had just entered the room, and wondered "who is red?"

They asked “red” to identify himself, resuming dialogue when he did so.

To avoid such communication break-downs, users can “challenge” one another and identify themselves throughout a session, particularly at the outset. Once, users even performed a “roll call” where people took the initiative to report who they are (e.g. red, “roll call”, red, “mark”, green “john”, blue, “jeremy”, green “hi”, as seen in a computer science lecture). Identities are established through a social process that everyone can witness and participate in. The group becomes more aware of each other.

Finally, we observed that group members developed a sense of user identity through non-explicit but physical means, such as associating Tablet use with screen activity, or gesturing to and looking at each other.

ANALYSIS

To explain how user identity is one important factor shaping collaborative group dialogue and how users resolve identity problems in the absence of cues provided by LN user interfaces, logins, or social processes like roll-calls, we developed a framework that extracts four dimensions of each educational setting that LN is deployed in. These dimensions are: physical stability (did people come and go, or change groups), temporal stability (did people stay with the tablet conversation), proximity (were people sitting near each other), and social familiarity (did users know each other previously). Each dimension affects how much group members are aware of each other. The higher the level of all dimensions, the more likely it is that groups will effectively resolve identity issues and generate sustained dialogue.

We did an initial analysis, to measure all five deployments in terms of the framework and created a relative scale to compare them along each dimension: see Table 1. This scale runs from low to high, based on our joint judgments of how much of each dimension each group appeared to have.

	Physical Stability	Temporal Stability	Proximity	Familiarity
STS	■	●	●	●
TSD	●	●	■	●
DMG1	○	○	●	●
DMG2	■	■	■	■
CS	■	●	○	●

legend: ■ high ● med o low

Table 1. Dimensions of each educational setting for the five deployments.

Deployments varied greatly in their dimensions and therefore the level of their distributed dialogue, measured by learning metrics such as: amount of dialogue, extent of participation by everyone, or the depth of ideas generated. Two architecture studio groups differed markedly in their dialogue rate and content because one group (DMG2) sat together and could see who the users were, while the other group (DMG1) was more dispersed and swapped Tablets frequently. DMG2 had high scores on all dimensions. However, when people overcome the lack of identity knowledge through social, participative processes like a roll-call, they appear to engage in greater dialogue. Other variables such as personality and the classroom setting (lecture or studio) also affect the level of dialogue.

Developing this framework leads us to conclude that the concept of identity needs further development in ubicomp. In ubicomp literature, key distinctions between digital, social, and physical identities are usually not made.

DESIGN IMPLICATIONS

Potential design solutions for identity issues exist to aid ubicomp applications in open educational settings. These solutions can use our framework to determine how identity is being continuously influenced in conditions where people swap Tablets, drop out and re-enter dialogue, come and go from classrooms, or are mobile.

One solution has been proposed by Maniates [4]: the introduction of a “person” layer to the network protocol stack used in wireless, mobile systems, or routing messages by recipient instead of machine names. Another solution is to change the user interface to enable a roll-call feature to help people identify each other through social, participative means. Another is that user activity can be incorporated into the group awareness display, thus augmenting user login and ink color information. Data from other sources of input (Active Badges, computer video cameras, and microphones) can also be cross-referenced to help determine identity. Hence, there are computational ways of enhancing stability and familiarity, overcoming the challenges that open classroom settings and workplaces pose to discourse. All these solutions are co-existing and target social, physical, and digital identities jointly. We plan to investigate how the solutions can be integrated in future iterations of LN interface design and deployments.

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Digital Message Sharing System in Public Places

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ABSTRACT

In this paper, we propose cPost-it, which allows users to share digital messages in public places by exploiting context such as the user's identity, location, and time. The cPost-it, consisting of the Client, Object, and Server, provides location based service (LBS) by retrieving embedded information from the real-world objects. Also, it provides the personalized information in the indoor environment according to the user's identity, location, time, etc. According to the subjective evaluations, the proposed cPost-it framework may play important roles in sharing information for the ubiquitous computing environment.

Keywords

Context-aware, Ubiquitous Computing, Personalized Service, Location based Service

INTRODUCTION

In general, it is inconvenient for users to share information in public places through the current information sharing system such as a whiteboard and post-it. For example, paper-based handwritten documents can be removed accidentally or be messily attached to an object. These problems have been relieved in part by NaviCam[1], CyberGuide[2], Guide[3], Cooltown[4], GeoNotes[5], comMotion[6], Stick-e Note[7], etc. by introducing digital messages (such as text, voice, picture, video, etc.) with a Personal Digital Assistant (PDA) according to the user's location. However, these systems mainly exploit location information to provide users with proper information, rather than considering various types of contexts.

In this paper, we propose cPost-it, which allows users to access digital messages with a PDA, i.e. augment or retrieve information of a real-world entity such as a place or object by exploiting the contexts such as user's identity, location, and time. The main features of the proposed cPost-it are as follows: At first, it provides a natural way to access augmented information related to a physical object through a short range wireless network such as IrDA. In addition, it allows users to retrieve personalized digital messages when the users approach the object of interest, e.g. office, classroom, shopping mall, etc. It also helps users to access classified information by providing messages in a good order based on the context such as the users' profile.

CONTEXT-BASED INFORMATION SHARING SYSTEM

The cPost-it, as shown in Figure 1, consists of Object, Client, and Server. The cPost-it Object links the information to the real-world entity by providing the cPost-it Client with URL of the cPost-it Server through IrDA. Then, the cPost-it Client provides the user's context to the Server and gets the augmented information on the object through the PDA. The cPost-it Server manages the request from the Client and provides corresponding information according to the user's context.

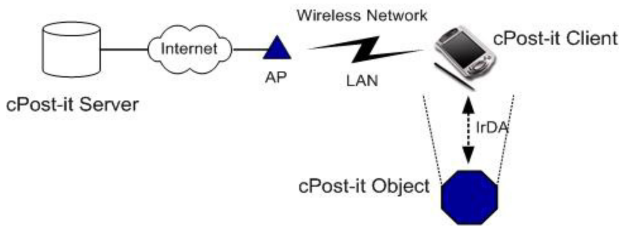

Figure 1: The concept of cPost-it

As shown in Figure 2, if the user with a cPost-it Client exists in the working area of a cPost-it Object, the Client receives URL of the cPost-it Server. When the Client connects to the Server, it transmits the user's identity, and current time as a user's context. Then, the Server generates the personalized digital message and transmits them to the Client immediately. The resulting information is in a good order according to the provided context. For handling the context, the cPost-it is implemented using the unified context-aware application model, what is called ubi-UCAM[8], which consists of ubiSensor and ubiService.

cPost-it Client

The cPost-it Client consists of the ubiSensor of ubi-UCAM [8] and (Web-based) user interface. The ubiSensor in the PDA receives the URL of a Server from an Object and then makes a connection between the Client and Server. After

This work was supported by University Research Program of MIC in Korea.

establishing the connection, it delivers the context to the Server. The interface transfers the user's identity to ubiSensor. The identity specifies the right of access to the shared information classified by the name of a user or group. Note that unspecified persons in public places belong to an "All" group. The resulting messages are provided in the form of Web.

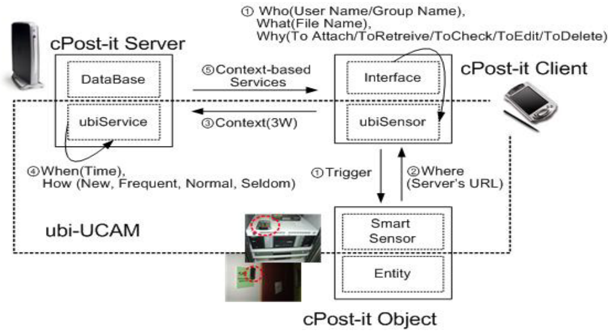

Figure 2: The Architecture of cPost-it

cPost-it Object

The cPost-it Object consists of a real-world entity and Smart Sensor. Anything can be used as the entity of the cPost-it Object which will be augmented with digital information. For example, the object can be a public place or an individual appliance such as door, TV, furniture, etc. The Smart Sensor, ubiSensor [8], is a device that includes a short range wireless networking module and a simple processing module to provide URL. It is bound with the entity. When a user triggers the signal of the IrDA within the working area of cPost-it Object, the Smart Sensor senses the signal and sends URL of the cPost-it Server to the Client.

cPost-it Server

The cPost-it Server consists of the database (DB) and Web-based ubiService [8]. The cPost-it Server manages the DB, the saved information of a cPost-it Object which is virtually connected to the cPost-it Server. To help ubiService generate context-based queries, it manages every digital message with additional information such as a file name, a right of accessing file, and the frequency of usage of each message in a day. The ubiService provides Web-based services such as adding, editing, removing the shared information according to the user's contexts from the cPost-it Client and the information of the DB.

PERSONALIZED INFORMATION SHARING

We used Compaq iPAQ H3130 and H3600 to implement the Smart Sensor of the cPost-it Object and the Client, respectively. The Server is implemented with MS-SQL2000 and the ubiService which is based on the Web server. As shown in Figure 3, when a user carrying cPost-it Client approaches the door (the cPost-it Object), the augmented information (personal notes, video manuals of appliances, public place notices, etc.) are retrieved on the PDA according to the user's identity. Also, cPost-it provides a user with personalized information services such as classified messages by exploiting the user profile about the message of interest entities.

The cPost-it guarantees to keep the individual notes and to share personalized messages among just group members. Because all messages are categorized into three parts; 'Personal', 'Group', and 'All', it provides users in public places with proper messages according to the access right which the user will specify. As long as the user's access right is preserved, the private messages can be safely shared in public places. In addition, all services of cPost-it are protected by the security mechanism of a Web server.

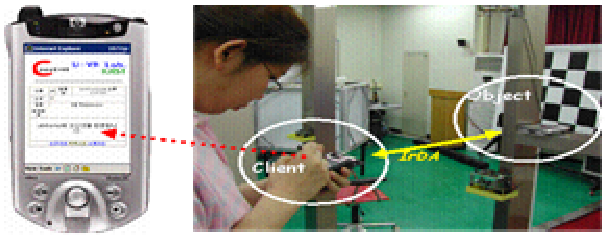

Figure 3: Implemented cPost-it System

FUTURE WORK

To prove the usefulness of the proposed context-based information sharing system, we have experimented implemented cPost-it in ubiHome [9], a test-bed for ubiComp-enable home environment in KJIST U-VR Lab. Now, we are improving the system based on the evaluation such as users' satisfaction about context-based services and system faults. After the usability tests, we will release the results of the improved context-based information sharing system.

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The Spookies: A Computational Free Play Toy

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ABSTRACT
We present Spookies, a computer embedded toy to support natural Free Play activities. Free Play is defined as creative, active and spontaneous everyday play activities where several children play together. Since this kind of play behaviour finds little support in the interactive toys of today, Spookies have been designed addressing this issue. Spookies presents children with a flexible yet simple tool to use as they see fit in everyday play situations. The fourteen specialised units of sensors and output devices can be turned into complex functions by pattern of physical assembly, providing simple end-user programming for creative use.

Keywords
Free Play, Interactive Toys, Embedded Computing, Tangible Interfaces, Physical Programming.

INTRODUCTION

Playing is a central activity in children's lives. It is essential to their well being but also to their cognitive, social and physical development [1, 2]. Playing allows children to learn about the world and experience life. In exploring their environment children enjoy engaging in various kinds of play activities; activities involving toys or defined games but also activities just involving playing with each other. Using their imagination they can create exciting play settings and experiences out of their everyday environment. A broom might become a horse, an old log might become a pirate ship and a lit-down kitchen might become a dungeon. This kind of pretending along with spontaneity, physical activity and social interaction states important elements to the definition of Free Play [3].

Supporting this kind of play with computer technology has previously been proven very difficult. The interactive toys available today are mostly designed to assume the role of a regular friend or a pet in children's lives. By accommodating this role the toys usually put themselves in the centre of attention, supporting a one-way interaction between the toy and its user, replacing the child's need of social interaction. Most interaction is further limited to a predestined purpose as a few built-in games and songs not supporting the child to use it as a part of other natural play situations. To sum up, few or none of today's interactive toys support Free Play any better than regular toys, generally far worse.

Figure 1: The Spookies

SPOOKIES

Meeting the call for an essentially new kind of interactive toy that supports Free Play activities, Spookies have been developed. Spookies are interactive, unlike most other Free Play toys, augmented by embedded computer technology. When trying to support Free Play behaviour with a toy it is important not to limit or restrict the play by adding a predestined structure of use. Thus, the toy must be flexible to support creative usage.

Hence, Spookies have been designed as a collection of specialised yet flexible units of input sensors and output devices, providing children with a strong tool for creative play. A total of fourteen different units divided into seven couples have been developed to this date: Audio; Tracker; Code; Light; Motion; Picture and Time, all designed with unique abilities (example in Figure 1). The communicational model of all Spookie units is set to predefined couples. These couples communicate with each other through a wireless network transmitting the specified sensory input of the particular units with a current range of 250 meters outdoors. This input is then displayed with a proper output medium on the receiving unit. Most Spookie couples could be understood by this simple transmitter-receiver model. The network protocol however also allows multiple receivers being connected to multiple or single transmitters enabling a distributed network structure. This enhancement is easily controlled by physical end-user programming, using a similar technique as described in [4], letting objects be grouped together by shaking them. The shaking generates a similar pattern perceived by accelerometer sensors and is then compared to other nodes in the network. Enriching the creative use of Spookies all units can also be physically connected to each other combining their abilities in order to create more complex functions. All units are connectable to each other in a consistent model of physical assembly without any limitations to how many Spookies can be included in one combination. Spookies are combined by magnet connectors hidden under the texture surface on the top, bottom, left and right side of the units. When connected, the state of a unit is important. Active units (defined by input sensor threshold or signal sent from the transmitter unit) can force or permit the activation of other physically connected units depending on the pattern of assembly. This physical distributed network is controlled by IR-diodes enabling sending and receiving information through the texture.

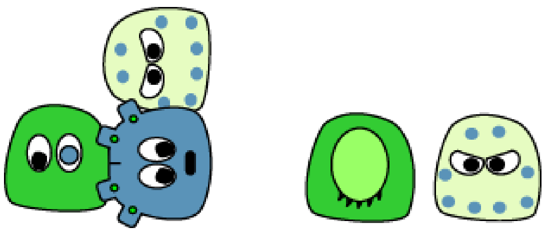

Figure 2: The Treasure Hunt.

SCENARIO

Figure 2 describes a play situation where the children playing are searching for a hidden treasure. The treasure has previously been hid by another child or a grownup and is defined by three Spookies: Photo Spookie; Timer Spookie and Tracker Spookie connected in certain combination. The children trying to find the treasure are equipped with an Image Spookie and a Tracker Spookie. To initiate the play the children searching opens the Image Spookie to receive a picture. A picture is then sent from the Photo Spookie to the Image Spookie giving a clue to what the environment surrounding the treasure looks like. Opening the Image Spookie also activates the Photo Spookie, in its turn forcing the Timer Spookie connected to it to activate. The timer then starts to countdown a preset period of time and will during this time keep the Tracker Spookie connected next to it active. During this period of time the children searching also are able to use the Tracker to see how their distance to the treasure changes. This is a good support, as the Tracker will notice if they are going in the wrong direction giving them a good initial hint of where to search for the treasure.

DEVELOPMENT & EVALUATION

Prototyping and User Participation have constituted a central part of the design process. The prototypes developed have provided a useful aid to communicate and evaluate ideas as well as in actively involving children in the design process. By letting a user group of five children aged four to nine play with a fully functional set of six Spookies (Figure 3) a lot of answers and support could be returned to the development process. The children used Spookies as a communicational platform supporting their already ongoing play of Hide-and-Seek, enriching it with the ability of secretly perceiving and communicating information about the seeker among the hiders. Used separately, Spookies proved a good tool for supporting active play events like: sneaking; hiding; seeking and running, stimulating spontaneous and physically active play. By combining different Spookies as bricks or building blocks the children could create new patters of functionality supporting their creativity but also stimulating their understanding of logics. Most interestingly, the children were able to easily come up with new areas or ways of usage not previously though of. This supports our idea of Spookies as a tool for inventive Free Play behaviour.

Figure 3: User Group

CONCLUSION

We believe that Spookies meets the expectations set in this project, utilizing a broad aspect of Free Play and contributes a resourceful computer-embedded support to natural play situations, old and new. This by not being designed in a manner that limit or restrict the play to some predestined structure or context of use but by providing a few main abilities given by the general concept and the individual units defining a flexible support to creative usage. Clearly important to the aspects of Free Play is the use of Spookies as a communicational platform when playing together in a group. Another strength lies in the users possibility of creating more complex functions by physically assembling several units into a pattern, easily reprogrammed by the end-user.

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k:info: An Architecture for Smart Billboards for Informal Public Spaces

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ABSTRACT

High-traffic public spaces in the workplace are rich breeding grounds for informal collaborations among knowledge workers; yet, very little technology currently inhabits these spaces today. *k:info* is a context-aware information billboard that aims to inspire informal interactions in these spaces by providing a dynamic display of items that are relevant and easily visible to users nearby.

1. INTRODUCTION

Public gathering spaces such as lounges, elevator lobbies, and hallways are places where informal social encounters occur most frequently in the workplace[4]. In addition to serving as the crossroads for day-to-day activities, these spaces harbor a relaxed social atmosphere, where people feel naturally inclined to gather and talk casually about anything that may be on their minds. As a result, these spaces encourage social connections to be made, shared interests to be discovered, and, perhaps most importantly, informal collaborations to form among people who may otherwise never have realized the opportunity to work together. Despite the importance of such social encounters and informal collaborations in knowledge-driven organizations [1], these spaces still largely lack any information infrastructure. This inspired the Ki/o project [5] to design such an information infrastructure, which consists of an *intelligent kiosk* platform and software architecture to be integrated into these spaces.

One of the first applications being developed for the Ki/o platform is a "smart" information bulletin/billboard called k:info that opportunistically uses available contextual clues from the environment to schedule items for display. Like the advertising billboards and dynamic newspaper information displays in Stephen Spielberg's science fiction thriller *Minority Report*, this information billboard dynamically adapts its display for its audience and based on contextual changes in the environment. But unlike the *Minority Report* advertising billboards which aim to persuade, the aim of k:info billboards is to spark informal social conversations among passers-by, by displaying information that coincides with their common interests.

2. DESIGN CHALLENGES

2.1 Content selection

Realizing content personalization on billboards and other wide-audience public information displays is challenging for a number of reasons. Most contemporary personalization systems exclusively rely on statistical collaborative filtering algorithms to choose what to display. These algorithms work by logically clustering people based upon how similarly people like or dislike items they have previously seen. Statistical collaborative filtering systems usually require users to state this information explicitly, such as by having users assign scores or specify rankings to each item. Obtaining scores in such a manner, however, is impractical for high-traffic public displays, due to the reason that the interaction duration between the user and such a display is typically extremely short. Furthermore, statistical collaborative filtering algorithms suffer from the "cold-start", or "ramp-up" problem, meaning that they require a large amount of initial data about each user before they can make recommendations. The problem is compounded by the potentially unbounded size of the user-base of such public displays, as well as the large probability that any given user may not have ever used the system before. Finally, making a collaborative filtering engine situationally or environmentally *context-aware* (as defined by [6]), requires an exponential amount of data to train the system, because new users must be classified along each of the contextual dimensions.

These observations have led us to a new approach that combines a conventional collaborative filtering engine with a symbolic knowledge-based recommendation architecture. This architecture explicitly represents various states of the world, such as user profiles, and maintains heuristics that can make context-sensitive recommendations based on this knowledge.

2.2 Information Composition and Display

Content presentation, or the way information is conveyed to users, may be made context-aware as well. Information pertaining to the capabilities and characteristics of the physical kiosk display, as well as user presence information, such as how closely users are standing to the display, or how many users are nearby, can be used to optimize an article for readability. If the display is small relative to the distance users are standing from the display, for example, k:info should choose a display technique that is well-suited and readable for users at their standing distance, such as a rapid-serial visual presentation (i.e., slide-show) method, instead of a bulletin-board, collage-style layout.[2] Similarly, if the system has identified a user with a disability in the vicinity, such as a user with a visual impairment, alternate channels such as text-to-speech may be activated.

3. APPROACH

3.1 Knowledge-Based Selection

The k:info system performs two functions: *collection* followed by *selection*. Specifically, k:info must collect updated display candidates (e.g., news articles and event announcements) and choose from among them what to display at any particular moment. To make this judgment, the system also needs to collect the contextual information it requires for determining the relevance of each item to the current context. This includes information directly perceived from the physical and digital "surroundings", such as the time of day, weather outside, or user presence and identity information, as well as more static information that can be explicitly updated by the system's maintainer, such as display device characteristics and configuration. Thus, k:info requires perceptual capability, as well as a facility that allows knowledge to be inspected and updated quickly and easily.

3.2 k:info Blackboard Architecture

Knowledge-based selection requires the ability to consolidate a large assortment of heterogeneous types of information. Blackboard architectures, as popularized by the *Hearsay II* first speech recognition system are well-suited for this task[3]. Blackboards consist of independent modules, called *Knowledge Sources* (KSes) that either embody a type of expertise or represent an external data source, and which communicate new information across the blackboard, a persistent knowledge repository. A simple Java blackboard architecture called the *Context Keeper* was designed for k:info.[5]

3.3 k:info Knowledge Sources

Knowledge sources in k:info are divided into three functional categories:

1. *Perceptual* Knowledge Sources. The first, perceptual KS agents, add the lowest-level information to the blackboard. This includes data gathered from hosts on the Internet, such as news feeds (currently CNN and BBC), announcement lists (currently MIT and CSAIL Events Calendars), e-mail messages, and the current date and weather. Other perceptual KSes provide presence and identity information of users in front of the display, through the use of local sensors such as cameras and motion sensors.

2. *Domain-specific expert* Knowledge Sources. The second category of knowledge sources contains domain-specific experts, which contribute external wisdom into the current situation by triggering on knowledge produced by lower-level perceptual KSes as well as by other domain-expert peers. An example of a simple domain-specific expert KS would be an agent which knows all national holidays, and posts these holidays when appropriate days arrive. These agents, in effect, classify concrete states of the world into familiar situational characterizations that are recognizable by the *recommender agents*.

3. *Recommenders*. Recommender agents form the highest-level agents in the k:info blackboard architecture. These agents associate world state with candidate items to display. Once an appropriate combination has been identified, a recommender posts a *recommendation* for either a single specific item, or a broader class of candidate displayable information items. These recommendations include a numeric value, indicating the strength of the recommendation, a reference to the item(s) being recommended, and the name of the recommender agent who made the recommendation. *Case-based* or *collaborative* recommenders use statistical collaborative filtering or classification techniques to make recommendations based upon "learned" past interactions, once sufficient data has been acquired.

3.4 Scheduling Display Items

Scheduling items for display, then, involves collecting the posted recommendations and producing a display schedule. The current simple scheduler bases its schedule on the total recommendation level (calculated as a sum over the recommendations for each item) as the probability that a particular item will be displayed next. Items with negative recommendation totals are omitted from the schedule.

4. FUTURE WORK

4.1 Performance and User Evaluation

The most important work that has yet to be completed is an evaluation of the system. From a developer perspective, the blackboard architecture has provided a useful structure that has simplified system development and improved modularity. A user study is planned, which will survey users as to whether they found displayed items to be of interest, and whether they felt the display provided a useful or detrimental distraction in public spaces.

5. ACKNOWLEDGMENTS

This work is being done with the Agent-based Intelligent Reactive Environments (AIRE) group at the MIT CSAIL Laboratory, under the supervision of Dr. Howard Shrobe and Dr. Kimberle Koile. It is being funded by MIT Project Oxygen.

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An Intelligent Broker for Context-Aware Systems*

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ABSTRACT

We describe Context Broker Architecture (CoBrA) – a new architecture for supporting context-aware systems in smart spaces. Our architecture explores the use of Semantic Web languages for defining and publishing a context ontology, for sharing information about a context and for reasoning over such information. Central to our architecture is a broker agent that maintains a shared model of the context for all computing entities in the space and enforces the privacy policies defined by the users and devices. We also describe the use of CoBrA in prototyping an intelligent meeting room.

Keywords

Context-aware systems, smart spaces, semantic web, agent architecture

1. INTRODUCTION

Context-aware systems are computing systems that provide relevant services and information to users based their situational conditions [3]. Among the critical research issues in developing context-aware systems are context modeling, context reasoning, knowledge sharing, and user privacy protection. To address these issues, we are developing an agent-oriented architecture called Context Broker Architecture that aims to help devices, services and agents to become context aware in smart spaces such as an intelligent meeting room, a smart vehicle, and a smart house.

By context we mean a collection of information that characterizes the situation of a person or a computing entity [3]. In addition to the location information [6], an understanding of context should also include information that describes system capabilities, services offered and sought, the activities and tasks in which people and computing entities are engaged, and their situational roles, beliefs, desires, and intentions.

Research results show that building pervasive context-aware systems is difficult and costly without adequate support from a computing infrastructure [1]. We believe that to create such infrastructure requires the following: (i) a collection of ontologies for modeling context, (ii) a shared model of the current context and (iii) a declarative policy language that users and devices can use to define constraints on the sharing of private information and protection of resources.

The need for common ontologies. An ontology is a formal, explicit description of concepts in a domain of discourse (or classes), properties of each class describing various features and attributes of the class, and restrictions on properties [8]. In order to create computer systems that can "understand" and make full use of a context model, the contextual information must be explicitly represented so that they can be processed and reasoned by the computer systems. Furthermore, shared ontologies enable independently developed context-aware systems to shared their knowledge and beliefs about context, reducing the cost of and redundancy in context sensing.

The need for a shared context model. CoBrA maintains a model of the current context that can be shared by all devices, services and agents in the same smart space. The shared model is a repository of knowledge that describes the context associated with an environment. As this repository is always accessible within an associated space, resource-limited devices will be able to offload the burden of maintaining context knowledge. When this model is coupled with a reasoning facility, it can provide additional services, such as detecting and resolving inconsistent knowledge and reasoning with knowledge acquired from the space.

The need for a common policy language. CoBrA includes a policy language [5] that allows users and devices to define rules to control the use and the sharing of their private contextual information. Using this language, the users can protect their privacy by granting or denying the system permission to use or share their contextual information (e.g., don't share my location information with agents that are not in the CS building). Moreover, the system behavior can be partially augmented by requesting it to accept new obligations or dispensations, essentially giving it new rules of behavior (e.g., you should inform my personal agent whenever my location context has changed).

2. CONTEXT BROKER ARCHITECTURE

Our architecture differs from the previous systems [3, 7] in the following ways:

- We use Semantic Web languages such as RDF and the Web Ontology Language OWL [8] to define ontologies of context, which provide an explicit semantic representation of context that is suitable for reasoning and knowledge sharing. In the previous systems, context are often implemented as programming language objects (e.g., Java class objects) or informally described in documentation.
- CoBrA provides a resource-rich agent called the *context*

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broker to manage and maintain a shared model of context[1]. The context brokers can infer context knowledge (e.g., user intentions, roles and duties) that cannot be easily acquired from the physical sensors and can detect and resolve inconsistent knowledge that often occurs as the result of imperfect sensing. In the previous systems, individual entities are required to manage and maintain their own context knowledge.

- CoBrA provides a policy language that allows users to control their contextual information. Based on the user defined policies, a broker will dynamically control the granularity of a user's information that is to be shared and select appropriate recipients to receive notifications of a user's context change.

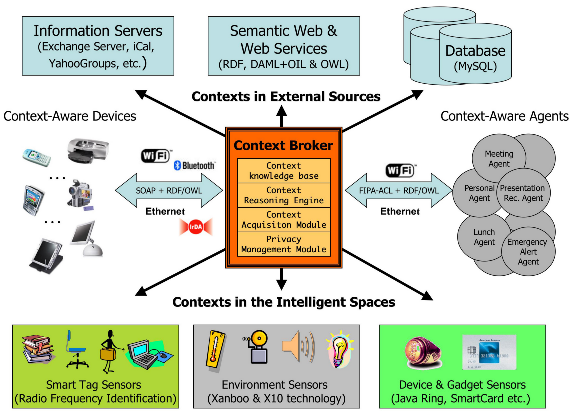

Figure 1: A context broker acquires contextual information from heterogeneous sources and fuses it into a coherent model that is then shared with computing entities in the space.

Figure 1 shows the architecture design of CoBrA. The context broker is a specialized server entity that runs on a resource-rich stationary computer in the space. In our preliminary work, all computing entities in a smart space are presumed to have priori knowledge about the presence of a context broker, and the high-level agents are presumed to communicate with the broker using the standard FIPA Agent Communication Language [4].

3. EASYMEETING: AN INTELLIGENT MEETING ROOM

To demonstrate the feasibility of our architecture, we are prototyping an intelligent meeting room system called **EasyMeeting**, which uses CoBrA as the foundation for building context-aware systems in a meeting room. This system will provide different services to assist meeting speakers, audiences and organizers based on their situational needs.

We have created an ontology called COBRA-ONT [2] for modeling context in an intelligent meeting room. This ontology, expressed in the OWL language, defines typical concepts (classes, properties, and constraints) for describing places, agents (both human and software agents), devices, events, and time. We have also prototyped a context broker in JADE[2] that can reason about the presence of a user in a meeting room. In our demonstration system, as a user enters the meeting room, his/her Bluetooth device (e.g., a SonyEricsson T68i cellphone or a Palm TungstenT PDA) sends an URL of his/her policy to the broker in the room[3]. The broker then retrieves the policy and reasons about the user's context using the available ontologies. Knowing the device owned by the user is in the room and having no evidence to the contrary, the broker concludes the user is also in the room.

4. FUTURE WORK AND REMARKS

We believe an infrastructure for building context-aware systems should provide adequate support for context modeling, context reasoning, knowledge sharing, and user privacy protection. The development of CoBrA and the EasyMeeting system are still at an early stage of research. Our short-term objective is to define an ontology for expressing privacy policy and to enhance a broker's reasoning with users and activities by including temporal and spatial relations. A part of our long-term objective is to deploy an intelligent meeting room in the newly constructed Information Technology and Engineering Building on the UMBC main campus.

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[1]Notice that we have a broker associated with a given space, which can be subdivided into small granularities with individual brokers. This hierarchical approach with collaboration fostered by shared ontologies helps us avoid the bottlenecks associated with a single centralized broker.

[2]Java Agent DEvelopment Framework: `http://sharon.cselt.it/projects/jade/`

[3]The description of the URL is sent to the broker in a vNote via the Bluetooth OBEX object push service

Containment: Knowing Your Ubiquitous System's Limitations

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1. Extended Abstract

1.1 Overview

This is a position paper outlining our current research in the area of ubiquitous systems security. We recognized that from the data objects' point of view, the frequency of context changes caused by migration through the environment implies changes in the threat models to which the data objects are exposed.

We propose a novel proactive security paradigm to mitigate the varying security risks by manipulating data objects' format. Here we concentrate on the modeling context for this purpose.

1.2 Motivation

Motivation for this research stems from consideration of threat models in the ubiquitous world. In general, threat models can be viewed as attributes of contexts. Entities in the ubiquitous world experience, through their mobility, frequent context changes. Thus, the security risks and threats that entities are exposed to vary as they migrate within the environment.

The notion of an *entity* in our research corresponds to individual *data objects* of arbitrary, sub-file, granularity. Data objects migrate within the environment either by being *contained* on a mobile device or by being *transmitted* through communications channels. This emphasizes the dynamicity of threat model changes for the data objects.

Due to the dynamicity and complexity present in the ubiquitous world, it is unrealistic to expect humans to be able to reason and act effectively to address security risks. We propose a new security paradigm that aims to mitigate security risks and threats present in contexts for data objects by automatic, proactive data format management.

As data objects are viewed on sub-file granularity the format management can, in addition to bulk file operations, provide fine-grained transformations such as e.g. anonymization, partial data quality degradation and other types of selective data constraining.

We identify three main aspects of the proactive data management system as: the policy definition language, reasoning engine and enforcement environment; an unambiguous and inseparable data object tagging system and application-level support; the context model.

In this work, we concentrate on modeling context for the purpose of applying it in the proposed security paradigm. To date, ubiquitous computing projects have largely exploited *location* to determine context [5]. This approach, although often efficient, has major drawbacks with regards to heterogeneity, compatibility, and availability as well as the inability to scale the proposed location infrastructures[4].

In contrast, we model context as *containment*, based on inter-device *visibility* (1.3) and inherently independent of traditional notion of location. One of the main aims of our research is to explore expressiveness and applicability of this approach, as envisaged in the next section.

1.3 Container-View Model

Containment is established by determining *physical enclosure* and locally *visible* devices. Visibility field of an device is defined with respect to its communication capabilities (1.3.0.1). Containments may exist in multiple instances concurently, depending on the granulairty at which they are defined. Each containment can be associated with a set of application specific attributes. In our example, we attribute containments with respect to risks and threats for data objects.

We split the notion of containment into: *physical containment* [1] and *views*. We name the resulting model *Container-View* model.

1.3.0.1 View

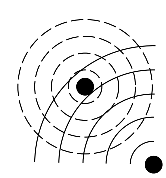

Figure 1. A spherical and a directed view.

A *view* (Figure 1) represents one-hop reachability within a communications channel. Each view has a *view generator*

[1] Referred to as *containment*.

and a *view type*. For example, if a PDA is IrDA equiped and is within range of a IrDA capable mobile phone we say that the mobile phone is within a view of the PDA; the view type is IrDA and the view generator is the PDA. Consequently, we define *visible* relation which is reflexive, antisymmetric and intransitive. By migrating through the environment, entities dynamically enter and leave views.

1.3.0.2 Container

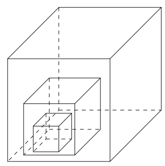

Figure 2. Nested containment.

The notion of a *container* defines a physical enclosure (Figure 2). Containers may be nested. The main characteristic of a container is that any movement action and its consequences are directly reflected onto enclosed entities. For example, a data object is contained within a PDA; the PDA is contained within a car; as the car moves, so do the PDA and the data object. *Contains* relation is irreflexive, antisymmetric and transitive. Physical enclosure, i.e. container, can be determined through the visibility property, in presence of *landmarks*, or by using dedicated infrastructural support (1.3.0.5).

1.3.0.3 Container-View relations

A container can be within a view of another entity. A container can be either *transparent* or *opaque* to a view. The former means that the contents are in the *direct* view as well. The only *per se* inference that can be made is that if a container is not within a view then its contents are not within the view either. To support other types of inference the model provides for *constraints* to be specified. Furthermore, we define inter-container and inter-view *paths* to denote one-hop links along which data objects can migrate among different containers and views; e.g. a door between rooms or a bridge between IEEE 802.11 and GPRS respectively.

1.3.0.4 Formal model

Owing to envisaged device constraints, heterogeneity of device capabilities and differing model usage the decision was made to model physical containment and views separately. As physical containment is highly hierarchical we are inclined to use lattices to model it. Apart from being computationally feasible, lattices, aid reasoning about neighbors, ancestors and descendants and can incorporate the notion of paths. Modeling views, on the other hand, is more demanding as the model has to be chosen based on the nature of a view type and its propagational characteristics, e.g. directional vs. omni-directional etc. We intend to develop a taxonomy of views to aid appropriate model choice. Individual models can be aggregated into a bigger picture based on individual application requirements. Our approach facilitates partial, distributed, model evaluation and constrained reasoning at differing levels of granularity as required by the highly heterogeneous environment.

1.3.0.5 Collaboration model

As entities migrate through the ubiquitous environment they will experience differences in quality and quantity of available Container-View model data. This will be reflected on the accuracy of the model. The model should support three ways of obtaining relevant information: through environment-embedded services which provide precomputed models as required; by using hints based on entity's sensing capabilities or obtained from other entities present locally; and through inference process. The model will also incorporate a trust management infrastructure for the collaboration and supports reasoning about containment information capturing confidence.

1.3.0.6 Inference

To provide entities with a certain level of independence from ubiquitous infrastructures, we are currently working on suitable inference mechanisms. There are two stages in the model operation at which inference is needed: determining, i.e. capturing, current model state and reasoning about the model. For the former, in cases where the model information is unobtainable from trusted third parties, we are focusing on Bayesian inference methods [2, 3]. Reasoning is to be supported by an algebra roughly based on Egenhofer's Container-Surface algebra [1] and substantially extended to support: considerable difference between physical surfaces and views, container-view relationship constraints, mobility and information vagueness and indeterminacy.

1.4 Summary

By considering security issues in ubiquitous computing, we have identified a need to address the problem of frequently changing threat models for migrating data objects. We propose a system for proactively managing data object format. As a first step, we define context as containment with respect to physical world and communications channels. The Container-View model represents formalization of the notion of containment based on local inter-entity relationships and is independent of absolute location and location infrastructures. We are set to evaluate the expressiveness and applicability of the Container-View model as envisaged.

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ContextMap: Modeling Scenes of the Real World for Context-Aware Computing

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ABSTRACT
We present a scenegraph-based schema, the ContextMap, to model context information. Locations with hierarchical relations are the skeleton of the ContextMap where nodes of people, objects and activities can be attached. Context information can be collected by traversing the ContextMap. The ContextMap provides a uniform method to represent physical and social semantics for context-aware computing. In addition, context ambiguity can be modeled as well.

Keywords
Context-aware computing, scenegraph, context ambiguity

INTRODUCTION

Context is the glue to link the real world with the virtual world. Context is "any information that can be used to characterize a situation" [4]. We call the situation a scene of the real world. The information can be the temperature of a region. It also can be the activity of a person, e.g., reading a book, or the activity of a group, e.g., having a meeting.

Both the physical and the social semantics of a situation are required by context-aware computing. Social semantics are embodied through physical activities, and physical activities can be fully understood only under certain social circumstances. For example, we can see "running" as a status of a person at a physical level. It can mean "catching a bus" at a social level. Activity theory [1] sees an activity as functionally subordinated hierarchical levels, i.e., activities, actions, and operations. Each action performed by a human being has not only intentional aspects but also operational aspects. This reveals how social activities can be performed through physical actions and objects.

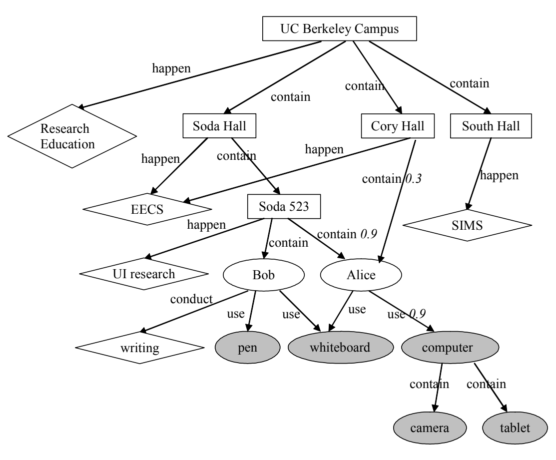

Figure 1: An example ContextMap. Rectangles indicate *Place* nodes. Diamonds stand for *Activity* nodes. *People* nodes are represented as ellipses and *Object* nodes are ellipses in gray.

Context information itself is recursively related. For example, linguistically, the context of a word is the sentence, which in turn gets its context from the paragraph. The Berkeley campus has the climate context of the City of Berkeley, which inherits it from the San Francisco Bay Area of California based on location containment.

To leverage the abundant interaction semantics of context, it is necessary to have an efficient way to model the context. We devised the ContextMap (see Figure 1) to model the situation of the real world for context-aware computing as a scenegraph-like structure. The ContextMap provides a consistent way to model context information and addresses the correlation and ambiguity of context data.

RELATED WORK

The Active Map [5] provides a basic organization of context that consists of a hierarchy of locations with a containment relation. We employed the location hierarchy as the skeleton of the ContextMap, but we include relations in addition to location containment.

Crowley et. al. [2] described context as a network of situations concerning a set of roles and relations. Roles may be "played" by one or more entities. Dey formulated three kinds of entities for context-aware computing: people, places and things (or objects) [4]. We model these roles and entities as nodes and edges of a ContextMap.

The scenegraph [6] has been widely used in computer graphics. Its dynamic propagation of graphical attributes greatly simplifies the representation of a scene and it proves an efficient way to model complicated scenes. To model scenes of the real world, we extended the scenegraph to deal with the context semantics of the real world.

INTRINSIC AND RELATIONAL CONTEXT ATTRIBUTES

The context information of an entity can be classified into intrinsic and relational attributes. Intrinsic attributes of an entity can be described without referring to others, e.g., the identity of a person can be his name. A person's status can be his age or health condition. However, relational attributes of an entity can only be specified by its relations with other entities. For example, the position of an entity can usually be described as a relative spatial relation with other entities, e.g., near or far and in or out.

NODES AND EDGES OF A CONTEXTMAP

Like a traditional scenegraph, a ContextMap is a directional acyclic graph (see Figure 1) and the context attributes are collected by a depth-first traversal. An entity, i.e., a place, a person or an object, is represented as a node of the graph. Each node maintains the intrinsic attributes of an entity that it represents. Relational attributes of an entity are represented by edges directly or indirectly linked to its node. So the context of an entity is represented not only by the attributes in its node but also by the node's position in the entire ContextMap. A ContextMap is a view of the real world that can be shared by multiple applications.

Another kind of node in a ContextMap is the *Activity* node, which represents the social semantics of an entity or a group of entities, e.g., reading a book or having a seminar. It can be applied to a sub-graph of a ContextMap like the dynamic propagation of graphical attributes in a scenegraph. It means that the activity is conducted by people with certain tools (physical objects) at a certain location. For example, in Figure 1, "UI Research" happens in Soda 523 and it indirectly indicates the activity of Bob, Alice and the tools they are using to achieve this activity.

Place nodes stand for entities that are places or sites. They can refer to a large region ("California") or a small area ("close to whiteboard"). The containment relation between *Place* nodes is stable and hierarchically structured, e.g., the UC Berkeley campus contains Soda Hall and will always do so. *Place* nodes and their containment relations constitute the skeleton of a ContextMap, which can be enriched by nodes describing people, physical objects, and activities. A ContextMap can be built by establishing a static *Place* hierarchy first. Directional edges from *Place* nodes can indicate *contain* relations for physical containment and *happen* relations for locations where some events, i.e., social activities or roles, happen. For example, "education & research" happens on the "UC Berkeley Campus". An *Object* node is for a physical object, e.g., a pen, which can have directional *contain* edges to its sub-components. *Contain* relations are transitive.

A *Person* node represents a person entity. Directional edges from a *Person* node can indicate *conduct* or *use* relations, specifying the person is conducting an action or using a physical object (tool), respectively. A *use* relation can transfer the semantics of a *contain* relation. For example, the fact that "Bob" is in "Soda 523" and he is using the "pen" indicates that the "pen" is also in "Soda 523".

A node can be referenced by multiple nodes. For example in Figure 1, both "Bob" and "Alice" are using the "whiteboard". The multi-reference to a node can also be used to model context ambiguity. For example, "Alice" could be either in "Soda Hall" or "Cory Hall" in Figure 1.

Intrinsic attributes of a node can be tagged by a timestamp to indicate when they are updated or a time span to indicate their validity. Moreover, a directional edge can be tagged to indicate the valid period of a relation.

MODELING CONTEXT AMBIGUITY

In reality, both sensed and interpreted context is often ambiguous [3]. The ContextMap models context ambiguity by tagging edges and the intrinsic attributes of nodes with confidence values. For example, the intrinsic attribute "health condition" of "Alice" could be 0.8. In Figure 1, the confidence of "Alice" in "Soda 523" is 0.9 and in "Cory Hall" it is 0.3. Edges without labelled values have the default confidence value "1.0".

Here we describe a simple method to calculate the confidence of transitive relations.

Given $x \xrightarrow{\alpha} y$ and $y \xrightarrow{\beta} z$, $x \xrightarrow{\alpha\beta} z$.

For example, the confidence of "Alice" using "computer" is 0.9. Since the confidence of Alice in Soda 523 is also .9, the confidence of "computer" in "Soda 523" is 0.81.

However, the confidence of "whiteboard" in "Soda 523" is the average of the confidences of all paths from "Soda 523" to "whiteboard". It is 0.95 based on [Soda 523, Bob, whiteboard] = 1 and [Soda 523, Alice, whiteboard] = 0.9.

CONCLUSION AND FUTURE WORK

ContextMap enables an efficient representation of complicated situations, particularly for relational context, by using dynamic attribute propagations and transitive relations. Both social and physical semantics of context can be represented in a consistent manner. Attributes and relations of nodes can be updated based on sensed information, e.g., a person's location and its confidence, or manually, e.g., an *Activity* node can be manually added in or manipulated beforehand or in runtime. ContextMaps will be provided as an infrastructure service to applications. We are continuing to refine the representation and evolution mechanisms of the ContextMap, and to enable easy construction of and access to ContextMaps.

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Service Platform for Exchanging Context Information

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ABSTRACT

This paper describes how to capture user's activities as a form of context information based on a complementary relation between user's activity and objects near the user. We propose a platform that stores users' context information, allows service providers to access that information, and provides various services to the users. We also present a prototype system of the messaging service for exchanging user's context information.

Keywords

context, service platform, ID-tag, privacy control

INTRODUCTION

Recent mobile communication systems with GPS enable mobile users to provide various location-based information (e.g., nearby shop information and related navigation maps). In order to provide more suitable information based on the user's demands, it is necessary to collect not only location information but also various information regarding the user's context, and it is also necessary to utilize context information for personalized service provisioning. In this paper, we first describe how to capture user's activities as a form of context information and then consider the requirement for the context-aware service platform. Finally, we present a prototype of our proposed platform.

A CASE OF CONTEXT INFORMATION: USER ACTIVITY

A number of RFID tag systems have recently been proposed (e.g. [1]). In these systems, passive RFID tags are attached to various objects in the physical world and information corresponding to each object (i.e. electric ID) is managed on a networked server in the virtual world.

In the physical world, a mobile user interacts with various objects. A user may rest by sitting on the sofa and taking refreshment. The act of resting involves interacting with nearby objects such as a sofa, a table and a cup etc. This means that the relation between activities and objects is complementary in that a user usually does not perform any activity without interaction with surrounding objects. We make the following assumptions in order to determine the user's activities.

- The above RFID tags systems are deployed and mobile users have a networked mobile terminal equipped with an RFID tag reader in order to identify interacting objects.
- The candidates of activity corresponding to each object are defined in advance. For simplicity, in this paper, we assume that one object corresponds to one activity. Examples of this correspondence are shown in Table 1.

In our prototype implementation, user activity is detected through the following procedure. First, an ID attached to an object is detected via a tag reader. Next, the property of the object is determined based on the detected ID and the candidates of activity corresponding to the determined object are inquired. Finally, the appropriate activity context is selected.

Table 1 Examples of object to activity relations

Object	Corresponding activity
Sofa	Rest / Meeting
Dining table	Breakfast / Lunch / Dinner (It depends on time)

SERVICE PLATFORM ARCHITECTURE

Service providers may have their own user's context such that they can provide services to specific users, but the amount of context detected by each service provider would be limited. This remains an unsolved issue that service providers are facing. This paper proposes a service platform in which aggregated user's context information (which is not limited to the user's activities described in this paper) is open to service providers under an appropriate access control such that various context-aware services can be provided. The proposed service platform is shown in Fig. 1, and the following functions are defined.

- The *Context registrar (CR)* has functions for capturing user's context information (Label 1 in Fig. 1) and registering it to the *Context manager (CM)* attached with an open level indicator (OLI) (Label 2 in Fig. 1). Every time a user detects an ID attached to an object, activity context related to the user is registered and accumulated. The *CR* also has a function for setting access level indicators (ALIs) to *Context-based service provider (SP)* and *Context User (CU)* (Label 3 in Fig. 1).
- The *Context Manager (CM)* has a function for storing the context information as a context repository. This context information is exclusively generated and registered for each user. The *CM* also has a function for executing the access control based on the relation between the OLI setting to the target context information

and ALI setting to *SP* and/or *CU*. The *CM* should be under perfect control of the *CR* and should maintain independence from other functions for the purpose of user's privacy protection.

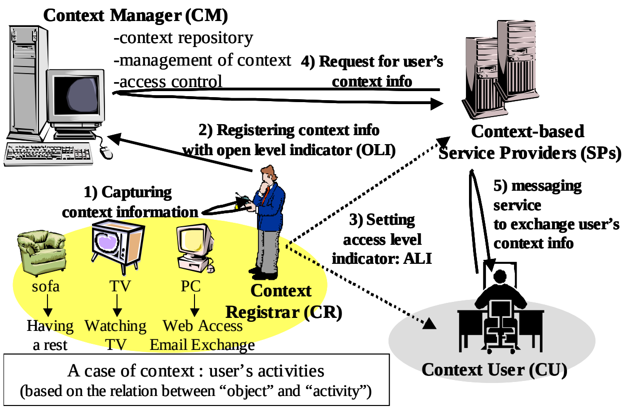

Figure 1 Schematic illustration of a service platform for exchanging user's context information

- *Context-based Service Providers* (*SPs*), which have high potential for providing various context-aware services based on context information, have a function for accessing context information (Label 4 in Fig. 1).
- The *Context User* (*CU*) has a function for accessing context information and then context-based services are provided through *SPs* (Label 5 in Fig. 1). It is necessary to clearly distinguish *CR* and *CU* because this platform aims at opening the context information to the *CU* via *SPs*.

In our prototype implementation, the functions of *CR* and *CU* are implemented on a user's mobile terminal, the function of *CM* is implemented on a user's personal server, and the function of *SP* is implemented as a network server.

ACCESS CONTROL TO CONTEXT INFORMATION

The CR_A sets the following values:

-OLI_A *(I)*, which represents OLI to context information *I* set by CR_A and indicates an integer with the range from 1 to n. The higher the value, the easier to open.

-$ALI_A(SP_1)$, and ALI_A *(B)*, which represent to ALIs to SP_1 and CU_B set by CR_A, and indicate an integer with the range from 1 to n, respectively. Users with smaller value are allowed much more context information.

When *CM* receives the request message that CU_B requires CR_A's context information via SP_1, if the condition described in Equation 1 is satisfied, then CU_B can access the target context information via SP_1.

$$OLI_A(I) \geq \max\{ALI_A(SP_1), ALI_A(B)\} \qquad (1)$$

In addition to this access control as a minimum condition, the certification of each user and authorization of context information access are also required.

CONTEXT EXCHANGING SERVICE

We designed the messaging service of exchanging user's activities with each other, which is provided by an *SP*. Mobile terminal A (MT_A) has the functions of both registering CR_A's context information and requiring CU_B's and CU_C's context information. The functions equipped with MT_B and MT_C are determined in the same manner as in MT_A. An example sequence in exchanging user's context information is presented in Fig. 2. The context exchange service is based on the trigger of *CU* and *CR*.

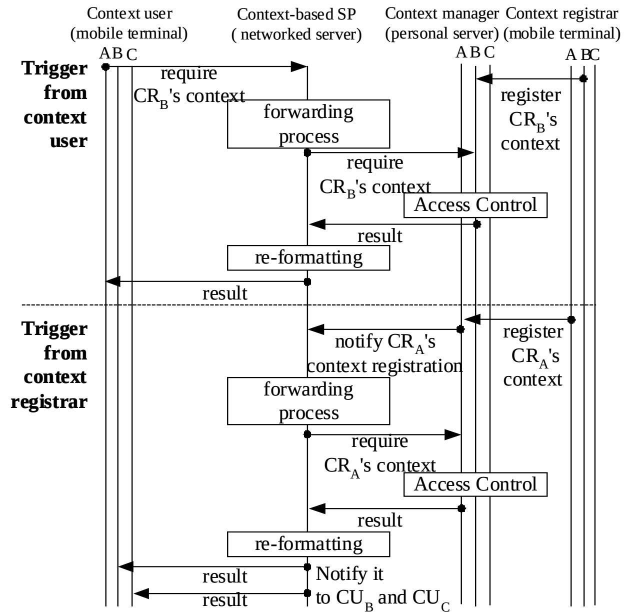

Figure 2. The sequence of context exchange service

RELATED WORKS

Ubiquitous applications based on passive RFID tags have already been studied [2]. Various kinds of context platform have also been studied [3] and it has been pointed out that privacy of context remains an issue [4].

SUMMARY

Based on the requirements of a service-provisioning platform for exchanging user's context information with each other, we developed a prototype and examined the configuration of the system. Details of the prototype system will be presented in the poster session.

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The State Predictor Method for Context Prediction

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ABSTRACT

Ubiquitous systems use context information to adapt appliance behavior to human needs. Even more convenience is reached if the appliance foresees the user's desires and acts proactively. This paper focuses on context prediction based on previous behavior patterns. We present the newly devised state predictor method, which is motivated by branch prediction techniques of current high-performance microprocessors. We exemplify the method by investigating two state predictors.

Keywords

context awareness, context prediction, location prediction, proactive

1. INTRODUCTION

Ubiquitous systems strive for adaptation to user's needs by utilizing information about the current context in which an user's appliance works. A new quality of ubiquitous systems may be reached if context awareness is enhanced by predictions of future contexts based on current and previous context information [1]. Such a prediction enables the system to proactively initiate actions that enhance the convenience of the user or lead to an improved overall system.

Humans are creatures of habit. Humans typically act in a certain habitual pattern, however, they sometimes interrupt their behavior pattern and they sometimes completely change the pattern. Our aim is to relieve people of actions that are done habitually without determining a person's action. The system should learn habits automatically and reverse assumptions if a habit changes. The predictor information should therefore be based on previous behavior patterns and applied to speculate on the future behavior of a person. If the speculation fails, the failing must be recognized, the speculatively initiated actions withdrawn, and the predictor updated to improve future prediction accuracy.

To predict a future situation learning techniques as e.g. Markov Chains, Bayesian Networks, Neural Networks are obvious candidates. In our work we choose a completely different approach. Branch prediction techniques [3] as know from high-performance processors are transferred and adapted to the domain of context prediction. We investigated several so-called state predictors [2] of which we choose the following two predictors for this paper: (1) the one-level two-state predictor and (2) a local two-level context predictor with 2-state predictors in the second level.

2. THE ONE-LEVEL TWO-STATE PREDICTOR

The 2-state context predictor is a modification of the two-bit branch predictor with saturation counter. The first entry denotes the next context. The second entry is used for changing between the strong and weak states. The context stored in the first entry is thus always predicted independently of the second entry, which influences training and retraining speed. The denotation "2-state context predictor" stems from the provision of two states for each predicted context.

The retraining of a 2-state predictor is slowed down such that an one-time change of the habit does not cause an effect. In the case of two successive deviations from the habit the system notes the change. If more than two deviations of a habit should not yet lead to a retraining, the number of states must be increased leading to a k-state context predictor.

3. THE TWO-LEVEL TWO-STATE PREDICTOR

Two-level context predictors regard a sequence of the last contexts that stand for a person to predict the next context. This could be either global or local to a specific context. The previous contexts are stored in a kind of shift register that constitutes the first level of the predictor. If a new context is occurred all entries of the register are shifted to the left and the new context is filled in from the right. The length of the shift register is called the order, which denotes the number of last previous contexts that influence the prediction. The second level consists of a pattern history table that stores all possible patterns of context sequences in different entries. Each entry holds additionally a 2-state predictor entry, which in fact predicts the next context. The pattern in the shift register is used to select an entry in the pattern history table.

4. EXAMPLE: LOCATION PREDICTION

Our sample application predicts the next location of people moving within an office building. We consider the floor plan in figure 1: C (corridor), S (secretariat), B (office of the boss), and E (office of the employee).

Figure 2 shows the corresponding prediction graph of the 2-state predictor for the corridor. Similar prediction graphs are necessary for the other rooms. The denotations of the states consist of the ID of the next room to be predicted and a counter. If a person enters for the first time the boss's office

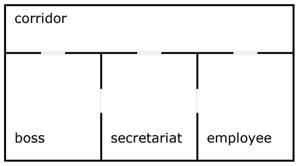

Figure 1: Floor plan of corridor, boss' office, secretariat, and employee's office

B from the corridor, the initial state $B0$ is set. If the person reenters the corridor, the office of the boss B is predicted as next location. If the prediction proves as correct, the predictor switches into the strong state $B1$. Thus, next time the office of the boss B will be predicted again. If the person interrupts her habit once by entering a room different from the boss' office, the state is set back from $B1$ to $B0$. Thus the boss' office is still predicted. If the person goes now from the corridor into the secretariat (resp. the employee's office) the predictor switches into the state $S0$ (resp. $E0$) independently of the room entered from the corridor before, and predicts thus the secretariat (resp. the employee's office) as next.

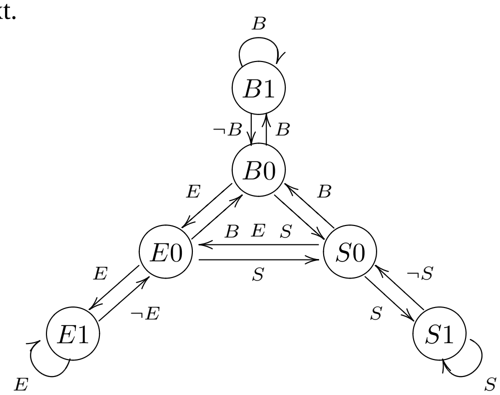

Figure 2: Prediction graph of two-state predictor for the corridor C

We assume an order of 3. For the local two-level two-state predictor for the corridor with 3 neighbor rooms there are $3^3 = 27$ patterns and therefore 27 entries in the pattern history table. Figure 3 shows this case assuming the room sequence E S B E B S E S E B S <u>E B S</u>. We consider the pattern E B S. After first occurrence no room was predicted, but as initial state for the two-state predictor $E0$ was set. After second occurrence the state $E0$ was changed to $E1$. Now the prediction is that the employee's office E will be entered next.

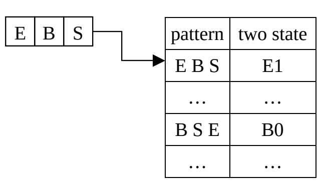

Figure 3: Local two-level two-state predictor for the corridor C

The two-level context predictors can be extended using a method motivated by Prediction by Partial Matching (PPM) from the area of data compression. Here a maximum order m is applied in the first stage instead of the fixed order. Then, starting with this maximum order m, a pattern is searched according to the last m rooms. If no pattern of the length m is found, the pattern of the length $m-1$ is looked for, i.e. the last $m-1$ rooms. This process can be accomplished until the order 1 is reached.

5. EVALUATION

Evaluation is performed by simulating the predictors with behavior patterns of people walking through a building as workload. The evaluation of the implemented predictors used synthetic movement sequences, because of the lack of real movement pattern. The usage of various synthetic pattern lead to a good differentiation between the predictors, which are summarized as follows:

The simulations show that the one-level two-state predictor reaches a prediction rate of 42.6% to 79.4% correct predictions, whereas the two-level two-state predictor reached even higher prediction rates of 55.4% to 98.2%. The two-level two-state predictors are better suited for complex patterns, but the advantage of the two-state predictor is its very fast training and retraining speed (for more details see [2]).

6. CONCLUSION

We propose two state context predictors suitable for appliances with limited resources which are motivated by branch prediction techniques and evaluated using person's movement patterns in a building.

To avoid misguidance of persons or systems with wrong predictions, the confidence of the predictions should be taken into account. Meaning that a prediction should only be made, if the prediction reaches a high confidence level and suppressed otherwise.

Our future work concerns construction of new predictors and evaluation of these and of the described predictors with real movement sequences. A person tracking system, currently build up at the University of Augsburg, will generate such real movement patterns. Time is another important point in learning human habits. Therefore the predictors shall be enhanced to be time-dependent.

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Collaborative Capturing of Interactions by Multiple Sensors

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ABSTRACT

We propose a notion of an interaction corpus, a captured collection of human behaviors and interactions among humans and artifacts. The corpus provides an important infrastructure for a future digital society for both humans and computers to understand verbal/non-verbal mechanisms of human interactions. Our approach employs multiple wearable and ubiquitous sensors, such as video cameras, microphones, and tracking tags, to capture all of the events from multiple viewpoints simultaneously. We demonstrate an application of generating a video-based experience summary that is reconfigured automatically from the interaction corpus.

KEYWORDS: interaction corpus, ubiquitous/wearable sensors, video summary.

INTRODUCTION

Weiser proposed a vision that computers pervade our environment and hide themselves behind their tasks [1]. To achieve this vision, we need a new HCI paradigm based on embodied interactions beyond existing HCI frameworks such as the desktop metaphor and GUIs. A machine-readable dictionary of interaction protocols among humans, artifacts and environments is necessary as an infrastructure for the new paradigm. As a first step, we propose to build an interaction corpus, a semi-structured set of a large amount of interaction data collected by various sensors. This corpus may serve as a venue for researchers to analyze and model social protocols of human interactions.

Our approach is characterized by the integration of many sensors (video cameras, trackers and microphones) ubiquitously set up around the room and wearable sensors (video camera, trackers, microphone, and physiological sensors) to monitor humans as subjects of interactions. Our system incorporates ID tags with an infrared LED (LED tags) and infrared signal tracking device (IR tracker) in order to record position context along with audio/video data. The tracking device is a parallel distributed camera array where any camera can determine the position and identity of any tag in its field of view. By wearing a tracking camera, a user's gaze can be determined. This approach assumes that gazing can be used as a good index for human interactions [2]. We also employ autonomous physical agents like humanoid robots as a social actor to proactively collect human interaction patterns by intentionally approaching humans.

Use of the corpus allows us to infer the captured event to interaction semantics among users by collaboratively processing data of the users who jointly interacted with each other in a particular setting. This can be performed without time-consuming audio and image processing as long as the corpus is well prepared with fine-grained annotations. Using the interpreted semantics, we also provide an automated video summarization of individual users' interactions to show the accessibility of our interaction corpus.

CAPTURING INTERACTIONS BY MULTIPLE SENSORS

We prototyped a system for recording natural interactions among multiple presenters and visitors in an exhibition room. The prototype was installed and tested in one of the exhibition rooms during our research laboratories' open house.

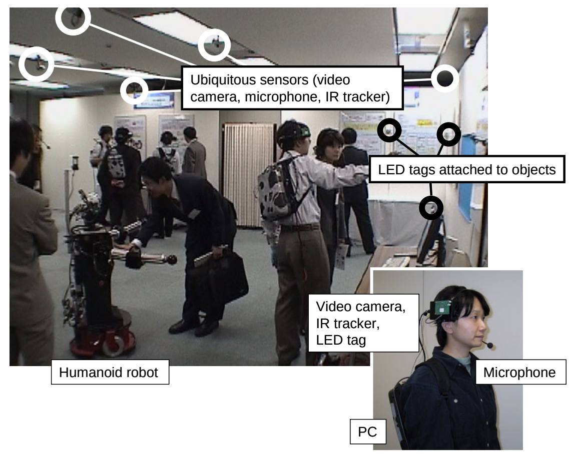

Figure 1: Setup of the ubiquitous sensor room.

Figure 1 is a snapshot of the exhibition room set up for recording an interaction corpus. There were five booths in the exhibition room. Each booth had two sets of ubiquitous sensors that include video cameras with IR trackers and microphones. LED tags were attached to possible focal points for social interactions, such as on posters and displays. Each presenter at their booth carried a set of wearable sensors, including a video camera with an IR tracker, a microphone, an LED tag, and physiological sensors (heart rate, skin conductance, and temperature). A visitor could choose to carry the same wearable system as the presenters or just an LED tag, or nothing at all. One booth had a humanoid robot for its demonstration that was also used as an actor to interact with visitors and record the interactions using the same wearable system as the human presenters.

Eighty users participated during the two-day open house providing $\sim$ 300 hours of video data, 380,000 tracker data along with associated biometric data.

INTERPRETING INTERACTIONS

To illustrate how our interaction corpus may be used, we constructed a system to provide users with a personal summary video at the end of their touring at the exhibition room on the fly. We developed a method to segment interaction scenes from the IR tracker data. We defined interaction primitives, or "events", as significant intervals or moments of activities. For example, a video clip that has a particular object (such as a poster, user, etc.) in it constitutes an event. Since the location of all objects is known from the IR tracker and LED tags, it is easy to determine these events. We then interpret the meaning of events by considering the combination of objects appearing in the events.

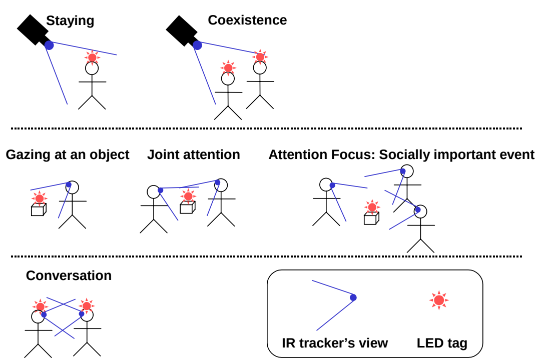

Figure 2: Interaction primitives.

Figure 2 illustrates basic events which we considered.

stay A fixed IR tracker at a booth captures an LED tag attached to a user: user *stays* at the booth.

coexist An single IR tracker camera captures LED tags attached to different users at some moment: users *coexist* in the same area.

gaze An IR tracker worn by a user captures an LED tag attached to someone/something: user *gazes* at someone/something.

attention An LED tag attached to an object is simultaneously captured by IR trackers worn by two users: users jointly pay *attention* to the object. When many users pay attention to the object, we infer that the object plays a socially important role at that moment.

facing Two users' IR trackers detect each others' LED tag: they are facing each other.

VIDEO SUMMARY

We were able to extract appropriate "scenes" from the viewpoints of individual users by clustering events having spatial and temporal relationships. Figure 3 shows an example of video summarization for a user. The summary page was created by chronologically listing scene videos, which were automatically extracted based on events. We used thumbnails of the scene videos and coordinated their shading based on the videos' duration for quick visual cues. The system provided each scene with annotations, i.e., time, description, and duration. The descriptions were automatically determined according to the interpretation of extracted interactions by using templates, e.g., *I talked with [someone]*; *I was with [someone]*; and *I looked at [something].*

We also provided summary video for a quick overview of the events the users experienced. To generate the summary video we used a simple format in which at most 15 seconds of each relevant scene was put together chronologically with fading effects between the scenes.

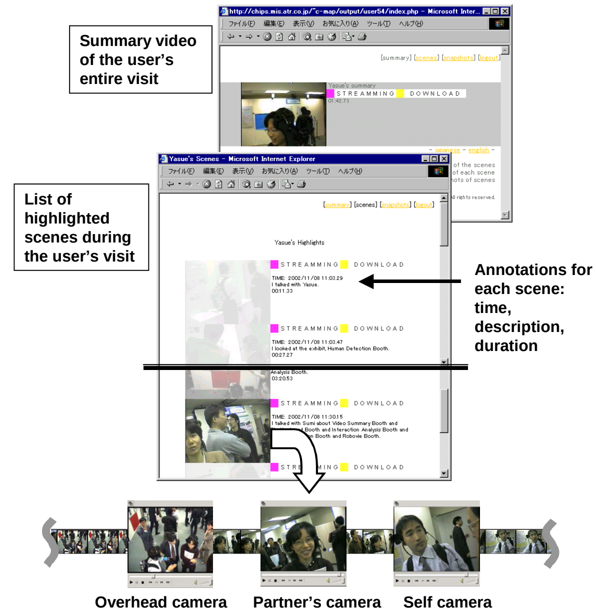

Figure 3: Automated video summarization.

The event clips used to make up a scene were not restricted to only ones captured by a single resource (video camera and microphone). For example, for a summary of a conversation "talked with" scene, video clips used were recorded by: the camera worn by a user him/herself, the camera of the conversation partner, and a fixed camera on the ceiling that captured both users. Our system selected which video clips to use by consulting the volume levels of users individual voices. Remember, the worn LED tag is assumed to indicate that the user's face is in the video clip if the associated IR tracker detects it.

CONCLUSIONS

This paper proposed a method to build an interaction corpus using multiple sensors either worn or placed ubiquitously in the environment. At the two-day demonstration of our system, we were able to provide users with a video summary at the end of their experience on the fly. In the future, we will develop a system that researchers (HCI designers, social scientists, etc.) can quickly query for specific interactions with simple commands and provides enough flexibility to suit various needs. We plan to work together with such research groups to improve our interaction pattern recognition and enrich the interaction corpus.

ACKNOWLEDGMENTS

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Ubiquity in Diversity – A Network-Centric Approach

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Wireless networking has witnessed strong growth recently due to the popularity of WiFi (802.11b-based WLANs) and world-wide deployment of wide-area wireless networks such as GPRS and 3G. Devices that can connect to multiple networks (e.g., GPRS-WLAN cards) are becoming increasingly affordable, and in future mobile devices such as laptops, PDAs and handhelds will be equipped to connect to multiple different networks. As the environment becomes more *diverse* and *heterogeneous* with a range of networks, devices and services to choose from – a key issue that will need to be addressed is that of heterogeneity. In this poster abstract, we discuss our practical efforts in building a truly ubiquitous environment for secure heterogeneous networking.

Using an experimental testbed that creates a heterogeneous environment, we are investigating the following:

- **Transparent Mobility with Mobile IPv6.** We are exploring how mobile users can transparently move across networks – wired as well as wireless. Here, we are investigating the performance of Mobile IPv6 for wireless networks integration, and schemes that can improve performance during vertical handovers [2].
- **Mobility Management with Context-Aware Networking.** Context can play an important role in heterogeneous environments. Although context has broader dimensions, we are interested in the *networking* context, one that enables mobile clients to be *situation aware* so as to efficiently adapt to various events during handoffs within and across different networks, and to other environmental events. We are currently building a mobility agent for such heterogeneous environments that can support adaptive mobility using network context.
- **Fine-grained Data Adaptation**. We are addressing a fundamental issue in data management – how can we efficiently manage data in presence of heterogeneous wireless links?. With links having vastly different characteristics as that typically seen in heterogeneous environments, there is a strong need to assist applications to perform better. We are looking at assisting applications in two different ways: firstly, with a data abstraction where its logical structure and type can be explicitly retained in the system (for example a file system) and, secondly, with a richer metadata model. An additional advantage for fine-grained data management comes from the *network* context information readily available from the mobility agent. This in turn allows for fine-grained data manupulation based on several environmental requirements.
- **Security in Heterogeneous Spaces.** Security issues stems while networking in heterogeneous spaces. These originate from using data models in systems that are present in some form within the device or transmitted through a communication link in the heterogeneous space. However, if the *context* in the heterogeneous space is known, we can easily identify relevant security and privacy *threats* that the data object is exposed to; and then mitigate the identified risks by proactively managing the data object format. The challenge in this context model is to match heterogeniety with device capabilities, quality as well as confidence levels available from the model, while at the same time tapping the full potential of myraid technologies for sensing the context.

In Cambridge Open Mobile Systems Project [1], we are investigating how we can achieve this vision of secure heterogeneous networking. As a first step, we have already investigated the extent to which Mobile IPv6 can be used to successfully migrate TCP connections during inter-network handovers [2].

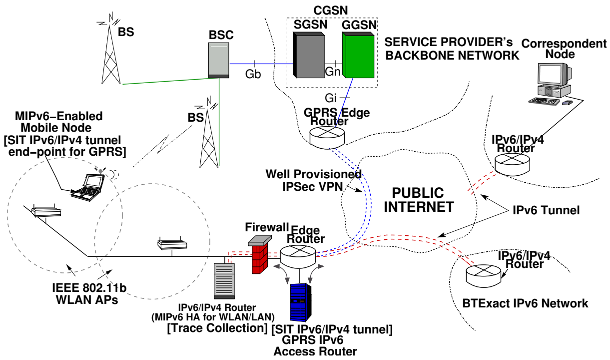

Figure 1: A 3G-GPRS–WLAN–LAN Testbed

We have implemented a loosely-coupled Mobile IPv6 based 3G–GPRS–WLAN–LAN testbed (see, figure 1). By using a testbed, consisting of the world's two most widely deployed wireless data networks – local-area wireless network (WLANs) and wide-area wireless (GPRS) – we have analysed what happens when multi-mode mobile devices perform vertical handoffs using Mobile IPv6. We have closely examined the handover process itself, its effects on TCP, and have given reasons for its under-performance (see, [3]).

To understand the performance issues during such inter-network handovers, we characterized a handover process in Mobile IPv6 in two steps – a handoff *decision* and *execution*. Handoff *decision* is the ability to decide (by the mobile node, or network or by both) of *when* to perform a handoff. After the decision to handoff is taken, the handoff *execution* process comes into play. Handoff decision and detection steps can overlap, as there are scenarios when decision process may require more probing of the network (for example, duplicate address detection time).

We have partitioned the handoff (execution) latency into three components – detection, configuration and registration times. We have investigated the extent to which Mobile IPv6 could be used to successfully migrate TCP connections during inter-network handoffs. Using the testbed, we have evaluated the impact layer-3 *hard* handoffs have on transport protocols such as TCP – a more thorough description is available in the form of a separate technical report [2]. Besides, we have experimentally evaluated schemes that improve vertical handovers – Fast Router Advertisements (RAs), RA Caching, and Binding Update simulcating in Mobile IPv6, smart buffer management using TCP proxy in GPRS, and *soft* handovers that improves TCP performance dramatically [2, 3].

Building further on this work, our ongoing research is focussed at broadening the concepts of secure and efficient heterogeneous networking under the aegis of COMS project [1]. As previously discussed, we have already evaluated schemes that improve handover performance and we are currently focussed into exploiting several potential areas for secure heterogeneous mobility – mobility management and networking with *context*, and using feedback information from this context to provide fine-grained adaptation for data, and to identify the *threats* of this data model.

Other practical applications of the testbed includes two potential research areas for mobile networking – Context Aware networking using the Sentient Car, and Mobile Access Router (MAR) [4]. The two research areas are closely knitted, and both require a good understanding of mobility in heterogeneous environments.

- **Sentient Car for Context-Aware Networking.** In this project, we are investigating how networking context (situation awareness) based on location, movement direction and speed can be used to make better, informed decisions during inter-network handovers.

Figure 2: Sentient Car for Context-Aware Networking.

  Any sophisticated handoff mechanism meant for heterogeneous environments, can make use of context-awareness in their implementations. For example, based on the exact position, movement direction and velocity information available to a highly mobile host (e.g., Sentient Car), a co-located infrastructure proxy can assist host mobility by tracking and accurately predicting when a handoff can occur. This in turn can assist in flow adaptation (e.g., TCP) even before a handoff occurs.

  To realize the full potential of Context-Aware Networking in highly mobile environments, we will use the Sentient Car that is situation aware based on its location (using GPS), movement direction and speed. The Sentient Car is an outcome of joint research of different departments of the University of Cambridge.

- **Mobile Access Router (MAR).**
  MAR [4] is a system consisting of a MAR Client – a multimode mobile device used as a mobile accesss router, and connected to different wireless networks simultaneously (e.g., GPRS, 3G, WLAN etc.) to communicate with a MAR Server proxy located in the wired infrastructure. The MAR client is a mobile access router to be placed in a car, bus, train etc., and performs bandwidth striping (aggregation) across multiple network interfaces to exploit the distributed spatial diversity available from different wireless access networks. Diversity provides a highly reliable "always-on" wireless communication channel. The MAR project can extend the use of Mobile IPv6 in this environment.

Our poster illustrates several such practical intricacies using a real testbed, and provides a sound description of our ongoing research on secure heterogeneous networking. Please visit our project COMS web-page,
`http://www.cl.cam.ac.uk/coms/`
for further details and information about our ongoing research and papers.

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A Peer-To-Peer Approach for Resolving RFIDs

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ABSTRACT

We present a system using a Peer-to-Peer network for resolving associations of Radio Frequency Identification (RFID) tagged objects to their virtual presence. A query, which consists of an identification string, is sent to the network and receives the appropriate resolution data. We pay particular attention to the authenticity and security of the exchanged data, in order to prevent tracing of resolution queries. The usage of a Peer-to-Peer network enables an non-authoritarian yet easily managed extension by further resolving services, such that these services do not need to share any information with an authoritative organization. Supply Chain Management (SCM) and Customer Relationship Management (CRM) represent potential application areas.

Keywords

Peer-to-Peer, RFID, Resolving Service, SCM, CRM

INTRODUCTION

In Ubicomp there is ongoing research regarding the unification of the real world with the virtual world, leading to the electronic acquisition of real world activities. Projects like CoolTown[1] have demonstrated the diversity of applications enabled by the transition of real world to virtual presences. CoolTown experimented with beacons, RFID transponders and other small devices that provide a unique identification string. This string was then mapped onto a URL in order to create the association with the virtual presence. The resolving mechanism here could either be manually selected or relied on a service similar to a domain name service (DNS). However, we present a Peer-to-Peer (P2P) approach for resolving such associations.

Motivation

In our approach we are using RFID transponders in order to identify objects. The transponders are cheap, small and robust. Nevertheless, available memory on the transponders enables storage of additional information apart from the built-in identification string. The usage of a P2P network has particular advantages when compared to other approaches. Other than centralized resolving services, the P2P approach does not necessitate the sharing of any information about a virtual presence with the network. DNS-like or tree-based resolving services typically require centralized knowledge about object-virtual presence associations, because the root node of the tree has to know all associations in order to perform a successful resolution. In a P2P approach no single authority can trace all resolution queries. Together with a strong encryption of queries and their responses this provides anonymity and security. Furthermore, P2P networks allow non-authoritarian extension. The information offered by a participant in this network is not restricted to a particular format..

Requirements

The P2P network for resolving RFIDs consists of enquirers, resolving services ("resolver") and an intermediate network directing queries and responses to respective parties. The enquirer and resolver do not talk directly to each other. Their communication is performed via multiple, intermediate peer systems. On a cautionary note, as neither party imposes control over the P2P network, their communication is susceptible to attacks like man-in-the-middle [2]. This implies that queries and responses have to be encrypted and authenticated in order to prohibit unwarranted disclosure of the content of the communication and to validate packet origin.

IMPLEMENTATION

We established a P2P network on several computers in our department using the JXTA[3] protocol set. A RFID reader for I-Code transponders was connected via a serial line to the enquirer. Two resolving services were then included on the network. The setup is summarized in figure 1.

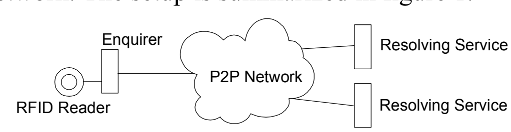

Figure 1: P2P Setup with Enquirer and Resolvers

When an object with an attached RFID transponder was read, the enquirer queried the network and the resolving service for the identification string and replied with extensive information regarding the virtual presence of this object. As a consequence of the requirements we used GnuPG[4], a freely available tool for secure communication using an asymmetric Public-Key algorithm. We consider communication authenticated and secure when the enquirer holds a valid public key for each resolving service. On the other hand, a resolving service must also possess the appropriate public key of the enquirer. Public and private keys were generated beforehand and installed on the respective computers. The key lengths were set to 1024 bits providing a strong encryption. The resolving mechanism works as follows: When a transponder is read it provides a fixed identification string of 8 bytes and a service identification string of 44 bytes from its memory. The enquirer uses the service identification to query the resolver. The network replies with peer advertisements matching the service identification. At this point the authenticity of the resolving service has not yet been proven. The enquirer therefore connects to all advertised peers. A message M_q containing a randomly chosen session ID, the service identification and the RFID from the transponder is encrypted with the public key of the resolving service, signed using the enquirer's private key and then sent to each connected peer. A resolving service can now verify the authenticity of the message using the public key of the enquirer and decrypt the message using his private key. The query request can then be fulfilled by the resolving service. A message M_r containing the received session ID, the service description and the response data is then encrypted, signed and sent back to the enquirer, which can now prove the authenticity of the resolving service. The next figure summarizes the resolving mechanism.

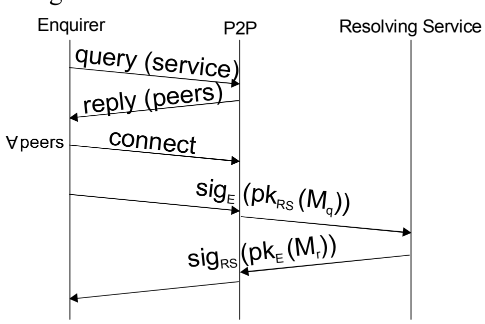

Figure 2: Resolving Mechanism

Our tests showed an average response time of six seconds for a query, mainly caused by the encryption algorithm and the delays while waiting for replies of peer advertisements.

DISCUSSION AND APPLICATIONS

Apart from the strengths like anonymity, authenticity and security, there are also weaknesses. The exchange of the public keys is an overhead during protocol initialization, making the setup of new resolving services and enquirers inconvenient. An initial direct and secure connection between enquirer and resolving service can be applied. Furthermore, the management of possibly several thousand keys on a machine requires a large effort to secure the enquirer and resolving services. There are also performance issues: the signature of all messages arriving at the resolving service must be checked for each known enquirer, which causes a huge load when the network scales up. Advanced features like group creation implemented in JXTA might be helpful to balance the load. On the application side we see a huge potential, when manufacturers can electronically trace their items. Applications in the field of SCM and CRM systems might benefit from the ubiquity of extensive information about items, which becomes easily and securely accessible by our approach. The major strengths of the P2P approach are the non-authoritative extensibility by just adding another resolving service or enquirer and the anonymity. A manufacturer providing a resolving service does not need to share any information with an authoritative organization, and can use his own identification scheme for his items. Anonymity grants that queries for item identifications are not traceable by others. Furthermore, the asymmetric encryption ensures authenticity and protects exchanged data. The control of information is completely on the manufacturer's side. Therefore we also see an application area in workflow management systems controlling processes interwoven between various manufacturers.

RELATED WORK

Auto-ID center[5] aims to create standards for an "Internet of things". Identification of objects is based on RFID transponders. The resolving service uses a DNS like tree-based system called Object Naming Service (ONS) returning a resource address for extensive information about an object. With CueCat[6] users could scan an item's barcode which was sent encrypted over the Internet to CueCat's manufacturer returning the URL of an appropriate website about the item. The encryption was cracked and it was found that the manufacturer collected personal data from each scanner device. In research on security on P2P networks reputation-based approaches and protocols like XREP[2] were developed to handle various attacks. However, reputations need to be shared and as in our scenario enquirers don't share information this method cannot be applied here.

CONCLUSION AND FUTURE WORK

We presented a system design and its implementation for resolving RFIDs using a P2P network where queries and responses are encrypted and signed. This approach is marked by anonymity, security and non-traceability of queries and responses. Furthermore, it enables easy adhoc and non-authoritative extension and redundancy. Ubicomp applications benefit from this system as it provides a middleware for resolving associations between real-world objects and their virtual presence. Future investigations will look into group creation for performance and redundancy reasons and into possibilities of using this system as a generic resolving mechanism.

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Single Base-station 3D Positioning Method using Ultrasonic Reflections

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ABSTRACT
In context awareness applications the locations of people, devices or objects are often required. Ultrasound technology enables high resolution position measurements indoors. A disadvantage of state-of-the-art ultrasonic systems is that several base stations are required to estimate a 3D position. Since fewer base stations leads to lower cost and easier setup, a novel method is presented that requires just one base station. The method uses information from acoustic reflections in a room, and estimates 3D positions aided by an acoustic room-model. The method has been verified within an empty room. It can be concluded that ultrasonic reflection data contains valuable information on the 3D position of a device.

Keywords
Location awareness, location systems, ultrasonic positioning

1. INTRODUCTION
In future consumer electronics, context awareness will play an important role. Often, the locations of people, devices and objects are part of the required context information of which consumer devices need to be 'aware'. Within the PHENOM project [1], several application scenarios were developed that require in-home 3D device position information.

The required position accuracy (typically ≤ 1 m) can not be delivered by wide-area systems like GPS. Therefore, a specialized indoor positioning system is required. It may use radio waves (RF), magnetic fields, ultrasonic waves, or combinations thereof. We investigate systems based on ultrasonic waves, because of the potential high accuracy at low cost. State-of-the-art ultrasonic systems calculate distances from ultrasound time-of-flight measurements, and then use triangulation algorithms to calculate a 3D position. A disadvantage of this approach is that several units of infrastructure are required at fixed known positions in a room. Generally four base stations (BS) are required in a non-collinear setup to estimate 3D position. In special cases like ceiling-mounted BSs, three is sufficient. Fewer BSs would make positioning systems cheaper, and easier to set up. Therefore we investigate whether a positioning system can work with fewer BSs, or with just one BS (of small size) in the extreme case.

2. METHOD
A novel concept was developed [3] to realize a single-base-station 3D positioning system. It exploits reflections of ultrasonic waves against the walls, floor and ceiling of a room. How these reflections may help in position estimation will be explained in this section. A typical (processed) ultrasonic signal measured at some receiver in a box-shaped room is shown in Fig. 1. At time $t = 0$ a source emits a burst-like signal. Using time synchronization between devices (e.g. by an RF link such as in the Cricket system [4]) the receiver can measure the time-of-flight of ultrasonic signals, and then calculate the distance to the source. In the figure, the first peak at 2.89 m is the line-of-sight distance. The subsequent peaks are caused by reflections. These reflections were found to contain information about the position of the receiver. The information is contained within the pattern of amplitude peaks, called the *signature*, shown in the figure.

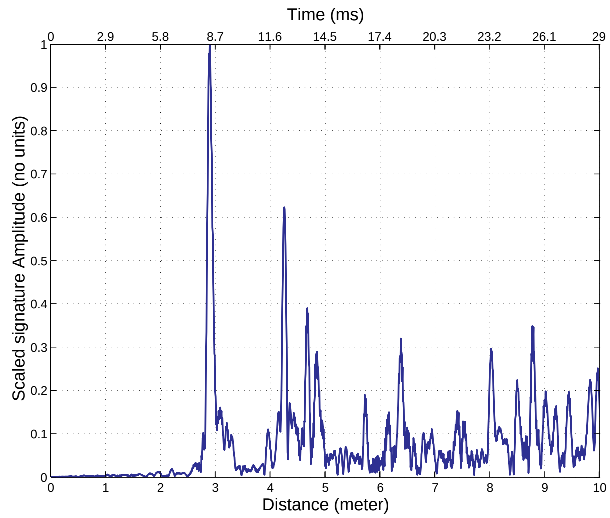

Figure 1: Measured signature at a receiver position. The horizontal axes show time (top) and corresponding distance interval $[0, 10]$ m.

Note that the fixed BS can be chosen to be either transmitting or receiving ultrasound. We chose it to be a transmitter, to allow many mobile device receivers to co-exist without causing ultrasonic interference problems between devices.

2.1 Acoustic model
To use reflections for positioning, a model was developed that relates 3D positions to reflection signatures. The fol-

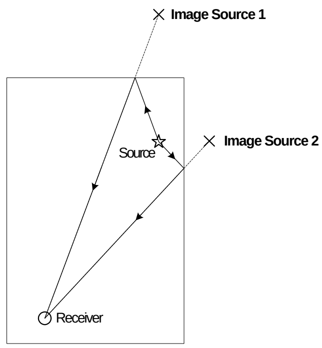

Figure 2: 2D top view of a room, containing one acoustic source and one receiver. Two acoustic reflections (arrows) and associated image sources (crosses) are shown.

lowing example will show the model's principle. Figure 2 shows a top view of a room with an ultrasound source. Two reflections of ultrasonic waves off walls are shown. These reflected waves can be considered as originating from two conceptual *image sources* marked by crosses. Many more image sources than those shown exist in a room, which can be calculated using the *image method* [2]. From here on we assume that the source shown is a BS at a fixed known position. It will give rise to many image sources, that can be seen as *virtual base stations* (VBS). We can think of VBSs as possible replacements for real BSs, thereby reducing the number of real BSs. To calculate the positions of VBSs, the room dimensions have to be known. The current room model includes 91 VBSs, and room dimensions are measured $\pm$ 5 cm accurate.

However, signatures are not only affected by position but also by device orientation. Therefore, source/receiver orientations and the directional beam pattern of ultrasound transducers are included in the acoustic model. The model furthermore includes the attenuation of ultrasound in air, resonance characteristics of piezo-electric ultrasound transducers, acoustic interference effects between reflection peaks (in case reflections arrive approximately at the same time), and wall reflection attenuation factors [3].

2.2 Signature matching method

Using the acoustic model, it is possible to calculate an expected acoustic signature given a 3D position and orientation. However, the reverse problem, of directly calculating 3D position and orientation given a measured signature, proves to be much harder. Therefore the former approach was used as our initial method for 3D position estimation, the *signature matching* method. It simply tries a set C of mobile device 3D candidate positions in the room, calculates an expected signature at these positions using the model, and compares those to the measured signature. Finally the best-matching candidate position is picked as the likely mobile device 3D position. Note that set C is a well-chosen subset of all possible room positions. Its size N_c ranged from 7243 to 11131 in our experiments, with a space between candidate positions of $\leq$ 5 cm. The current computational load for signature matching over set C is of the order $O(N_c \cdot 10^5)$ FLOPS, implying an update time of 1-10 s per measurement for an optimized implementation on a modern PC. This could be significantly improved by a smarter choice of C.

Since the acoustic model also needs a candidate *orientation* to calculate a signature, this orientation has either to be known in advance or estimated on-the-fly. Initially the former approach was used [3], but currently methods of orientation estimation are being developed.

3. RESULTS

A measurement setup was built to test the method. It consists of one piezo-electric ultrasound transmitter base station (BS) and one receiver, both connected to a measurement PC. All processing steps are implemented in software. Preliminary experiments have been performed in an empty office room, to verify the acoustic room model and to test the method in best-case conditions. The transmitter BS was fixed at a wall and the mobile receiver was placed at 20 different positions. A good position estimate was found in 18 positions, all with a positioning error of less than 20 cm. Two positions had higher errors of 0.77 m and 1.20 m. The errors were caused by a combination of three effects in the measured signature ('missing' peaks, 'noise' peaks, and random deviation of peak-amplitude from its expected value) that will be further investigated.

4. CONCLUSIONS AND FUTURE WORK

It can be concluded that measured ultrasonic signals contain useful information about the mobile device's 3D position. We propose to use this information to perform device position estimation, using a single base station per room. The *signature matching* method was developed for this purpose. Initial experiments show that the method works within an empty office room.

Future work is aimed at applying the method in realistic non-empty rooms. To realize this, several improvements to the basic method are being considered for increased robustness and calculation speed. One approach is a tracking system that integrates information from several measurements over time. Other approaches are based on small-sized transducer arrays, embedded in the base station.

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Prototyping a Fully Distributed Indoor Positioning System for Location-aware Ubiquitous Computing Applications

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ABSTRACT

This paper describes an indoor positioning system called DOLPHIN (Distributed Object Localization System for Physical-space Internetworking) that enables various physical objects to obtain their location in a fully distributed manner. We present prototype implementation and experimental evaluation of the DOLPHIN system made from off-the-shelf hardwares.

KEYWORDS

Indoor Positioning System, Distributed Algorithm

INTRODUCTION

In ubiquitous computing environment, physical location of indoor objects is one of the key information to support various applications. To obtain indoor location information, several positioning systems have been proposed. Active Bat [1] and Cricket [2] use ultrasonic pulse TDOA (Time Difference of Arrival) to measure high precision 3D position and orientation in indoor environment, but they require an extensive hardware infrastructure. However, such systems usually require manual pre-configurations of the locations of reference beacons or sensors. The setup and management costs would be unacceptably high if we apply them to large scale environment such as an office building. Ad-hoc localization mechanism described in [3] can be applied to such problem. In [3], the authors proposed collaborative multilateration algorithm to solve localization problem in a distributed manner, and performed detailed simulation-based analysis of a distributed localization system. To design practical location information infrastructure, we believe that experimental analysis is also needed to discover practical problem in distributed localization system.

From this point of view, we have developed a distributed positioning system called DOLPHIN (Distributed Object Localization System for Physical-space Internetworking) that can determine objects' position using only few manually configured references. The system is made from off-the-shelf hardware devices, and implements a simple but practical distributed positioning algorithm.

Positioning Algorithm

Figure 1 shows overview of the DOLPHIN system. The system consists of a number of DOLPHIN nodes that containing 2400bps RF transceiver, several 40kHz omni-directional ultrasonic transducers, and a HITACHI H8S/2215 16MHz CPU. The CPU is for calculating the location of the nodes. The RF transceiver is used for time synchronization and message exchange among nodes.

The key idea in our positioning algorithm is based on hop-by-hop localization. For example, in the bottom left of figure 1, node D can determine its position by receiving ultrasound pulses from the reference nodes A, B, and C. However, node E and F cannot receive ultrasonic pulses from reference nodes due to physical obstacles such as wall. Here, if the position of node D is determined, and node E can receive ultrasonic pulse from node D, node E can compute its position by using distances from node B,C, and D. If the locations of node D and E are determined, node F can compute its position using node C, D, and E. In this way, all nodes in the DOLPHIN system can be located. There are two main advantages to this mechanism. First, the system requires only a few (minimum three) reference nodes to determine all node positions. Second, nodes can determine their positions even if they cannot receive ultrasound from any reference nodes directly.

The positioning algorithm runs by exchanging several messages as shown in figure 2: ID notification message (IDMsg), measurement message (MsrmtMsg), and the location notification message (LocMsg). The nodes in the system play three different roles: there is one master node, one transmitter node, and the rest are receiver nodes. Consider the example depicted in figure 1, where nodes A, B, and C are reference node, and nodes D, E, and F are normal nodes (the position of the nodes are unknown). Here, we assume that nodes A, B, and C have node lists [B, C], [A, C], and [A, B] respectively. We also assume that node E and node F could not receive ultrasonic pulse from node A because of obstacle such as a wall.

Now consider that node A acts as a master node. Figure 2 shows the timing chart of our positioning algorithm. First, node A chooses one node randomly from its node list [B, C]. If node B is chosen, node A transmits MsrmtMsg including ID of node B. On receiving the message, node B becomes transmitter node and generates ultrasonic pulses. At the same time, nodes C, D, E, and F become receiver nodes and start their internal counters (synchronization phase). When a receiver node detects ultrasound from node B, it stops its internal counter and calculates its distance from node B. After several ms (this depends on the time taken by the overflow of the internal counter), node B sends LocMsg to notify receiver nodes of its position. Receiver nodes that could detect the ultrasound pulse from B store the location of node B and their distances to node B in their position table (measurement phase). After that, all nodes listen IDMsg for several ms (advertisement phase). If there is node that could determine its position based on three or more distances, it advertises its ID in this phase. This ID is added to the node list of every other node. In the above example, because nodes D, E, F cannot determine their positions, no IDMsg is sent in this phase. The sequence of the above phases defines one cycle of the positioning algorithm in the DOLPHIN system.

In the next cycle, node B, which acted as a receiver node in the previous cycle, becomes a master node. And the positioning algorithm proceeds in the same manner. After three or more cycles of positioning, node D can determine its position based on measured distances from nodes A, B, and C. At which time, node D can send its IDMsg in the advertisement phase. All other nodes that received the IDMsg from node D add the ID of node D to their node lists, and node D is recognized as a candidate master node. After node D becomes master node, node E and node F can measure their distances from node D. Then, node E can determine its position and advertise its IDMsg. Finally, based on nodes C, D, and E, node F can determine its position. In this way, we can locate all nodes in the DOLPHIN system.

In the DOLPHIN system, we have to prepare for two types of failures, node failure and recognition failure, to continuously execute the above mentioned positioning algorithm. The node failure is that the node suddenly stops because of unpredictable accident, and the recognition failure is that the IDMsg transmitted from the node capable of master node does not reach other node because of bad communication channel or message collision. To recover from those failures, each node in the system has a recovery timer and an advertisement timer. The recovery timer is set when nodes receive MsrmtMsg, and expires if there has been no MsrmtMsg for a certain period (e.g. 1.5 second). If the recovery timer expires, a node is chosen to become a master node randomly, and the positioning algorithm continues. If a node capable of master node does not receive MsrmtMsg from other nodes within a certain period (e.g. 10 seconds), the advertisement timer in the node expires. Thus, that means the node is not recognized as a node capable of master node by other nodes. In this case, the node retransmits IDMsg at advertisement phase in each positioning cycle. Note that to avoid IDMsg collision at advertisement phase, the node sends IDMsg at a certain probability which determined by the number of nodes in the node list.

Experimental Result and Future Work

We placed seven nodes as shown in figure 3, and computed the average and the variance of the measured position of each normal node (nodes D-G) for 1000 cycles. The results showed that the system could determine objects' position with an accuracy of around 15 cm in actual indoor environment. However, positioning error increases at nodes E-G compared to that at node D. This is because the positioning error at node D affects position determination of nodes E-G that determine their position based on node D. Although this error propagation problem is inherently unavoidable in the DOLPHIN system, we expect to minimize positioning error by placing reference nodes at appropriate locations.

Since current prototype is a handmade system, the performance of the system may be insufficient to support many indoor location-aware applications. In addition, the number of nodes is too limited to measure the performance in large scale environment. Currently we are designing improved version of the system that can handle practical problems such as multipath propagation, node mobility as well as scalability problem in large scale environment.

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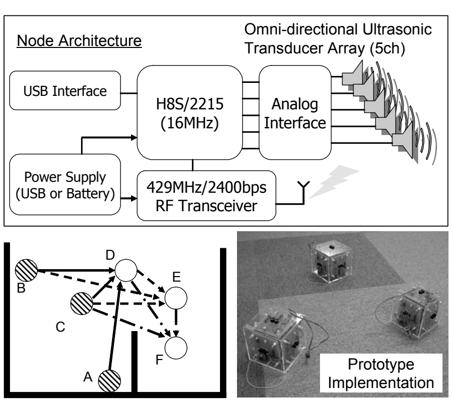

Fig.1 System Overview

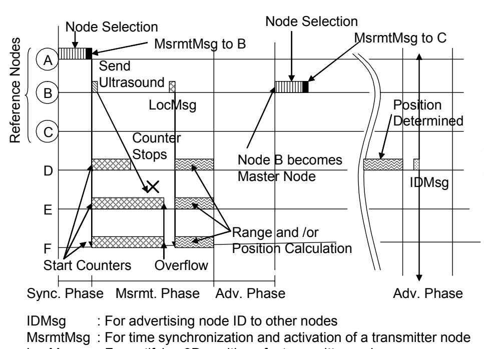

Fig. 2 Positioning Algorithm

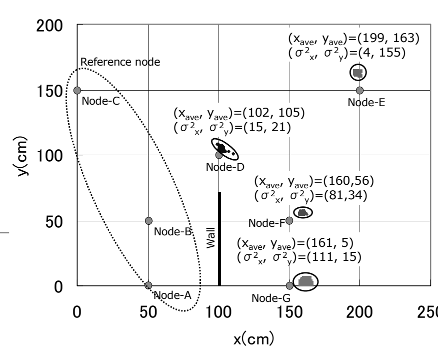

Fig. 3 Experimental Result

Connectivity Based Equivalence Partitioning of Nodes to Conserve Energy in Mobile Ad Hoc Networks

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ABSTRACT
The nodes in Mobile Ad Hoc Networks (MANETs) work on low power batteries. So, reducing energy consumption has been the recent focus of wireless adhoc network research. The power in the nodes dissipates even when the network interface is idle. In this paper, we present a topology maintenance algorithm, *Equivalence Partitioning method* which is based on the connectivity among the nodes in the network. This algorithm partitions the network into equivalence sets in which one of the nodes in the set is active and the other nodes in the set turn off their radio. This algorithm takes care that the capacity or connectivity of the network does not diminish significantly. This is a simple, distributed, randomized algorithm where nodes make local decisions to form the equivalence partitions and go to on or off state. In addition, this topology maintenance algorithm can be made to work along with the 802.11 power saving mode to improve communication latency and system lifetime.

Keywords
Equivalence partitioning, on state, off state, active node

INTRODUCTION

Wireless multi-hop adhoc networking has been the focus of many recent research and development efforts for its applications in military, commerce and educational environments. Most of the protocols that have been proposed to provide multi-hop communication in wireless adhoc networks [2, 3] are evaluated in terms of route length [4], routing overhead, and packet loss rate. But minimizing the energy consumption is an important challenge in mobile networking. Since the network interface may be often idle, power could be saved by turning off the radio when not in use. But the coordination of power saving with routing in adhoc wireless networks is not straight forward. The subject of this paper is to present a topology maintenance algorithm which partitions the network in such a way that one on the nodes in each partition must be active so that the connectivity of the network does not diminish and the other nodes can turn off their radio. The responsibility of the active node is randomly changed so that every node is treated equally and the life time of the over all network is increased.

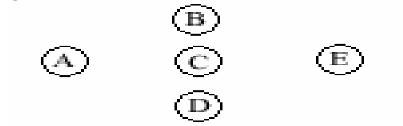
RELATED WORKS

Reducing energy consumption has been the recent focus of wireless adhoc network research. The Geographic Adaptive Fidelity (GAF) [5] scheme of Xu et al. self configures redundant nodes into small groups based on their geographic locations and uses a localized, distributed algorithm to control node duty cycle to extend network operational lifetime. But in many settings, such as indoors or under trees where GPS does not work, location information is not available. The dependency on global location limits GAF's usefulness. In addition, geographic proximity does not always leads to network connectivity. The SPAN [1] scheme of Chen and Jamieson proposes a distributed algorithm for approximating connected dominating sets in an adhoc network that also appears to preserve connectivity. SPAN elects coordinators by actively preventing redundant nodes by using randomized slotting and damping. Equivalence partitioning differs from GAF as it constructs the partitions based on the connectivity information rather than the geographic location of the nodes. Also unlike SPAN, it constructs equivalence partitions and randomly rotates the active nodes within the partition.

EQUIVALENCE PARTITIONING DESIGN

In Equivalence Partitioning technique, we divide the network into different sets of equivalent nodes, so that one of the nodes in the partition can be active in order to maintain the connectivity and the rest can remain in their power saving mode. The role of the active node is randomly chosen so that the burden of forwarding, sending and receiving data is distributed evenly to all nodes.

Partitioning the network into Equivalence Sets



Figures 1: A network with five nodes

This is a distributed randomized algorithm for connecting equivalence partitioning among the nodes in the network. Consider the network shown in Figure 1. The nodes B, C, D are in the path between the nodes A and E. In this case all the three nodes need not be awake to forward the packets from node A to E. We treat that the nodes B, C, D form an equivalent partition it is sufficient that one of the nodes to be awake to maintain the connectivity. This Equivalence Partitioning algorithm is as follows.

- The node N_i constructs its neighbor set by sending HELLO packets to its one hop neighbors. The nodes hearing this packet respond with a HELLO reply so that the node Ni constructs its neighbor set. Let NH_i be the neighbor set of node N_i
- Now, N_i advertises its neighbor set to its one hop neighbors so that it can find out the number of pairs of its neighboring nodes connected via this node.
- Find the intersection between the neighbor sets of the adjacent nodes. Let C be the cardinality of the intersection set with the first neighbor.
- If the cardinality is equal to or more than two, then form an equivalence partition and assign a unique partition id to the nodes.
- Consider the next neighbor. Let C' be the cardinality of the intersection set between the node Ni and its neighbor currently considered. If C' > C, a new group is formed between the node Ni and this neighbor, destroying the previous partition.
- If C' = C with same elements then add the new neighbor to the same partition and assign the partition id.
- Repeat the above process until each node receives the neighbor set from all its one hop neighbors.

Each and every node is exactly in one of the partitions.

Active Node Announcement

Once the Equivalence partitions have been constructed and the nodes have their partition id, the active node in the partition must be elected. The following strategies can be used to elect the active node.

- When we start with a new network all the node will have the same power. In this case, the node with the least id in the partition can be chosen to become the active node.
- When the power among the nodes in the partition is not equal, then the node with the maximum power or the maximum estimated lifetime can be chosen to be active.

The nodes remain active for a time T seconds which is dependent on the application. The active nodes can be randomly rotated in round robin fashion or based on heuristics which take the expected life time of the node into consideration.

Compatibility with 802.11 Power saving mode

This topology maintenance algorithm can be used along with the 802.11 power saving mode to improve the system lifetime. An interesting question is how a node in the *off state* handles traffic originating from it or destined to it. In the former case, if the node has data to send it can simply power on its radio and send out data. In the later case, the 802.11 power saving mode can be used in which the active nodes can temporarily buffer data for the nodes in the *off state* and send data later.

RESEARCH CHALLENGES AND FUTURE WORK

The simplicity and the fast convergence of the Equivalence partitioning algorithm would further lot of research challenges. We are currently working on in finding the optimal way of choosing the active node in a partition and the random rotation policy. Different heuristics related to the rotation of the active nodes are being analyzed so that all the nodes in the network are treated evenly and the overall network lifetime increases. More evaluation of the partitioning algorithm should be performed, to determine convergence time and the adaptability to network mobility. The cases in which the active node moves far from the remaining nodes and the value of the optimal time after which the partitioning algorithm must be undertaken should be analyzed. We have presented a topology maintenance algorithm, and have shown its benefits. It is our belief that this approach opens up new areas of research in energy conservation in mobile adhoc networks. We have provided a basis for discussion of a number of research issues that need to be addressed to improve the performance of the overall network.

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Self-configuring, Lightweight Sensor Networks for Ubiquitous Computing

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ABSTRACT

We show that it is possible to extract geometric descriptions of the spaces observed by sensor networks, even if the network consists of sensors that are of very limited ability: such as motion detectors. By using statistical techniques and relying only on the unconstrained patterns generated by the occupants of the building we show how to recover information about sensor geometry. This is important to the ubiquitous computing community since ubiquitous sensors and the context that the provide will only become a reality if the sensors are cheap, low-power, and self-configuring.

Keywords

sensor networks, adaptive, geometry, calibration

1. INTRODUCTION

The occupants of a building generate patterns as they move from place to place, stand at a corner talking, or loiter by the coffee machine. A cheap network of sensors can sense these patterns and provide useful information to all of the context sensitive systems in a building, but what makes such a network cheap? As the sensing and computational elements become cheaper to manufacture, the cost of such a network is quickly becoming dominated by installation, configuration and maintenance costs.

This paper explores some of the possibilities that exist for such networks to auto-calibrate, given only the unconstrained movements of those being observed. Furthermore we strive to adopt an approach that will limit computational overhead. That means that the algorithms should not require recognition, tracking, or any but the absolute simplest of perceptual mechanisms. In fact, we will assume for the rest of this paper that our sensors are simple motion detectors. We also assume that the system will consist solely of sensors embedded in the environment, and not any component that navigates or is carried through the environment.

2. RELATED WORK

Many ubiquitous context projects start from the assumption that the human inhabiting the space will be an active participant in the system[6], or that the system will accomplish calibration by utilizing an active element that can explore the environment[4]. For many applications, the level of detail desired about the building geometry does not warrant this level of labor cost or system complexity.

There is a significant body of literature on modeling typical patterns and finding atypical patterns in behavior of observed humans[1, 3, 5]. These approaches all assume accurate tracking as a precondition. This paper strives to demonstrate that this expensive perceptual process may not be necessary for some tasks, such as auto-configuration.

3. OUR SENSOR NETWORK

We have covered $175m^2$ of office space with 17 ceiling-mounted sensors and collected motion event data. The sensors report motion events in their active area at 7.5Hz. They adapt to novel, but perfectly stationary objects, and other changes in the environment, on a 20 second time-scale.

The area covered consists of the high-traffic core of our building: the elevator lobby, reception lobby, restroom entrances, and connecting hallways.

In fact, for this experimental setup, the sensors are cheap, IEEE-1394, board cameras. They are mounted in the ceiling, pointed straight down at the floor with 75 degree angle lenses. The imagery from the cameras is processed by an adaptive background subtraction algorithm[7] built on top of the Open Computer Vision Library[2]. Obviously this is not the cheapest way to implement motion detectors, but it does provide the maximum flexibility for experimental design.

4. THE EXPERIMENTAL SETUP

Since the sensors are cameras, it was possible to use well-known techniques to recover the geometry of the cameras relative to the space observed. This provides us with ground-truth about the positions and viewing areas of the sensors that we can use to validate our experimental results.

Since we treat the cameras simply as motion detectors, the underlying representation of the data will be the *event list*: $E_{j,t}$. The event list $E_{j,t} = 1$ if there was a motion event at time t in sensor j. These events indicate merely the presence of some kind of motion anywhere in the field of view, but no indication of the number of people, the direction of motion, or any other such secondary information.

Our low-cost perceptual engine will be co-occurrence statistics: $C_{i,j,\delta}$. The co-occurrence is the count of events that co-occur at a given temporal offset:

$$C_{i,j,\delta} = \sum_{t=0}^{\inf} E_{i,t} E_{j,t+\delta}$$

where $\delta \geq 0$, and $E_{i,t}$ is a boolean value. For a given temporal offset, it is useful to manipulate the $i \times j$ co-occurrences between all sensors, for a given time offset, as a matrix. For

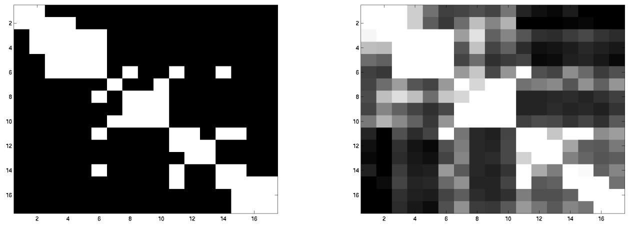

Figure 1: The ground truth overlap (left) compared to the statistical transition probability matrix (right).

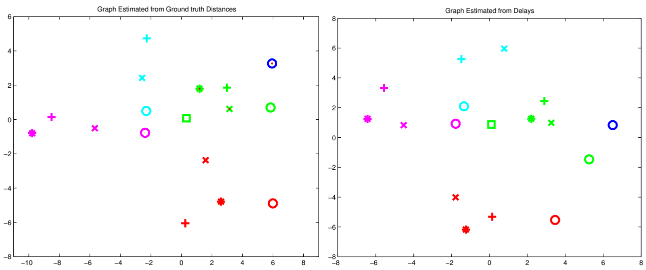

Figure 2: The ground truth distance map (left) compared to the peak-delay map (right). Distance in meters.

a given pair of sensors, it is also useful to consider the family of co-occurrences parameterized by the temporal offset. Taken together, the $C_{i,j,\delta}$, for all possible δ are equivalent to the cross-correlation of the event lists for sensors i and j. However, the entire cross-correlation is not useful, and is very memory-intensive to compute, so we will only ever consider relatively small values δ: in particular, values that represent time-scales that are relevant to human behavior.

5. RESULTS

We can demonstrate two things from this data: co-occurrence matrices that reveal the structure of the sensor overlap and structure in peak offsets in the co-occurrence matrices that reflect the relative distances between sensors.

The $C_{i,j,0}$ co-occurrence matrix shows us the sensors that exhibit synchronized events. Since sensors always instantaneously co-occur with themselves, we see the highest values on the diagonal. However, off-diagonal elements with high values indicate sensors that overlap: they are often seeing the same event. Given that there are an unrestricted number of people moving around the space, we expect noise from coincidental events, but Figure 1-right shows that this noise is low compared to the signal. For this sensor network, we get 97% of the 136 non-trivial overlap decisions correct. Furthermore, all the false-negatives (3 of the 4 total errors) are actually mistakes in the ground-truth: two situations where un-modeled walls block views from sensors that would otherwise overlap, and one case where the geometry predicts a tenuous overlap that is obscured by un-modeled radial distortion in the lens of the sensor. Leaving out these errors gives us a 99% accuracy.

The windowed cross-correlation represented by $C_{i,j,\delta}$ over all δ and a given pair of sensors provides a way to estimate the average trip time between the two sensors. The time offset corresponding to the first major peak for a set of cameras provides an estimate of the average trip time between the sensors. If people only ever transit uninterrupted between these sensors, then we could simply take the maximum of the cross-correlation, as in audio localization. We can use these pairwise constraints to form an estimate of the relative geometry of the whole network. These results are shown in Figure 2. On the left is the recovered geometry from the ground-truth distance constraints. On the right is the recovered geometry from the estimated inter-node transit times.

For our dataset, discounting the global scale ambiguity, we obtain an average error of $2.2m$ with only 4 hours of data. If we only consider a sub-set of the sensors that do not overlap, we obtain a slightly higher average error of $2.4m$. Our sensors monitor $3.7m \times 4.9m$ rectangles, so both of the figures represent sub-pixel accuracies.

6. CONCLUSION

We have shown that it is possible to extract descriptions of the spatial arrangement of a sensor network with very little computation, very poor sensors, and limited constraints on the behavior of the people inhabiting the space. This is important to the ubiquitous computing community since ubiquitous sensors will only become a reality if they are cheap, low-power, and self-configuring.

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Grouping Mechanisms for Smart Objects Based On Implicit Interaction and Context Proximity

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ABSTRACT
When everyday objects become equipped with computation and sensors, it will be important to explore interaction techniques that rely on natural actions. We show examples of how non-accidental simultaneous movement of "smart" objects can be exploited as implicit interaction. Applications include implicit access control when opening a door and an automatic packing list creator. This principle of implicit interaction based on non-accidental movement patterns can be extended to other context parameters, forming a context proximity hierarchy.

INTRODUCTION
As defined by Weiser, ubiquitous computing is "invisible, everywhere computing that does not live on a personal device of any sort, but is in the woodwork everywhere." [3] In some ways, this vision could prove to be as much a problem as a solution! When more and more everyday artifacts and environments become augmented with computation and sensing, new problems arise in the design of human-computer interaction, since every object becomes a potential input device. Much like peripheral and ambient information displays have been introduced to lessen the strain of information overload, various ways of background sensing and interaction will need to be developed to avoid potential problems in users' interaction with computer-augmented environments.

One solution to this problem would be to design interfaces based on *implicit human-computer interaction.* This has been defined as "an action, performed by the user that is not primarily aimed to interact with a computerized system but which such a system understands as input." [2] In other words, whereas the user continues to interact with everyday objects as normal, we may use these actions as a sort of "side-effect" to also produce input for a computer system.

We are exploring how we can create implicit interaction with everyday artifacts that are equipped with sensors of various kinds. More specifically we exemplify how *non-accidental movements of objects* can be used to support implicit HCI. By using accelerometers attached to everyday objects, it is possible to detect if two or more objects share the same movement pattern. This information can be used to support everyday tasks, without introducing any additional interaction demands to the user. Other context parameters besides movement can be used in a similar fashion for implicit interaction. We call the resulting principle the *context proximity hierarchy*.

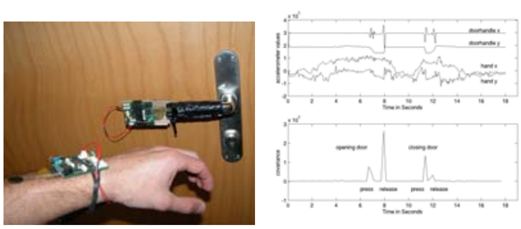

Figure 1: Access Control example, showing the door handle and the person's wrist equipped with accelerometers (left). Acceleration values of the door handle and the persons hand (top right). and the correlation measure use to detect the use of the door handle by a certain person (lower left).

AN EXPLICIT GROUPING MECHANISM: SMART-ITS FRIENDS
Smart-Its Friends [1] is an example of a grouping mechanism based on *explicit* interaction. When a user wants to tell two or more "smart" objects that they belong to the same group, she holds them together and shakes them. Via radio communication, all objects continuously communicate their trajectory, as determined by accelerometers. Since the objects that are shaken together will be the only ones that have the same trajectory, they can use this information to create a grouping.

The underlying principle of Smart-Its Friends uses an explicit gesture – shaking – to group and establish a special relation between objects. This principle has many interesting applications: If you want to be sure that your wrist-watch beeps whenever you leave your cell-phone behind you simply shake them in order to make them "friends". Even though the underlying principle is general and powerful in itself it does require an explicit action from the user. Rather than to rely on explicit interaction this paper explores implicit interaction based on non-accidental movement patterns to establish a special relation between objects.

TWO EXAMPLES OF IMPLICIT INTERACTION BASED ON NON-ACCIDENTAL MOVEMENT

Access Control
Today, many access control systems are installed, so that (restricted) access can be granted to people. Those access control systems usually require an explicit action from the employee such as to swipe an identification badge or to use a specific number key which are prone to be lost or forgotten.

Here, we propose to use the action of pressing the door handle – which is necessary to open the door – to identify the person, and give him the appropriate access. For this we use two accelerometers: one on the door handle and one on the person's wrist (Figure 1). When the person presses the door handle we detect the simultaneous acceleration pattern of the door handle as well as the wrist. By verifying that the owner of the wrist-accelerometer is indeed allowed to access this particular door, the system can grant permission to that person by opening the lock. This is an example of implicit interaction since the only action required from the person is the normal door-opening action namely pressing the door-handle. Figure 1 shows 2D-acceleration data of the door handle and of the person's hand pressing the handle twice. The correlation measure between the signals clearly shows how the pressing of the door handle can be detected.

Automatic Packing List Generation

The task of packing a set of goods into a box and then having to generate a packing list is common in both industry and everyday life. For instance, at a typical Internet retailer, books or other items belonging to an order are packed in a box and an invoice is generated. In other industries mechanical parts, computers, or raw materials are packed and labeled before shipment. Even when moving your household you would be happy to know in which box you packed that fragile set of crystal glasses or some essential piece of clothing.

By attaching accelerometers to the goods, we can record the individual movements of the goods and determine which possess similar movement patterns. The normal action of moving the box around serves as an implicit grouping mechanism of all items in that particular box. The similarity of the movements of those items is again non-accidental since the items packed in the same box will be the only ones that have the same trajectory. Determining the similarity of the movements is therefore sufficient to group those objects, which are packed together. When the objects have been grouped, a packing list of all items can be generated, or other checks on the goods could be performed such as completeness of an order.

Implementation Details

The above demonstrations are based on Smart-Its technology [4]. We used the standard configuration of the Smart-Its sensor board including a 2D-acceleration sensor (ADXL 202). This is combined with a radio frequency communication module, also part of the Smart-Its platform. To decide whether two or more objects are moving together, it is sufficient to calculate the correlation value between the objects acceleration values signals, which gives us a measure of how likely the objects, are to be in the same group. In the demonstrations a Smart-It was attached to each object, transmitting its acceleration values to a central processing unit, which is then responsible of calculating the similarity between the movement trajectories.

CONTEXT PROXIMITY

The detection of non-accidental movements can be viewed as comparing a part of their context. The next step is to compare other contextual information of objects to enable applications where the moving of objects is not realistic or not desired.

Table 1: Context Proximity Hierarchy

Level	Physical characteristics/events
dynamics of the objects	object movement, light changes, …
dynamics of the environment	people moving, light switching on/off, doors banging, …
static state of the environment	"weather", temperature, light level, noise level, …

Table 1 shows a more general approach to classifying different types of physical characteristics for comparing context. We call this approach a "Context Proximity Hierarchy" as the context of two entities can be compared on any of the given levels. In this hierarchy we have classified the movement of the objects in the first level, namely the "dynamics of the objects". All examples presented above draw their context information from this level. When object movement is not available the "dynamics in the environment" can be used to gain knowledge about the situation the objects are in. Here the effects of events such as people moving about in the surroundings, doors being banged, people talking, or lights being switched on and off can be captured by sensors. On the lowest level the comparison of the static characteristics of the environment is modeled. These consist of the physical parameters of the environment such as light, noise level, and temperature, which might be subsumed as "weather" data. They can be used to get a prior about whether the objects might have a similar context or not. This information could for instance be used as a baseline to make the grouping mechanisms more reliable.

CONCLUSION AND FUTURE WORK

We have shown how a basic grouping mechanism can be implemented and used to provide implicit input for everyday tasks. Our current implementation is based on exploiting the non-accidental movements of two or more objects to determine if they are moved together. In the future, as the cost of sensors and communication technology decreases, we will likely see sensors added to a variety of objects and find a multitude of uses for them. In this case implicit interaction techniques such as those presented above might help to decrease the complexity of human-computer interaction in many everyday situations.

ACKNOLEDGEMENTS

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Inside/Outside: an Everyday Object for Personally Invested Environmental Monitoring

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ABSTRACT
Inside/Outside explores distributed networking, information delivery, and wearable technology. We have developed a wearable accessory that measures and displays environmental factors in real-time and keeps a data diary of environmental exposure. The accessory can be networked with other accessories to form a mobile distributed environmental sensor network, providing users with locally specific and personally invested access to information about their environment.

Keywords
Mobile, ad-hoc, ubiquitous, wearable, fashion, smart textiles, distributed systems, networks, data collection, information retrieval, visualization

INTRODUCTION
This work is part of a body of research that focuses on the behavior of people in public and urban space. While services exist to alert individuals of daily environmental conditions few personal devices exist to provide real-time and cumulative information regarding environmental exposure. This research explores how ubiquitous everyday objects can be used to deliver such information to users in urban zones personal and engaging ways. In particular Inside/Outside integrates environmental sensors with an ordinary fashion accessory (the handbag) to provide an aesthetically and functionally integrated object. Through the manipulation of the fashion features of the bag Inside/Outside has the ability to present information to the user in alternative and new ways. This *Information in Disguise*, can provide an aesthetic experience while fulfilling a functional role of data gathering and data visualization. When multiple Inside/Outside bags are worn by different individuals at the same time a distributed and mobile environmental sensor network is formed, providing users with locally specific and personally-owned access to information about their environment. Information about environmental exposure can be shared with others, possibly leading to collective changes in urban behaviors, and altered urban economic relationships as new valuations and mappings of the city are formed by the provided data. This paper illustrates the main design concepts involved in the project and describes the initial prototypes that have been designed as part of this research.

RELATED WORK
Before detailing Inside/Outside it is useful to note the increased interest in the design of everyday objects and smart textiles for a ubiquitous computing environment. Conductive fabric, embroidery, and textile materials are enabling the integration of interactive elements into clothing, accessories, and furniture. [1] Meanwhile design approaches that integrate aesthetics and functionality [2] are gaining new currency, alongside the development of applications for ambient media. [3] However, despite the emergence of networked and distributed systems utilizing familiar interfaces such as *Pin & Play* [4] few projects have integrated these concepts into clothing and everyday wearable accessories.

Figure 1. Changes in environmental factors cause the handbag surface to change color.

CONCEPTUAL OVERVIEW

Digital Familiars
Like many common everyday objects the handbag has a familiar interface and functionality that many people can already relate to. While an ordinary handbag might collect physical objects, Inside/Outside collects *digital data* about the surrounding environment. The combination between new and established qualities of the everyday object promotes cooperative interaction between the object and the user.

Information in Disguise
By embedding information into everyday objects new significations of existing objects can emerge. Useful data is integrated into everyday objects in a way that neither

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disrupts nor fundamentally alters the object's original use, but *enhances* the functionality already present. When presenting the collected digital data back to the user, the decorative qualities of the handbag are accented creating a spontaneous street "performance" for the user and casual observers. People who do not own an Inside/Outside bag can benefit from being able to view and interpret the data presented on bags carried by other people on the street.

Personally Invested Information Access

Inside/Outside can function as a stand-alone personal environmental monitoring system or be part of a distributed sensor network. The environmental sensing capabilities of the bag belong personally to the user. This creates a sense of identification and empowerment as data is collected locally and stored, allowing users to decide for themselves how to use and interpret the information they receive. When a network of bags form and collective readings of the sensors input are examined, detailed and locally specific information about "micro-climates" of pollution can be identified for the community, possibly changing behavioral patterns in the city over time.

IMPLEMENTATION

The Inside/Outside handbag is integrated with environmental sensors, and smart textiles and utilizes the DAWN [5] wireless network infrastructure (DAWN is a Trinity College wireless network test-bed). Initial conceptual designs were based on informal surveys and workshops conducted with city dwellers and pedestrians from Dublin, Ireland and Los Angeles, California. The two cities were selected to maximize differences in lifestyle, culture, and urban behavior.

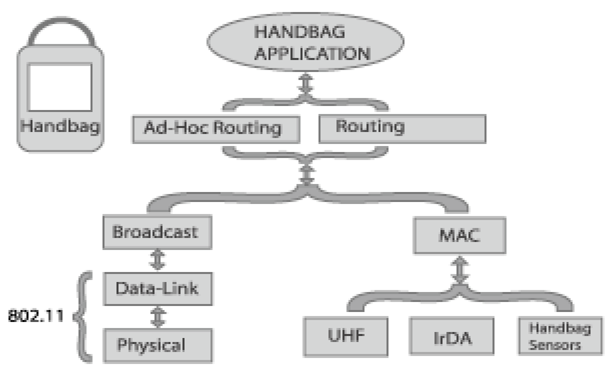

Figure 2. System Diagram

The Handbag

The Inside/Outside handbag uses an air quality sensor and audio microphone input connected to a microcontroller. As the user carries the bag through the city, changes in ambient air quality and noise levels cause conductive embroidery on the bag surface to heat and subsequently cool. [Fig.1] Thermo-chromic pigments mixed with acrylic paint and applied onto a fabric substrate create a visible color change that is both controlled and programmable.

Network Communication and System Design

Inside/Outside sits on top of the DAWN ad-hoc network. [Fig.2] Sensor data is sent through the communications stack to the desktop application. The aggregate data provides a *data diary* of environmental exposure levels. The project has the potential to make use of all the ad-hoc networking capabilities of DAWN, as modular design of the system will allow for additional functionality to be easily added to the system as development of the project continues.

CONCLUSION &FUTURE RESEARCH

Initial prototypes for Inside/Outside are complete. Early evaluations show promising results. There is interest in the project from individuals who are usually un-interested in computing gadgets, though detailed user studies need to be conducted to confirm this. New scenarios and prototypes, which address intercommunication between the Inside/Outside handbag and other environmental elements and bag nodes, will developed, as well as continued exploration and exploitation of the ad-hoc networking capabilities of the project, especially in relation to mobility and parasitic deployment of sensor networks within the urban zone. As a wearable everyday object Inside/Outside provides a compelling context for research into public space and urban behavior.

ACKNOWLEDGMENTS

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i-Beans: An Ultra-low Power Wireless Sensor Network

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ABSTRACT

This paper presents a newly developed short-range, ultra-low power wireless device called the "i-Beans", an ad hoc, self-organizing network protocol, and their application to low data-rate ubiquitous computing applications.

0.1 Keywords

Wireless sensors networks, low-power sensor networks, low data-rate networks, i-Beans.

1. INTRODUCTION

Self-organizing, wireless sensor networks have immediate utility in a variety of industrial, medical, consumer and military applications. But, several challenges need to be addressed before these applications can be realized.

We think designing a sensor network that is suitable for applications with very different requirements - data rates, reliability, power requirements, cost, etc can be too complex a design problem to solve. We have focussed our research on developing a sensor network tailored for applications that require low-data rate (< 115 kbps) and limited computing resources. By studying these applications, we find that the following represents the most common modes of acquiring and propagating sensor data: 1. Periodic Sampling (for e.g., temperature sensing in a conditioned space) 2. Event Driven (for e.g., fire alarms, door and window sensors) 3. Store-and-Forward (sensor data can be captured and stored or even processed by a remote node before it is transmitted to the central base station).

To support these applications, we have developed a reliable and ultra low-power sensor network platform called the i-Bean network. The system details are presented next.

2. SYSTEM DETAILS

As shown in Figure 1, the i-Bean network is composed of three types of devices that are interconnected using RF links. The devices are:

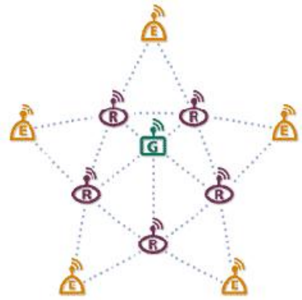

Figure 1: i-Bean Network. (E - Endpoint, R - Repeater, G - Gateway)

1. i-Bean (or Endpoint) - These are the devices that are directly connected to sensors and embedded in the operating environments. They are tiny (25 x 15 x 5 mm) and power efficient. Each endpoint provides four 8-bit analog input channels, four digital I/O channels, and an UART port for interfacing with sensors and actuators. Multiple sensors/actuators can be connected to an endpoint.
2. Repeater (or Router) - Repeaters extend the transmission range of endpoints. Routers are small - 56 x 33 x 5 mm. They consume more power than endpoints as they remain active all the time.
3. Gateway (or Base station) - Gateway is also compact (64 x 51 x 5 mm). It serves as the gateway between i-Bean network and host computers. A base station can be connected directly to a RS-232 port of a host computer and gets power from it. While there can be multiple repeaters and endpoints, there is only one gateway in an i-Bean network.

2.1 User Interface

We have developed a simple monitoring program that runs on host computers. This program can be used to monitor the state of i-Bean networks and modify various operating parameters of i-Beans such as sampling rate, digital input-output channels, ADC and DAC channels etc.

2.2 Significant Features

The significant features of this system are power efficiency and a robust networking protocol. They are described in the following sections.

2.2.1 Power Efficiency

Power efficiency is a critical factor in wireless sensor networks. Although power consumption must be minimized at all points in the system, power consumed by endpoints must be optimized to a higher degree since there are more endpoints in the network than any other device and also replacing their batteries would be more difficult, as they could be deployed in inaccessible operating environments.

We employ the following techniques to optimize power consumed by i-Beans:

- Dual Processors - Each endpoint has two processors: 1. a high speed processor that usually executes tasks related to RF circuitry. 2. a low speed processor that usually executes conventional computing and I/O tasks. A process called coordinator running on one of these processors allocates tasks in such a way that tasks are run on slower of the two processors and the unused processor is placed in sleep mode. A substantial amount of power is saved by putting the high speed processor in sleep mode for most of the time.

- Heterogeneous Nodes - Endpoints, repeaters and gateways perform totally different functions. Endpoints can either be source or destination of network data, but cannot forward data for any other nodes. This frees endpoints from active listening and they can conserve power by being in sleep mode while not communicating or computing. The repeaters are solely responsible for routing data in the network. Further, i-Beans conserve power by transmitting low-power signals; the repeaters in the vicinity forward their packets to the destination using high power signals.

- Bottom-Up Networking - Endpoints do not waste precious power listening to periodical beacon signals; instead they stay in power saving mode most of the time and wake up occasionally according to their own communication schedule.

Please see our paper [4] that focuses on power conservation strategies for complete details.

2.2.2 Robust Network

The devices in the i-Bean network self-organize themselves into a network and reconfigure themselves if there is any change in the network. The network is self-organizing, self-healing and yet power efficient. As shown in Figure 1, the topology of i-Bean network is a star-mesh hybrid. This hybrid topology takes advantage of the power efficiency and simplicity of the star topology for connecting i-Beans to routers and reliability and reach of mesh networks for interconnecting routers to achieve fault tolerance and range.

We also utilize several other innovative techniques such as generating true random numbers from RF noise, progressive search (devices search using short messages and employ complete messages only after establishing connections) etc to increase reliability of these networks. Please see the publications on our website for further details.

3. RELATED WORK

Researchers have developed several wireless sensor networking platforms. A few prominent ones are Smart Dust [2], BTnodes [1], and Pushpin Computing [3]. i-Bean network is different from these platforms in the following respects:

1. These systems are composed of homogeneous nodes (identical hardware) that perform specialized functions in runtime by using different software; whereas i-Bean network is composed of three different types of devices. The heterogeneous system makes it possible to assign complex functionality to routers and to simplify endpoints, thereby reducing their power consumption.

2. They intend to be general purpose sensor networking platforms, whereas i-Bean network is tuned for low data-rate applications.

3. Their end nodes are capable of performing relatively complex computations. We use endpoints only to interface with sensors and actuators.

4. DISCUSSIONS AND FUTURE WORK

From our preliminary studies, we find that power consumption in i-Bean networks is extremely low. For instance, when powered by a small coin battery (CR2032) with a capacity of 220mAh, the average current consumed by an i-Bean is approximately 100 μA, when the sampling rate is one sample per second and therefore battery will last for about 80 days. If the sampling rate is decreased to one sample per 120 seconds, average current consumption drops to 1.92 μA and increasing the battery life to about 13.1 years. [1]

We need to perform more experiments to understand the impact of our design decisions and tradeoffs when the network is extremely large (> 1000 nodes), since even simple protocols and algorithms can exhibit surprising complexity at scale.

We are also working on further optimizing our algorithms, protocols and hardware.

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[1] Any number more than 10 years may be meaningless, since the battery shelf life itself may be less than the computed time.

A Rule-based I/O Control Device for Ubiquitous Computing

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ABSTRACT

In this paper, we describe a rule-based I/O control device for constructing ubiquitous computing environments, where we can acquire various services using embedded computers anytime and anywhere. The capability of our device is very limited, however, it has flexibility for changing its function dynamically by applying rule-based technologies to describe the behavior of the device. We design the behavior description language and develop a prototype of this device.

Keywords

I/O Control, ECA Rule, Active Database

INTRODUCTION

In this paper, we propose a new computing style using rule-based I/O control devices for realization of ubiquitous computing environments, where we can acquire various services with embedded computers anytime and anywhere. In ubiquitous computing environments, following three characteristics are required for computers:

(1) Autonomy: computers process automatically without human operations

(2) Flexibility: computers are applied for various purposes

(3) Organic cooperation: complex behaviors are achieved by organic coordination with multiple computers

We propose the rule-based ubiquitous computing to satisfy these three characteristics.

RULE-BASED UBIQUITOUS COMPUTING

Generally, a person comprehends an event in the real world as a causal relation. Therefore, we apply this principle to describe behaviors of ubiquitous computers by using ECA rules as the programming language. An ECA rule consists of following three parts:

- EVENT(E): Occurring event
- CONDITION(C): Conditions for executing actions
- ACTION(A): Operations to be carried out

ECA rules have been used for describing behaviors of an *active database*. An active database is a database system that carries out prescribed actions in response to a generated event inside/outside of the database. Since system behaviors are expressed by a set of rules, system functions can be changed/customized easily by adding, deleting, modifying some rules.

In conventional active databases, database operations such as *SELECT*, *INSERT*, *DELETE*, and *UPDATE* are considered events and actions. Since ubiquitous computers may have little processing power and small memory, we simplify language specification of the ECA rule while keeping the capability to fulfill various requirements in ubiquitous computing environments.

As shown in Figure 1, we suppose that various sensors and devices are connected to our device. The device evaluates inputs from these sensors and devices, and outputs information to connected devices. With this assumption, we defined the events and actions as shown in Tables 1 and 2.

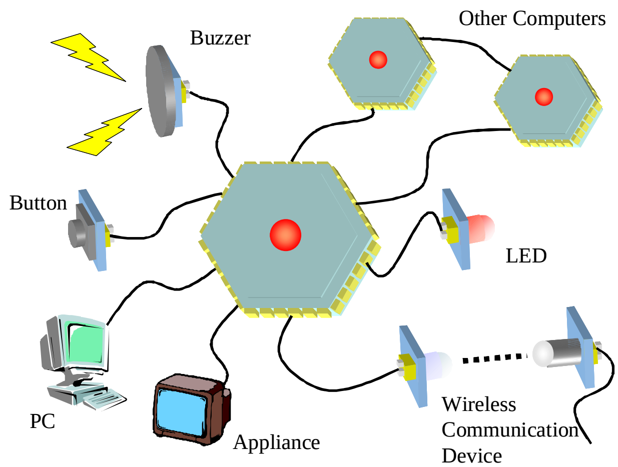

Figure 1. A Supposed Ubiquitous Computer

Table 1. Events

Name	Contents
RECEIVE	Data reception via the serial port
TIMER	Firing a timer

Table 2. Actions

Name	Contents
OUTPUT	On/Off control of output ports
OUTPUT_STATE	On/Off control of state variables
TIMER_SET	Setting a new timer
SEND_MESSAGE	Sending a message
SEND_COMMAND	Sending a control command
HARDWARE	Hardware control

Table3. Commands for the SEND_COMMAND action

Name	Contents
ADD_ECA	Adding a new ECA rule
DELETE_ECA	Deleting specific ECA rule(s)
REQUEST_ECA	Request for specific ECA rule(s)

As an example of ECA rules, we show *door-buzzer* rules in Figure 2. These rules represent a service that sounds buzzer if a user leaves the door open for more than 5 seconds. *Rule1* detects the door opening and sets a 5 seconds timer. *Rule2* sounds the buzzer when the timer fires. If the door is closed within 5 seconds, *Rule3* resets the timer.

RULE1	RULE3
E:	E:
C: I1=0, S1=0	C: I1=1, S1=1
A: S1=1, TIMER(5sec)	A: S1=0, TIMER(0), O1=0
RULE2	
E: TIMER	I1 : input from the door sensor
C:	S1: state
A: O1=1	O1: output to the buzzer

Figure 2. An example of a set of rules

PROTOTYPE DEVICE

We developed a prototype of rule-based I/O control devices as shown in Figure 3.

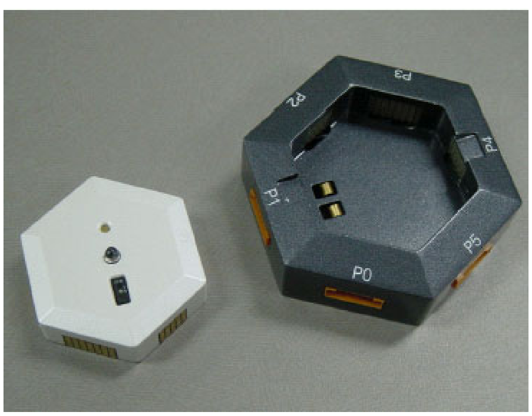

Figure 3. A Prototype of Rule-based I/O Control Device

This device consists of two parts; one is the core-part (34mm) that has a micro processor (PIC16F873), the other is the cloth-part (59mm) that has Li-ion battery and connectors for attaching sensors and devices. As shown in Figure 4, the core-part has 6 input-ports (IN1-6), 12 output ports (OUT1a-6a, 1b-6b), 6 power-supply ports (VCC), and 2 serial ports (COM1-2). Figure 5 shows the connection example between prototype devices, sensors and other devices.

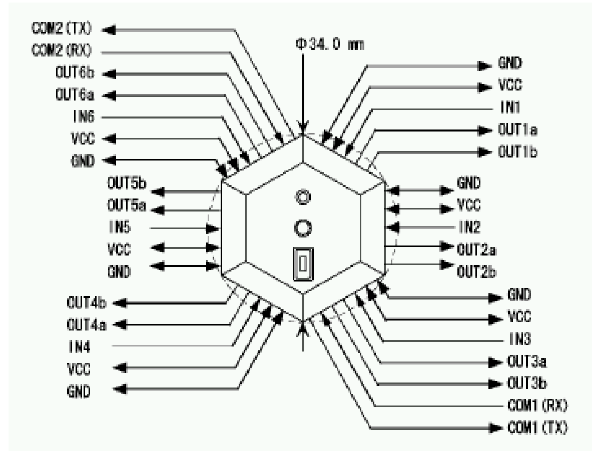

Figure 4. I/O Ports of the Prototype Device

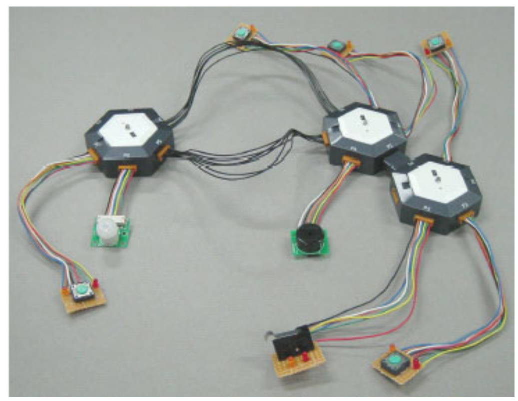

Figure 5. An Example of Connections

CONCLUSION

In this paper, we designed and developed the rule-based I/O control device for ubiquitous computing. Using our devices, we can construct the ubiquitous computing environment based on rule-based architecture as shown in Figure 6.

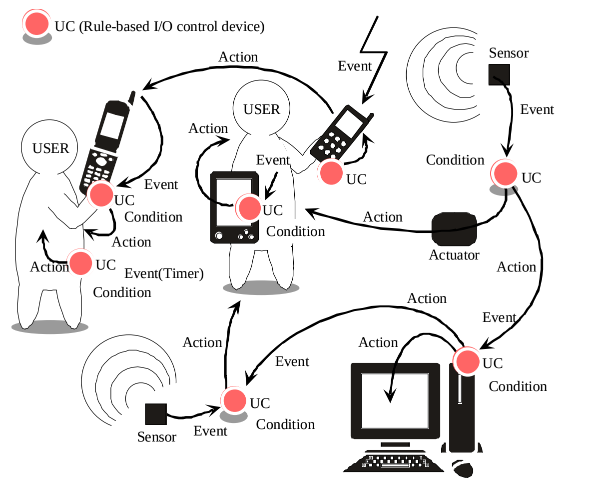

Figure 6. The Ubiquitous Computing Environment with Rule-Based I/O Control Devices

Smart Things in a Smart Home

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ABSTRACT
This work presents a prototype context-aware system for household applications built up from a number of everyday objects augmented with sensing, communicational and computational capabilities. The main challenges in making everyday objects smart are raised by the limited computing resources of the objects and mobile devices and the need to deal with large quantities of objects. The system presented here is dealing with these problems by adding interaction capabilities and organising the objects into temporal collectives according to the current task, so that each collective fulfils its task independently and communicates with the mobile device only for the presentation of results.

Keywords
Smart objects, sensing, context-awareness, interaction

INTRODUCTION
The constantly decreasing size and price of computation and communication hardware will soon allow it to be embedded into literally any artefact, but its computational capabilities will be very limited, while the number of smart artefacts will be large. This work presents a system prototype for household applications intended for mobile users, since this does not need a powerful central computer. The smart objects themselves have very little computing power, as the application runs on PIC microcontrollers, but they are nevertheless able to work as a group and to make conclusions about the joint context of the group. Thus, a central computer is needed mainly as a means of communication between the user and the smart objects.

The capability for involving the user in the resolving of ambiguities helps to provide services with a simple system configuration. The system is intended to complement future smart environments capable of learning the patterns of their users' lives.

APPLICATION SCENARIO
When we start to think what kind of support we would like to have from computing systems in order to make our everyday interactions with personal belongings easier, we find several different modes of interaction. First, we address objects as individuals (e.g. "Where is my passport?"). Second, we address objects by certain features (e.g. "Which spices do we have at home?"). Third, we spend a lot of time organising our things into temporal sets. Examples include: finding which products have use-by dates that expire within a few days; finding low-fat products; finding the ingredients for a certain recipe; finding which parts of a suit are waiting to be washed; or helping to collect all the things needed for a journey and checking continuously that no items are lost.

SYSTEM DESCRIPTION
The system prototype was built by attaching generic hardware called Smart-Its [1] (developed for research purposes in Smart-Its project) to everyday objects (see Fig. 1).

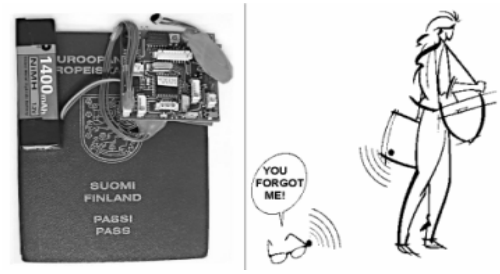

Fig. 1 A smart object and a "journey" application scenario

The user can exchange information with the objects via a central node (desktop computer or Pocket PC) with a Smart-It attached to it via a serial cable. The objects can work as a group and individually. The central node has a list of tasks and lists of items corresponding to each group task in its memory. After the user has edited or confirmed the task and the items involved, the task-related information and the list of items are broadcast by the radio. In the case of group work, the items with IDs on the list become members of the group which have to determine whether they all satisfy the task requirements. They try to detect this by exchanging and analysing radio messages containing the items' IDs and their own context data. The item with the freshest battery broadcasts the result of the analysis.

CONTEXT RECOGNITION
In group work each object has first to detect its own context, to compare this with the task requirements and broadcast the result in the form of ***member_data*** messages (see Fig. 2), which contain the object's ID, energy and task-dependent symbolic context value. An object's own context consists of its movement type, location and context attributes such as its class (food, clothes, container etc) and features which are important in this respect (e.g. use-by date and percentage of fat for food, contents and size for a container). In some tasks an object can decide for itself whether it is a "good" or "bad" item by comparison of own

context with the task requirements. For these tasks the symbolic context value is simply this decision. (E.g. for the task of finding parts of a business suit, an object is "bad" if it is waiting in the bathroom to be washed. The decision is made based on location context. Similarly a food product can be "bad" if it contains more fat than specified in the task requirements.) In the "journey" task the objects cannot decide whether they are "good" or "bad" at this stage but send their movement type as the context value.

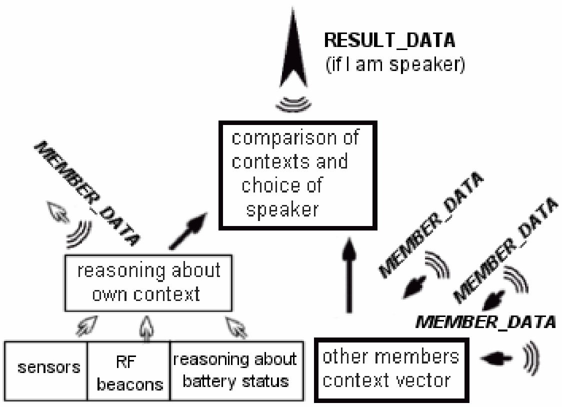

Fig. 2 Tasks of each smart object

The next step for each object is to compare the contexts of all group members. This results in the creation of a list of "bad" IDs (objects which are absent or fail to satisfy the task requirements) and the choice of a speaker (decision on whether the item should send this information by radio itself or let another item send it). For the "journey" task, objects can decide which are "bad" (forgotten) with greater or less certainty depending on the user's preferences. Objects are considered "bad" with a high degree of certainty in two cases: 1) after disappearing from the communication range of the other group members; 2) if the movement type of several other group members is "shaking", while they have a different movement pattern. Objects are considered "bad" with less certainty if they stay in the same place while the other group members are leaving. In this case false alarms are more probable, but both this and the detection by "shaking" movement type helps to identify missing objects before they pass out of the communication range.

The energy awareness of Smart-Its is based on the fact that all boards have an identical program and the battery status is affected mostly by the number of temporal sets in which the object has taken part and the number of messages sent. Choice of a speaker (Fig. 2) means that objects' conclusions (***result_data*** messages) are sent by the object with the freshest battery, either according to timing requirements specified in the task description or upon shaking of the objects. Each object decides for itself whether it should send ***result_data*** message or not. If some objects are out of the communication range of other objects, they also send ***result_data*** message with there own conclusions, and the central node should summarise the received messages.

Since the system is intended to be deployed everywhere in an ad-hoc manner, and since the computing resources of smart objects are very limited, the system includes certain interaction capabilities [3] in order to help the user to resolve ambiguous situations.

1. The items know of special situations which increase the certainty of context detection and help to choose the moment for receiving the system's opinion. For physical objects, one such situation is shaking, and it is very easy to distinguish items which are simultaneously shaken hard [2]. Shaking helps to give an alarm at the right moment, much earlier than if the system were to wait until one or more objects disappeared from the communication range. Further, the system would normally be silent when nothing is missing, but it sends an "OK" message upon shaking.
2. The system includes explanation capabilities intended to correct both the user's mistakes and its own. Objects send explanation data either upon request from the central node or upon shaking. Possible sources of mistakes are a change in the usual contents of a container or the effect of reflection on the beacons' communication range. It is sometimes necessary to move a beacon half a metre to tune the system, but the user needs to know which beacon's data caused the error in the system. This option also facilitates addition of new objects to a database.
3. The system allows the user to add or remove items from a group at any moment. This helps e.g. to deal with the objects left somewhere intentionally or bought after the user has left home.

CONCLUSIONS

The group work of smart objects with limited computing recourses was implemented by enabling each object to make conclusions about the joint context of the group without comparing them with the opinions of other group members. According to our tests, members' opinions differ mainly when the situation changes (e.g. items start or stop moving); however, addition of the ability to analyse conclusions of other group members can be useful. Group work by smart objects reduces the workload of a central node, which is important, if there are many objects and many central nodes and all of them have limited resources.

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Resource Management for Particle-Computers

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ABSTRACT
We present a system for real time management of the resources of Particle-Computers. The particle-Computers are a type of Smart-Its - a Ubiquitous Computing platform equipped with sensing, computing and communication hardware. Our management system provides the developer with easy access to real time features needed in almost every application for Ubicomp environments that is based on periodic or sporadic evaluation of sensor values.

Keywords
Real-time, resource management, Particle-Computer, developer support

INTRODUCTION
Particle-Computers (Figure 1) are technically advanced Smart-Its [1], a Ubiquitous Computing platform that was developed in our lab at TecO under the roof of the Smart-Its project [2]. As most platforms for context aware computing, Particle-Computers feature a number of input channels including different sensors and inbound communication, a computation unit for analyzing and processing of contexts and output channels like actuators and outbound communication.

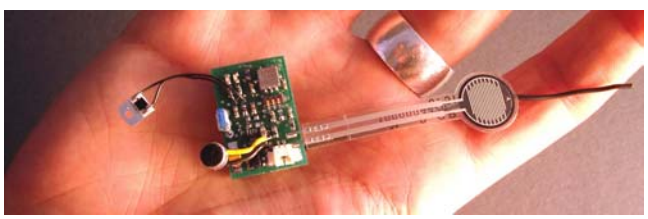

Figure 1: Particle-Computer

Many applications in Ubiquitous Computing involve data gathering or the provision of newly generated context information in per defined periodic time intervals as well as sporadic when changes in the environment are detected. These parallel functions like sampling different sensors, computing new contexts and communicating can best be implemented in separate tasks. Thereby it is more important to be able to guarantee a maximum time for an operation to be completed, like taking sample form a sensor, than just to complete every operation as fast as possible. So we developed the P-RMS (Particle Resource Management System) to provide real time scheduling functionality of the resources of Particle-Computers to the software developer. The system is intended to manage the execution of multiple (real-time) tasks with a minimal overhead on our Ubiquitous Computing platform.

Software Architecture
For providing maximum performance given the limited computing power and the small amount of available memory, the software of the P-RMS was split in two main components: a runtime environment, implemented on the Particle-Computer platform and a development tool running on a standard personal computer.

P-RMS DEVELOPMENT TOOL
The P-RMS development tool takes over some of the functionality of a real-time resource management system that can be applied at development time of the software for Particle-Computers. This is reasonable due to the resulting reduction of the load on the Particle-Computers at runtime. Functions that where transferred to a powerful personal computer are the feasibility computation of a given set of tasks, the check of the reservation of shared resources other than the processor and the generation of a runtime configuration for the Particle-Computer program.

To achieve maximum flexibility it is possible to feed the development tool with a configuration containing different real-time task-sets that may be executed on the Particle-Computer alternatively. Thus we overcome the disadvantage of a single predefined task-set at development time. For all task-sets the feasibility computation is done separately. This allows us to switch between the different sets of tasks at run time on the Particle Computers.

The scheduling we perform for the task-sets is an earliest deadline first (EDF), non-preemptive scheduling strategy without inserting idle times and using dynamic priority for tasks. Multiple sets of real-time tasks and one background task can be scheduled. The system supports temporal as well as permanent resource reservations. Schedulability computation is performed for non-concrete task-sets containing sporadic and periodic tasks according to the formulas in Zeng and Shin [3], that were adapted to our special requirements.

P-RMS RUNTIME ENVIRONMENT
The runtime environment of the P-RMS includes the scheduler, a real-time clock (RTC) and management routines for switching between task-sets and single tasks. It needs about 5,5 Kbytes of program memory; the exact amount of data

memory required depends on the number of tasks in all task-sets and the maximum number of instances of theses tasks. It can be computed to

$(96 + \mathit{MaxNumberOfInstances} * 4 + \mathit{NumbeOfTasks} * 4)$ bytes.

This is feasible as the Particle-Computers are equipped with 32 Kbytes of program memory and 1536 bytes of data memory, leaving enough recourses for user applications, e.g. a typical test configuration we used contains 4 real-time tasks and a background task needs about 132 bytes of data memory.

The P-RMS runtime environment provides various functionalities to the applications running on the Particle-Computers. This includes the management of periodic tasks by setting the period length and ensuring that they are started periodically. Furthermore, the runtime environment creates sporadic tasks based on input events and sets their starting time. The runtime environment also includes the service routines for switching between the different predefined task-sets.

Scheduler

The scheduler is responsible for assigning the processor and the other allocated system resources to activated tasks in the order of their priority and running the background task when the processor is not assigned to a real-time task. Priorities of the real-time tasks are assigned following the EDF scheduling strategy. The P-RMS scheduler works very efficient due to the fact that the schedulability tests are performed at development time of the application software. This guarantees that only schedulable task-sets are contained in any given application.

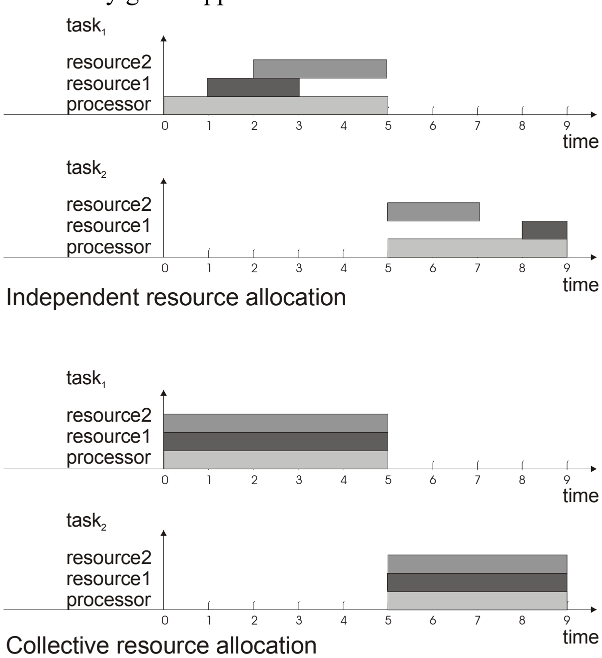

Figure 2: Assignment of resources performing independent or collective allocation

Resource assignment in general can be performed independent for each available resource or collective for all resources allocated by one task (see Figure 2). The advantage of independent resource assignment is that any given resource is allocated only as long as it is needed. This enables maximum parallelism of tasks. The disadvantage of that approach is, the schedulability of every resource has to be checked separately and dependencies between reservations have to be handled explicitly. In the P-RMS we decided to go for collective resource assignment due to the fact that only one processing unit is available and no virtual parallelism of tasks can be introduced performing non-preemptive scheduling. Details on all design decisions in P-RMS can be found in [4]

IMPLEMENTATION AND TESTING

The implementation of the P-RMS followed the "test first" strategy, known from extreme programming [5]. Using this method, tests for the functionality of every unit of code are designed and implemented prior to the implementation of the code unit itself. This results in an early detection of errors in the implementation.

EVALUATION AND FUTURE WORK

The evaluation of the P-RMS is still in process. We were able to determine some areas where further improvements in the performance and memory consumption of the system may be possible. E.g. one major improvement will be a further reduction of the runtime of the scheduler on the Particle-Computers. The maximum runtime of the scheduler depends on the maximum number of instances of tasks in a task-set. This maximum is seldom reached, so performance enhancements can be achieved by better prediction of those maxima. Additionally, a simplification of the RTC structure could reduce the runtime of a RTC-query from 299 cycles to 26 cycles at the expense of some loss in comfort in reading the current time and data. Another improvement we already identified for future implementation is the introduction of a hierarchical ordering of the resources. This will simplify the reservation of compound resources.

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Using a POMDP Controller to Guide Persons With Dementia Through Activities of Daily Living

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ABSTRACT
Researchers at the Centre for Studies in Aging and at Simon Fraser University are developing ubiquitous assistive technology to aid persons with dementia complete routine activities. To ensure that the system is useful, effective, and safe, it must be able to adapt to the user and guide him/her in an environment that may not be fully observable. This paper discusses the merits of using partially observable Markov decision process (POMDP) algorithms to model this problem as POMDPs are able to provide robust and autonomous control under conditions of uncertainty. A POMDP controller is being designed for the current prototype, which guides the user through the activity of handwashing.

Keywords
POMDP, dementia, Alzheimer disease, ADL, assistive technology, cognitive orthosis.

INTRODUCTION
It is estimated 1 in 3 people over the age of 85 has dementia, with Alzheimer disease (AD) accounting for 60-70 % of cases. The number of Americans with AD is estimated at 2.3 million and expected to reach 14 million by 2050 if present trends continue [1,2]. At the onset of dementia, a family member will often assume the role of caregiver. However, as dementia worsens, the caregiver will experience greater feelings of burden, which frequently result in the care recipient being placed in a long term care facility. A solution to relieve some of the financial and physical burden placed upon caregivers and health care facilities is a ubiquitous, autonomous system that will allow aging in place by improving the quality of life for both the care recipient and their caregiver.

People with advanced dementia may have difficulty completing even simple activities of daily living (ADL) and require assistance from a caregiver to guide them through the steps needed to complete an activity. Examples of ADL are handwashing, dressing, and toileting. While there have been several cognitive aids designed to assist ADL completion, all of them require explicit feedback from the user, such as a button press, to indicate that a step has been completed. This makes them unsuitable for persons with moderate-to-severe dementia as this group does not possess the capacity to learn the required interactions.

OBJECTIVE
Our objective is to design a more robust control system by using partially observable Markov decision process (POMDP) algorithms to model the activity of handwashing. We anticipate that using POMDPs will enable the device to guide users more effectively and offer a model that can be readily expanded for more complex activities.

APPROACH
The current prototype, dubbed COACH, uses colour-based tracking software to follow the user's hand position through a camera mounted over the sink as the user performed the ADL of handwashing. Figure 1 depicts six steps of handwashing and the various alternative pathways the user could correctly wash their hands. Our first artificially intelligent (AI) agent employed neural networks to associate hand position with corresponding steps and a simple vector search through the taxonomy

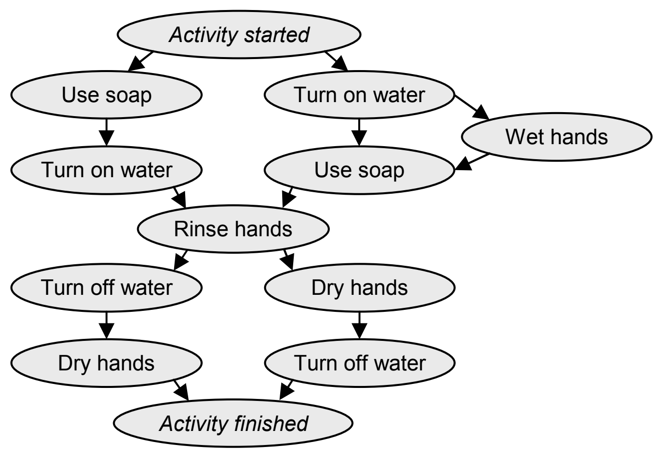

Figure 1: *Acceptable sequences of steps required to complete the ADL of handwashing. Note wetting hands is considered optional in the prototype as liquid soap is used.*

constructed from Figure 1. This identified what step in the ADL the user is attempting to complete and if the user's actions were correct. If the user seemed unsure of the next step or s/he attempts an inappropriate action, COACH played an audio cue to guide the user to the next appropriate step. If the user did not respond to prompts, the caregiver was called to intervene. COACH has been tested through clinical trials involving AD inpatients in a retrofitted washroom at Sunnybrook and Women's College Hospital's long term care facility [4]. It was found to significantly decrease the number of caregiver interventions by about 75 %.

The current prototype assumes full observability of its washroom environment. This simplification does not account for inherent uncertainty in step identification introduced through factors such as instrumentation noise and obscured views. Upgrading the AI agent to a POMDP based controller provides a solution to this problem by directly modeling the uncertainty. The incomplete and noisy information provided by the tracking system is translated into a probability distribution over the possible conditions of the user and the washroom environment. This distribution is continuously updated to reflect observations made by the tracking system as time progresses. By combining this distribution with a stochastic model of the user's future behaviour and a cost function measuring the consequences of playing various prompts, the POMDP agent is able to optimize the choice and time of prompts despite uncertainty. Following the principles of utility theory, the agent selects the course of action that minimizes expected future cost based on the estimate of the user's status (modeled as a probability distribution). Please see [3] for a more detailed review of POMDPs. The ability for the COACH system to make good decisions under uncertainty is especially crucial to complex ADLs, such as toileting, where observations will likely be limited and the costs of poor control are high.

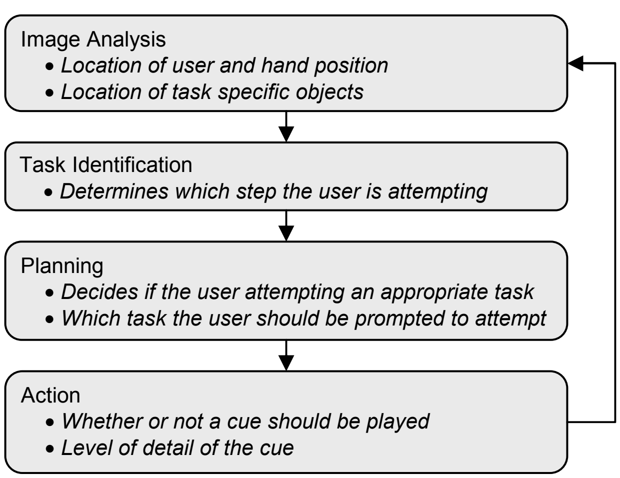

Figure 2: *Interaction of modules that constitute COACH controller.*

DESIGN AND BENEFITS

A POMDP model is being constructed to guide a user through the ADL of handwashing. COACH is separated into four modules, as can be seen in Figure 2. POMDP algorithms will create a central controller that encompasses the step identification, planning, and action modules. A great advantage to using a POMDP model is that it eliminates the requirement of explicit user feedback, such as a button press, because the agent autonomously estimates when a step has been completed through observation of the activity. Another challenging aspect of this research is to design an effective method of determining user preferences, as there is no user feedback. POMDPs provide an excellent solution to this difficulty by obtaining and incorporating user preferences autonomously. For example, by keeping track of which cues have been observed to be the most effective in the past, the system can not only tailor itself to the user, but also be sensitive to changes in user performance that accompany the progressive nature of AD and will accommodate accordingly. The self-tailoring ability of a POMDP controller also eliminates the need for extensive interaction with the caregiver, making this technology user friendly.

SIGNIFICANCE AND OUTCOMES

Results from this research are applicable to the development of ubiquitous intelligent monitoring and prompting of all people with cognitive limitations, including those with traumatic brain injuries, learning disabilities, and Alzheimer's disease. Successful implementation of POMDPs to the COACH handwashing problem would represent one of the most advanced applications of this technology.

ACKNOWLEDGMENTS

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The Chatty Environment – A World Explorer for the Visually Impaired

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ABSTRACT

Ubiquitous computing systems have often suffered the criticism of providing only marginal value and not justifying the serious amount of money spent for research in this area [1]. In this extended abstract, we describe the vision and the prototype of a ubiquitous computing environment for visually impaired people. The aim is to help them orient themselves in new, unknown environments and thereby enable them to lead a more independent life.

Keywords

Ubiquitous computing, visually impaired.

INTRODUCTION

Everyday Problems for Visually Impaired

Visually impaired people encounter many problems during their daily routine that sighted people wouldn't neccessarily think of. Take for example shopping in the local supermarket. Thousands of items, feeling all the same, spread over dozens of shelves, all the same shape. Visually impaired people will typically only go shopping to their local supermarket and buy only few products in well known locations. Or think of a modern airport terminal. Where is the check-in counter for a certain airline? Where does one collect the luggage after landing? Without external help, these issues are almost unsolvable for the visually impaired.

The Basic Idea

The common source of these problems is that the world reveals itself to us mostly over visual stimuli, which are being withheld from visually impaired people. To cope with some of these problems, we propose the paradigm of a *chatty environment*. In this environment, the world uses an alternative channel, namely audio, to reveal itself to the user. While walking by, entities in the environment keep talking to the user, thereby revealing their existence: "Here is the shelf with milk products, down the next aisle are the fridges with meat and ice", "Here is track 9, do you want more informations on the departing trains?"

This (at first sight rather naive looking) feature of the system will probably seem annoying to most sighted people. An environment talking endlessly to the user sounds like a headache to many of us that we would surely turn off after a few minutes. However, speaking to members of the Swiss Association of the Blind, it turns out that for visually impaired people there can almost never be too much audio stimuli. This is comparable to the huge amount of visual informations sighted people pick up every second, few of which they really use. Here, too, it feels far from annoying to continuosly receive that much unneccessary information since one has learned to focus on the interesting aspects only.

THE SYSTEM

We are currently in the process of building a prototype of the chatty environment as part of the ETH Zurich campus. The prototype consists of several components: a large number of tagged entities in the environment, a *world explorer* in form of a portable device for the visually impaired user, and a tag reader connected to the world explorer to pick up the tags.

Smart Entities

The objects of the chatty environment are electronically tagged, either by passive tags – using radio frequency identification (RFID) technology – or active tags – these could for example be active RFID tags, Berkeley TinyOS Motes [3], or Smart-Its [4]. The main requirement is that the communication between the tags and the user device does not need line of sight. Not only do we want to follow Weiser's vision of a ubiquitous computing system that works unobtrusively in the background without requiring explicit interaction [2], we also need to make sure that a system for the visually impaired does not require the user to point the portable device to a certain object for triggering an action. Therefore, infrared beacons are not suited for tagging the environment objects. In our prototype, we use the Berkeley Motes.

World Explorer

The portable device carried by the user receives the data transmitted by the environment objects. It can be either a stand-alone device carried by the user in her pocket or backpack, or an extension of the user's cane.

The most important data the smart entities send is their identity, such as "ticket booth", "escalator", "men's restrooms", "track 9", or "train to Geneva".

The device we are currently using as world explorer is an iPaq PocketPC, which will be replaced in a later project phase by a PDA especially designed for the visually impaired. These devices have the advantage of providing Braille input and output.

User Interface

The chatty environment keeps revealing itself to the user until she chooses to investigate one of the environment's objects. By pressing a button on the device shortly after an environment object has been presented to her by the device, the user is capable of selecting this object.

The user is then presented with a standardized audio interface to the object. In the current implementation, the interface consists of four options:

Information

By choosing this option, the user receives further information about the chosen entity. This information is highly dependend on what kind of object was selected. With a supermarket product, the information could for example be: “producer”, “ingredients list”, and “expiration date”. For a train, the information might be: “final destination”, “departure time”, “next stop”, and “list of all stops”.

Some of these points may in turn provide further details. “Ingredients” may have as subitems “vegetarian (yes/no)”, “organically produced (yes/no)”, and “display complete igredients list”.

Actions

Some of the objects in our chatty environment will allow the user to take some action on them. One example is a train or bus allowing the user to open its nearest door. This is a well-known problem for visually impaired people, for whom it is easy to miss a bus or train because they are unable to find its doors during its brief stop at the station.

Leave traces

The user can also decide to leave virtual post-its for herself or other users on an object. These will typically be audio files reminding her of something that she noticed the last time passing by. On a traffic light, for example, one could leave the information: “Big crossroad ahead, must be crossed very quickly”. Information left like this would be automatically pushed onto the user’s device the next time she would pass this object again.

Our current prototype features only two options for leaving or hearing a message: leaving messages just for oneself or for anybody else, and hearing just personal messages or hearing everybody’s messages. This approach obviously needs to be refined in future versions of the systems.

Take me there

By choosing this option, the user is guided to the currently described entity, e.g., for an item on a sign.

Virtual Information Boards

Sighted people orient themselves in a new and unknown environment not only by the objects they are able to see. They also learn about distant or hidden objects through signs. By mapping visual signs to audio-signs for the visually impaired, they can learn about objects not only in their immediate neighborhood, but also further away, too.

To realise this goal, signs in our chatty environment are enhanced by the same beacons used by all other objects. But instead of revealing *themselves* to the user, a sign tells her about the objects they are pointing to. By selecting one of these objects, the user can subsequently be guided there using the “Take me there” interface option.

We are currently working on integrating a navigation feature using a locally developed location system. The system relies on the signal strength of WLAN 802.11, Bluetooth and active RFID tags.

User Input

Currently, the user can only interact with the system by listening to the list of nearby objects (with support for skipping back and forth) and then choosing one of the four options described above. Future versions should also allow the user to actively search for an environment entity, either using Braille or voice input. For example, it should be possible to find a pharmacy, even if it is neither in the immediate neighbourhood, nor on a virtual signboard.

Communication Issues

There is a huge amount of data to be transferred from the environment objects to the user device. Since the tags are typically small devices with limited ressources, only the object identity, some basic information and a hyperlink is stored on the object itself. By following that link through the device’s Bluetooth or WLAN 802.11 network interface, arbitrary additional information can be gathered from the wide-area computing infrastructure. Note that in case of intermittent connectivity, the world explorer’s text-to-speech engine can still render the human-readable object identity stored directly on the tag (this could be aided by a dictionary in foreign-language environments).

Information Filtering and Selection

A challenging issue is choosing which information should be presented to the user. For example, when entering a shop the third time, a user might not want to receive the same information again. A similar problem arises when the user enters an area with so much information that it cannot be presented in a timely fashion. These issues of information filtering and selection are currently under investigation and will be addressed in future prototypes.

ACKNOWLEDGEMENTS

Jürgen Bohn has contributed many ideas in early stages of the “Chatty Environment” project, while Jürgen Müller provided many helpful pointers regarding the daily routine of visually impaired.

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Support for Nomadic Science Learning

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ABSTRACT

We describe multiple scenarios and design challenges for nomadic computing tools intended to support informal science learning and teaching at the Exploratorium, an interactive science museum in San Francisco.

Keywords

Museum applications, usage scenarios, RFID, handhelds

INTRODUCTION

The I-Guides research project, a collaborative project between the Exploratorium and HP Labs, investigates uses of nomadic computing technologies to support informal science learning and teaching. Specifically, our goals are to understand ways in which handheld devices and wireless networks can be designed to support lifelong science inquiry: learners ask questions, seek explanations, and carry out personally relevant investigations with museum exhibits or other learning resources to make sense of science. Informal learning and teaching occur across multiple episodes, physical settings, and virtual spaces which may or may not have the benefits or constraints of structured classroom-based learning. Building upon our prior Electronic Guidebook research, we aim to accomplish the following:

- Create a functional nomadic computing infrastructure and online personalized delivery system to support nomadic inquiry.
- Identify an instructional design framework for creating resources and interactions for informal science learning, teaching, and community-building capable of being delivered on multiple devices.
- Conduct user studies exploring the impact of a system that balances virtual and real-world information on the learners' use of museum resources before, during, and after a visit.

AUDIENCE AND USAGE SCENARIOS

The first step in our design process was to identify distinct audience groups and better understand the needs of these audiences. Based on discussions, informal interviews, and focus groups conducted with educators, museum staff, visitors, and other museum researchers, we identified general visitors, educators, and museum docents ("Explainers") as three distinct audience groups. Several versions of sketches and usage scenarios were made, validated, and refined based on user feedback (figure 1).

For General Visitors: Capturing and extending a visit

This audience consists of individuals and families who visit the museum as an enjoyable way to spend leisure time that has the added benefit of learning something new. Our prior research has established that this population has difficulty carrying handheld devices while interacting with the museum exhibits [2,3]. They prefer that their hands be free to manipulate the exhibits. An adult in a family group may want to know more about the scientific phenomena being demonstrated by the exhibit but often is pulled away by the children to the next event. Thus, alternative forms of recording and capturing user experiences at the museum such as a smart watch, an RFID card, or a keepsake toy are being considered. A token could be used to bookmark an exhibit, capture a memorable photo on the spot, or track one's conceptual pathway through the museum. Back home, the visitor can review additional information on a computer via a personalized Web page.

For Explainers: Support tool for explanation

Explainers are students and staff (ages 15–20), who help visitors be better at inquiry and explain science phenomena. Explainers answer questions about the exhibits, perform demonstrations, shepherd fieldtrip groups, and help maintain exhibits. New explainers come to the museum on a regular basis and their background knowledge about science and the exhibits varies. A wirelessly connected handheld was identified as a promising information support tool, mobile training resource, or workflow organizer to be used while not directly involved with visitors. Explainers would use a handheld in the presence of visitors to remotely control a larger exhibit, as a data collection device to capture the interesting phenomena, or as an appliance to read a visitor's tag and email the visitor addition information.

For Educators: Linking schools to museums

Teachers and other educators use Exploratorium resources to support current school-based curricula. They organize field trips and spend considerable time on preparation and follow-up to the museum visit. This group also uses the Exploratorium for personal professional development as members of the Teacher Institute program or as veteran teachers charged with training and coaching other teachers in their school districts. While this audience has some unique goals, we believe that many of their needs could be addressed through tools developed for helping Explainers, as well as tools for capturing and extending museum visits.

DESIGN CHALLENGES

In the process of creating usage scenarios and prototypes, we identified several design challenges:

Data-driven versus inquiry-driven – One design tension is what type of learning to support: learning that can occur because of rich media delivery or learner-centered inquiry that is supported by careful prompting. Because volumes of online science content exist, a tendency in the design process is to focus on data-driven models of learning rather than providing guidance for learner-driven inquiry, group gaming activities, or collaborative learning. We plan to address this issue by conducting studies that compare different instructional designs with Explainers.

Complex environment – The Exploratorium typically has several hundred exhibits about science, art, and perception. Many of the exhibits are noisy and involve sand, water, electricity, magnetism, heat, or soap. The exhibits are frequently relocated within the museum as part of a continual prototyping process. Some exhibits involve observation or one-handed manipulation to move a knob or lever, while others involve two-handed manipulation or whole body interaction. Visitors often complain they are overwhelmed by the many choices, activities, and noise. Introducing nomadic computing technologies into this environment requires deliberate design that doesn't contribute to the complexity of the environment and improves the user experience.

Addressing multiple stakeholder interests – Collecting stakeholders' viewpoints is critical to identifying key design issues in the scenarios. Stakeholders include the end users, museum staff, designers, technologists, industry partners, and others. Listening to stakeholders enables us to understand the barriers to adopting nomadic computing tools in the museum. Adoption of a particular solution by the end user will only happen if we fully understand the existing context in which the technology is being introduced.

Addressing these design challenges requires the development of tools that go well beyond the existing research on mobile guides [1,5]. We are building on our prior work which has established the feasibility of the basic components and the infrastructure. Over a hundred users have already tested the prototypes, helping us understand device form factors, interfaces and usability issues for various audiences [2].

ACKNOWLEDGMENTS

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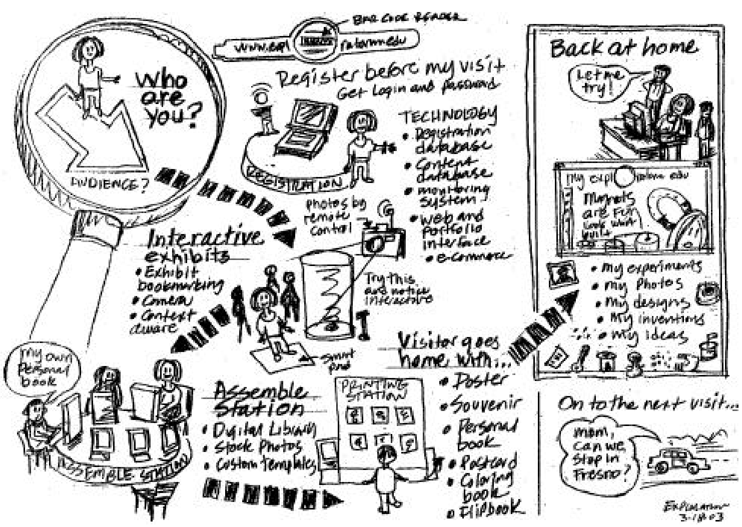

Figure 1: Sample scenario of informal science learning: general museum visitor with a smart watch

Development of an Augmented Ring Binder

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ABSTRACT
The era of ubiquitous computing gives rise to a variety of new technology. We have developed an augmented binder that supports document handling and workflow. This binder can provide automatic tracking of document flow, linking physical and virtual documents.

We needed our binder to fulfill a few basic functional requirements. The most essential was that the binder should be able to detect insertions and removals of documents. Also, many applications will require some kind of alarm when certain conditions are fulfilled. For example, important documents could be marked as such, so that the binder may warn if they are missing. All these requirements had to be accommodated while keeping the restrictions of weight, space and battery time in mind.

Keywords
Ubiquitous computing, Collaborative work, Distributed Cognition, Document handling, Office application, Workflow, TINI, Bluetooth, RFID

Figure 1: Front of binder with pushbuttons and the display visible.

INTRODUCTION
As shown by Luff et. al [1], artifacts play a crucial supporting role in today's collaborative workplaces. For example, Bång [2] points out that clinicians depend heavily on patient folders in their daily work. In an office, a lot of activity is centered on documents that are in binders. Therefore, by augmenting the binders with ubiquitous computing technology, it is our hope that the work can be made more efficient.

Target audience
Because binders are used in so many different contexts it is difficult to identify the typical user. However, we believe that our conviction that most of the people that use binders should benefit from this. We have therefore concentrated our work on the common denominators we have found. Among those is the ability of the binder to detect insertions and removals, as well as registering the history of such actions. On this basic functionality, it is then possible to build more complex and customized software for specific applications.

Uses
The use of patient folders in a medical setting is an area that may benefit from our approach even at the current cost levels. An augmented binder may warn healthcare workers if any documents are currently missing. If new data for the patient is available that has not yet been printed on paper, the binder may say so. Thus, the clinicians can avoid making decisions on incomplete information, thereby reducing the risk of mistakes.

TECHNOLOGY
Our goal was to construct a wireless and portable device, small and light to integrate with a ring binder. As we shall see, this turned out to be a very general task. The resulting design should be useful in many similar circumstances.

The identified technical requirements as obtained from the functional ones included:

- Internet capability to enable access to external information, such as a central document server.
- A small display fixed to the front of the binder to provide information and feedback to the user.
- The user interface should not be more complex than a number of pushbuttons.
- An RFID reader capable of reading multiple tags inside the binder**.**
- Readily available tools for easy software development and prototyping.
- A battery operating time of a couple of hours.

CPU
Early on we concluded that one of the several available micro java platforms [3] would readily satisfy about half of our requirements. We eventually chose the TINI platform, mostly because of its small form factor and low power requirements, but also because it is a mature product with a large user base. The TINI runs Java programs, however one should keep in mind that the TINI is limited to a subset of the JDK1.1 specification. This is normally no problem when developing from scratch, but may cause significant rewrites when porting present applications.

Wireless
The wireless property was a problem from the start. Our options seemed limited. Many of the common solutions (WI-FI, bluetooth) were unavailable to us because they require interfaces the TINI doesn't have, such as USB or PC-card. We eventually

found a product, Blue2Link, which essentially is a virtual ethernet cable over bluetooth.

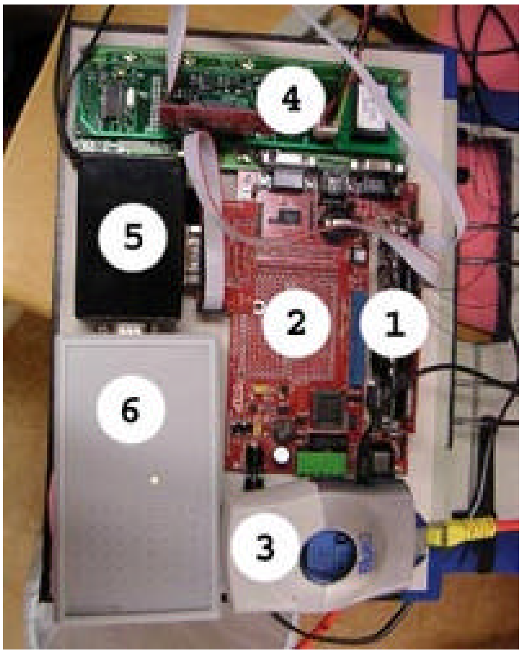

Figure 2: Hardware as mounted in the binder. 1. TINI (viewed from side), 2. TINI-experimental platform, 3. Blue2Link, 4. Display, 5. RFID connector adapter, 6. RFID-reader.

RFID Reader

We expected the selection of RFID reader to be a straightforward task, but it turned out to be not quite that simple. Especially the capability to read multiple tags still seems to be unstable. Eventually we ended up with the reader Feig MR100 which works very well, but turned out to be more expensive and power hungry than we expected from our first quick look at the options available to us.

Display

There are many options available in this area. We were however limited somewhat by the low speed of our chosen CPU. Therefore, we restricted our search to displays with built-in memory and processing capability, for example character plotting and line drawing. This increases the cost of the display, but the extra cost is accompanied by a corresponding gain in responsiveness as well as application programmer productivity because of the supplied high-level API. We chose a GLC24064 from the US company Matrix Orbital. With a display area of 132 x 39 mm and a resolution of 240 x 64 pixels, it is among the largest such displays available.

Battery

A standard accumulator pack of 1500mAh provides about 10 hours of operating time, more than enough for a prototype such as ours. All hardware runs on the 12v accumulator, except the display, which requires 5v. Since the display has very low power usage, we have simply given it its own power supply consisting of regular battery cells.

Cost

Total cost of the hardware in the project is about €1000. The largest individual costs were the wireless ethernet devices with €400 for a pair, the RFID reader for €270 and the LCD display for €230.

Software

None of the hardware came with suitable drivers. Luckily, most of the protocols involved turned out to be mostly very simple but the software writing still took a good part of our 6-month project. We eventually produced about 10000 lines of Java code and 70 classes for the binder and supporting software (a simple document server and a PC binder management GUI).

FUTURE RESEARCH

We have so far identified four plausible directions to pursue:

- Location and tracking. The system can be enhanced with online tracking and location of documents. This approach could for instance be used to compare supposed to actual workflow.
- By adding linking between physical and virtual documents one can for instance obtain easy access to documents in the computer. For example, removing a physical document from a binder, the same document could be opened in its virtual form on the computer, removing the need for a possibly laborious, manual search.
- Usability studies / UI-design. The current prototype does not emphasize usability studies or UI-design. This is an important aspect to consider since we want the usage of the folder to be kept as simple and streamlined as possible.
- Version tracking. The user can immediately know if the document they have in their hand is the latest version. This is useful in any situation where people collaborate on a set of documents, for example a patient folder in a hospital setting.

SUMMARY

We have built a prototype wireless document handling aid in the form of a binder, using off-the-shelf products. The result has many promising areas of use. However, any specific application would require significant customization of software.

ACKNOWLEDGEMENT

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Meaningful Traces: Augmenting Children's Drawings with Digital Media

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ABSTRACT
Paper is widely used by children in drawing and art making, but it does not have the ability to contain other media such as a child's audio description of the drawing. Also, paper artifacts fade, tear, and get lost over time. We describe a system designed for recording and archiving children's drawings together with their description of what is depicted (audio), the sequence of creation for each piece (traces), parents' annotations, and a tagging system to link the drawings on paper to the associated digital media.

Keywords
Children's art, children's drawings archive, mixed reality, augmented reality, paper user interface, capture and access

INTRODUCTION
In the same way that children learn to talk, they learn to express themselves through pictures. The first time they reach for a pen or pencil and the first scribbles are as exciting as the first words they say. A similar emotional feeling is attached to the first drawing they create and label "mom", "dad", etc. [1]. For parents, such drawings are reminders of moments in their children's lives that they want to remember and cherish. "No more than you ignore their chatter would you ignore their makings on a paper [1]." Drawings are also a source of constant wonder to children as they grow older, leading them to ask: "Did I ever do things like that?" rather than the more usual questions: "Did I ever look like that [1]?"

It is not only the drawings that are memorable and fun to look at. Children often talk about what they have drawn in compelling ways and their comments make the scribbles meaningful. However, in most case all that parents can save is the drawing on paper. There is no systematic way to save the stories and words attached to them. Very few of the artifacts in any form, saved by parents are annotated, even with simple dates [2], because annotation is very time-consuming.

Psychologists and educators generally agree that children's graphic constructions should be viewed as a process or a sequence of steps. Sequence and direction are important aspects of many activities: driving a car, playing the piano, and giving a talk. In all these activities, the starting point makes a difference to the success of the total action. This rule applies to children's drawing activity as well; analysis of meaning depends heavily on the order in which the child lays down the pencil or brush strokes [3]. However, it is almost impossible to extract this information from the artifact once it is complete.

Meaningful Traces is a digital device for capturing children's drawings and the sequence and context of their creations; e.g. dates, child's audio description of the drawing, and parents' text annotations. The digital copies serve as a back-up (in case paper artifacts are lost for some reason or simply fade over time). They facilitate different methods of display and sharing and can be automatically organized by dates.

PAPER AS THE BASE FOR INTERACTION
There is a growing interest in developing tangible multimodal systems in which users can continue to employ their familiar physical tools such as paper, with computational enhancements [4, 5]. On the other hand, paper based activities are very common among children because paper is widely available, cheap, tangible, and easy to use and carry. Paper does not require batteries, does not generally break or stop functioning [6], and poses little direct danger to children. *Thus, instead of trying to replicate physical paper and drawing mediums on a computer screen, Meaningful Traces aims at augmenting paper with digital capabilities.* To facilitate the creation of this tool we first conducted a user study and then built a non-functional prototype as a base for further user studies.

USER STUDY: DEFINING DESIGN GOALS
At this phase children ages 6-8 are identified as the target users. To inform the study, ten parents who have children in this age range were interviewed. According to these interviews, drawing is one of the most popular activities among children. They draw in various positions, on the floor, on the couch, in their bed, and at the kitchen table. Seven out of ten children whose parents were interviewed talk about their drawing after finishing it, while they show it to others, and two describe it as they draw. The interviewees save from 20% to 85% of their children's drawings for sentimental reasons, to see the progress in their children's development, and for children themselves to have a sense of history as they grow up. They all express

interest in having a digital copy as a back-up although they believe that these copies will not replace the actual physical drawings on paper. However, they believe the digital copies can replace some of the ones which are less important to them. Seven out of ten parents currently annotate the drawings mainly with dates, and four wished they had time to do so. Four out of ten write descriptions and stories down on some of the pieces.

Consequently, the goals of Meaningful Traces are 1) semi-automatic capture which does not require parents' involvement and time 2) portability and ease of use in different positions by the child.

PROPOSED PROTOTYPE

The Meaningful Traces tablet is specifically designed for the child to draw on. It is equipped with sensors on its surface to record the pen strokes, a detachable sheet feed scanner, a tagging system, a built-in microphone, and a limited memory to store a number of records.

What is captured?

Every record in the digital archive consists of: 1) the scanned copy of the drawing, 2) the date, 3) ID tag, 4) child's audio description, 5) "traces", which are referred to the process of the piece creation (They are in the form of snapshots of the work in progress or an animation of how the work was created), 6) parents' text annotations.

Scenario of Use

When the child starts drawing[1], the device senses the activity and the built-in sensors begin recording the pen strokes (traces). Once finished drawing, the child initiates scanning by pressing two buttons on the top of the device (Figure: 1). The device also attaches a tag (a number) to the back of the paper at this step. Audio recording can be initiated at any time during or after the time of drawing. The system automatically attaches the audio to the most recent record (records may be modified later). The records are downloaded to a computer to be viewed, annotated and modified in an interface specifically designed for this purpose. Viewers can also search for keywords in the annotations, print the drawings, or email them. They can input the tag number to retrieve the media related to a drawing on paper. The tablet can also be used to scan and input the drawings that have not been created on it.

Challenges and Next Steps

The current design of the physical prototype can only input standard-sized paper (8"x11") and does not accommodate children's tendency to draw on larger sizes. The device should be light and child proof: i.e. it should be safe, should not break if food or drink is spilled on it, or if it falls to the ground.

[1] Almost any utensil can be used. Traces may not be recorded for the mediums such as water color which apply very low pressure. Finger paints may also be used, but to capture finger paint another set of sensors (heat sensitive) are also required. The scanner gap prevents wet paper to be smudged and can input thicker paper and collages.

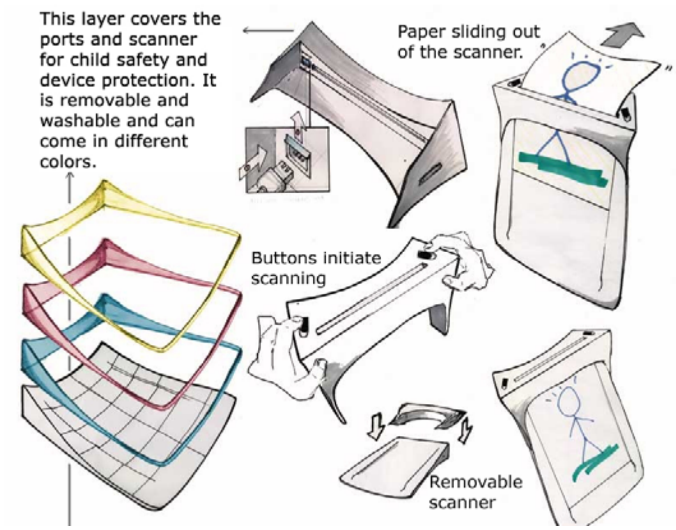

Figure 1: The drawing tablet

The user study will be extended and children behavior concerning drawing activity will be studied. A non-functional prototype of the tablet will be tested with children. The results will be used to revise the design. Later, a functioning prototype will be developed and tested.

CONCLUSION

Meaningful Traces can be used to keep record of a child's artistic development. Parents can use it to archive and preserve their children's creations as reminiscences of their development. This preliminary research only addresses the needs and requirements of parents as the end users. However, psychologists, art therapists, social workers, and teachers can all potentially benefit from the proposed tool.

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The Junk Mail to Spam Converter

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ABSTRACT

The junk mail to spam converter is a prototype designed and built to demonstrate the idea of a physical-to-virtual filter. A piece of mail is fed into a slot in the front of the machine, and a webcam takes a picture of the envelope and emails it to your account before the letter is shredded.

Keywords

junk mail, spam, converter, filter, physical-to-virtual

INTRODUCTION

As computers spread out from the desktop into the environment [1] they threaten to compound the problem of clutter in our physical spaces. To offset this trend we propose the use of physical-to-virtual filters to shift superfluous physical objects into the virtual realm and free up physical space. The junk mail to spam converter (JMtoSC) does not solve the problem of junk mail, it transforms it into spam so that it no longer intrudes on our limited physical space.

IMPLEMENTATION

Form

As it is intended to be your constant companion at home or in the office, the JMtoSC is conceived as a sculptural object. Like the three-headed dog at the gates of hell, this sheet metal Kerberos shreds your mail's physical instantiation and casts its digital memory off into the abyss of your email inbox.

Functionality

When a letter is fed into the slot in the front of the sheet metal structure, it slides down a chute through the JMtoSC's innards where it triggers a breakbeam made of a laser pointer and a light sensor. A handy board [2] bolted into the guts below listens for the beam to be broken and signals an applescript to snap a photo of the doomed missive and send it to your email account before the handy board flips the relay controlling to the shredder in the bowels of the beast and grinds the letter into compost.

Architecture

The skeleton is composed of hand-bent sheet metal pieces riveted together. The front panel has an opening to insert letters and comes down into two front legs. The mail chute connects this front panel to the rear section where the paper shredder is mounted over two shorter hind legs. The hind legs continue up past the paper shredder to provide a place to mount the laser pointer and web cam. Four rubber feet on the ends of the legs protect your furniture from scratches and prevent the vibration of the paper shredder from causing the JMtoSC to skitter around.

Figure 1 letter being fed into the JMtoSC

A handy board mounted beneath the letter chute watches for mail in the chute and coordinates its documentation and destruction. A light sensor located under a hole in the letter chute directly in front of the shredder is wired into one of the handy board's analog sensor ports. A battery-powered laser pointer directed at this light sensor from above functions as a break beam. The handy board control loop listens for a drop in the light level due to a letter obstructing the laser beam. When a drop in the light level is detected, the document and destroy sequence is initiated.

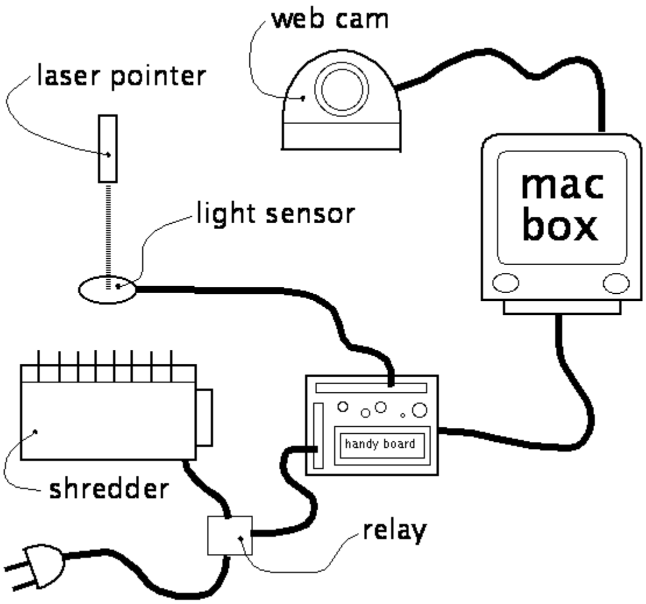

Figure 2 junk mail to spam converter architecture

The handy board sends a signal over its serial cable to a desktop computer running Mac OS 9 to initiate an applescript program that documents the letter. The applescript activates the web cam and captures an image of the envelope. It then composes an html email containing the image and sends it to your email address.

After pausing to allow the applescript to run the handy board activates a relay spliced into the paper shredder's power cord. The paper shredder is allowed to run for a set period of time more than sufficient to grind a business size envelope into confetti before the relay is turned off again and the handy board returns to its control loop while the JMtoSC awaits its next meal.

FUTURE WORK

The JMtoSC illustrates the concept of a physical-to-virtual filter but does not provide any particular practical advantage over throwing your junk mail in the recycling bin because you must first filter out by hand any mail you would not like to have shredded. A future goal of the project is to explore methods for filtering physical mail before you receive it at home.

The Junk Mail Early Warning System

When mail is initially processed and run through the zip code sorting machine, a digital photo is taken of each letter. A photo of each envelope addressed to you is sent to your email account as an html email. If you check your inbox before the letter has been delivered to your local branch post office there is a button next to the picture that says 'shred'. If you click the shred button the letter is shredded as soon as it arrives at your local branch.

Opt-in Virtual Mail

If you sign up for this program with the post office, when letters addressed to you arrive at the processing center they are opened by a machine rather than being routed to your local branch. The envelope and contents are scanned front and back, and then everything is immediately shredded. The image files are sent to your email account. By combining this system with optical character recognition software, your mail could be run through a spam filter with the rest of your email to automatically filter out junk mail.

Figure 3 web cam image from email

CONCLUSION

As embedded computing promises to bring information processing out into the environment with us, physical-to-virtual filters will mine the environment for physical artifacts whose primary purpose is information transfer and storage. Converting these bulky physical records into virtual form will free up physical space and make information readily available to be processed by embedded devices.

ACKNOWLEDGMENTS

We thank the UW Architecture Department for supporting the Physical Computing program, Ken Camarata for providing technical advice, and Fred Martin for developing the handy board.

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Part IV

Doctoral Colloquium

Communication from Machines to People with Dementia

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ABSTRACT

In this paper, I describe work in progress investigating effective means of communicating messages to people with dementia that will be understood and in some situations effect a behaviour change. Different media will be investigated for their effectiveness. Communications will be evaluated in domestic and laboratory contexts using hardware designed for this work and existing hardware from the Gloucester Smart House Project.

Keywords

Dementia, communication, machine, behaviour, media, human/machine interface.

INTRODUCTION

Dementia

Dementia is defined as 'a progressive global impairment of cognitive function in a conscious person that is usually untreatable.' It mostly, but not exclusively, affects older people. Its primary symptom is the loss of short-term memory. Other symptoms include an inability to plan task execution, the loss of the ability to reason, the loss of the ability to learn, temporal disorientation, and social disinhibition.

Communications

It is the objective of this work to be able to present to a human/machine interface designer a series of guidelines for the design of interfaces actiong between machines and people with dementia; specifically the most effective means of communicating information from a machine to a person with dementia.

This work is part of the Gloucester Smart House [2] project, which aims to develop devices and technology that will enable people with dementia to live more independently whilst being supported by technology. For these devices to be successful, they need to be able to communicate information to a person with dementia.

Similar work is in progress in Canada [1] where the washroom has been used as a context to evaluate the response of people with dementia to verbal prompts during a daily living task.

MESSAGES

The research is addressing two main classes of message to be communicated to the person with dementia.

The first is informative and does not necessarily require a response. It informs the user that, for example, an action by a device has been completed or that a person will be calling to visit shortly.

The second class of message is directive and is intended to modify the behaviour of its recipient. For example, a message may be generated to discourage a person from leaving the house at night in cold weather or to encourage a person to go to the toilet in the bathroom when they get up at night. Other messages may combine these two classes.

MEDIA

Many different media are available. Most people are familiar with visual communications from televisions, computers, advertising hoardings, books and magazines; and audible communications from the telephone, radio, CD or record player or public address system. There are other media that are not usually associated with communication that may prove useful in this research such as music, odour and directed lighting.

Medium: Audio

Audio is a versatile medium for messaging in a building and is frequently used in large public spaces.

Audio is pervasive – the message is present (for a hearing person) in all parts of the room simultaneously, whatever direction the person is directing their attention in. It is a means of communication that people are accustomed to.

Audio is transient. When message transmission has ceased, the message is no longer present except in the hearer's memory which in the case of a person with dementia will be poor. It may be possible to loop an audio message, but this could be very irritating for the hearer.

Other questions present themselves such as whose voice should be used to deliver the message? Should the message use the first or third person? Should the message be delivered by a concealed or visible audio device? A concealed device allows for a physically present speaker.

Using a familiar existing audio device such as a radio may habituate the user to acting on instructions, whereas a new device may need to be introduced early in the course of the dementia so that the user is comfortable with the device.

Medium: Text

Text is another versatile message delivery medium used in public spaces. It is persistent: it doesn't disappear on delivery and is there for a reader to come back to. It does not imply that the author is physically present.

Text is localised and requires the gaze and attention of the reader to be directed towards it for it to be effective. When a message is delivered, the attention of the user must be gained before any communication can begin.

Other issues that must be addressed when designing a text message are the type or script used, colours and size.

Medium: Video

Video too has advantages and disadvantages that do not make it an obvious choice as a communication medium.

Like audio, video with sound is transient unless it is looped. If video is used without sound it is localised and persistent like text.

Video does not imply the physical presence of the actor and can be used with real or animated faces. It is possible that an animated face will be perceived as a machine where as a recorded face will be perceived as an remote actor.

Video requires large electronic hardware overheads which have cost implications for communications devices and networks (if the video is not stored locally in each device).

Other Media

Other media such as odour (which is powerful stimulus of memory) and lighting will be introduced to highlight specific message from other messaging devices, or to stimulate the memory of a previous communication.

Hardware requirements

A versatile communication device is being developed that will be able to transmit audio, video and text to the user for the purpose information and behaviour modification. Control of lighting will be achieved with the installation of a bus system in the house. In a domestic context this will be a wireless bus.

EXPERIMENTAL WORK

The first stage of the experimental work will compare the responses of people with and without dementia to instructions given for a simple task to determine key differences in the way that people with dementia respond to instructions when compared to each other and people without dementia.

The arbitrary task selected is to present the subject with an instruction to turn one of two knobs to a particular numbered position. At the time of writing, the task equipment is being designed and built at BIME

Secondly people with dementia will be observed in their homes by carers and non-video sensors as they respond to prompts around key areas of the home. These areas are the kitchen, bathroom, front door and the whole of the house at night-time.

'Wizard of Oz' experiments with people with dementia will enable the testing of simulated devices in context, allowing changes to be made quickly and reactively. A concealed operator (the 'Wizard of Oz') can simulate the actions of an intelligent device interacting with the subject of the experiment.

Hardware developed for the Gloucester Smart House Project is being used for medium term evaluation of user response to messaging systems. A compact battery powered long-term data logger will record the user responses.

DEFINITION OF MESSAGES.

The messages used for this work are being defined for four domestic contexts.

The kitchen - a cooker monitor has been developed for the Gloucester Smart House project that can intervene to prevent a dangerous situation and inform the user of actions taken.

The bathroom – a bath and basin monitor has been developed for the Gloucester Smart House project that can intervene to prevent a flood and inform the user of actions taken.

The front door – a reminder system has been developed that, with a timer and proximity sensors, will prompt a user on appropriate exit from the building.

The bedroom – a system (the Night Light) has been developed that uses lighting and prompts to guide a person at night-time.

These systems in context currently use their own messaging systems (audio) but will be developed to use a general purpose messaging device being designed for this project.

ACKNOWLEDGEMENTS

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Dr. Roger Orpwood, Bath Institute of Medical Engineering, University of Bath, UK.

Dr. Ian Walker, Department of Psychology, University of Bath., UK.

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Context Information Distribution and Management

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ABSTRACT
In my research work I am investigating ways to combine both hierarchical and distributed hash table lookup methods for the distribution of contextual information. This combination allows context information to be managed locally, and the privacy of the information kept within the user's control. I also stress the importance of mobility in context environments.

Keywords
Context information, location aware services, content based messaging, distributed hash tables, context mobility

INTRODUCTION
Ubiquitous computing services are aiming to be able provide computing facilities to anybody, anywhere at any time. To provide these services an infrastructure must be developed that allows application programs running in the environment to efficiently locate the services in the user's local area. The system must also be able to supply information about the user's current context. This context information may be basic sensed information such as ambient temperature or more rich context such as "the user is involved in a meeting."

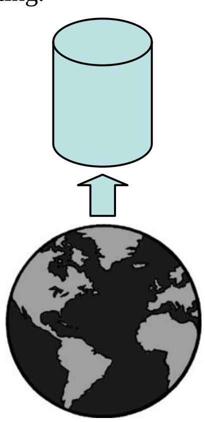

Figure 1 Single Database model

Context information is necessary if we are ever to achieve a completely invisible computer. An example scenario of how context information may be used is as follows:

> A user leaves Sydney for a conference in Seattle. The user has their personal CD collection that they own catalogued in their context repository. As they walk down the street, they pass a music store that sells a CD from a band that is common in their collection that they do not own. A message is sent to their mobile phone to inform them that the CD is available.

An architectural solution to this problem has been commonly addressed in two ways. The concept of using a single large centralized database (Figure 1). In this case any updates to context information must be updated at the single point. Another solution, as pressed by the GLObal Smart Space[1] project, is to have a large number of context databases that manage geographic areas (Figure 2).

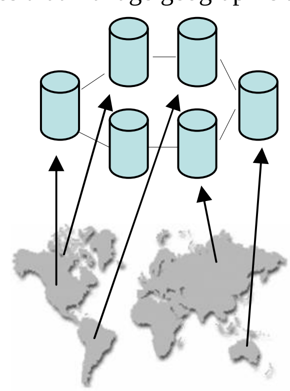

Figure 2 Distributed Database based on geographic location

MOTIVATION
There are problems with these two approaches that I aim to address. The single database model has a clear central point of failure. Also, the number of updates that would be required to be performed to manage the contextual data for the entire world would be enormous. The single database solves the problem of locating a user regardless of where they are. Distributed databases make it harder to find a user's location based on their identity as many databases may need to be searched.

Both of these models revolve around the user's context data being stored in a central infrastructure controlled database. This means that the user does not have complete control over who has access to their data.

The single database model would be able to achieve the scenario, but at the cost of giving up the user's privacy to store the CD collection. The distributed database model does not support tracing the user's location as they pass a music store.

I aim to try and develop a system that will allow users to efficiently access their context information regardless of their location. I want the user to be in complete control of their data by storing the information on their local resources.

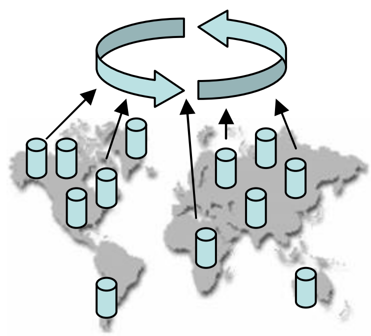

Figure 3 Proposed model with decentralised database

PROBLEM STATEMENT

A problem arises when users start to travel from one area to another. The infrastructure must be able to detect and identify these people regardless of where they are initially from. Also the users should be able to be detected without prior arrangement with the local environment. I have developed applications that use the Bluetooth transmitters in mobile phones as a kind of "Active Badge"[2]. This technique passively detects the Bluetooth hardware address of the user's phone, and matches this to a known profile for the user. The Bluetooth hardware address is not a hierarchical name, and as a result there is no simple way of doing a global lookup between the user's phone's address, and their profile

My research work aims to develop an infrastructure that combines the features of the hierarchical naming structure for static entities in the environment (such as rooms, buildings, and locations), and a distributed peer-to-peer database for mobile entities that can move between geographic areas (such as people or mobile phones) (Figure 3).

Each user is associated with a data storage solution in a local home network; this would be similar to a user's mail server. In this way, the user is in control of his/her data, and they have the option as to what data is made available to querying applications. Pointers back to these servers are entered into the distributed hash table as a means of locating the individual server.

Using the scenario as an example I envision a system where the client would be able to leave their home network, and upon arriving in a foreign area the network would be able to detect the user by their Bluetooth mobile phone. The Bluetooth ID would then be used as a key to the distributed table, returning a pointer to the user's home database. A message could then be sent to the user's home system, alerting it to the user's immediate surroundings. This information could then be used to inform the user about the availability of the CD.

EVALUATION

I am to implement this strategy using the Elvin[3] content based messaging service as means of handing the fixed location entities, and using a distributed hash table such as Chord[4] for creating pointers into this network for mobile devices. I wish to then evaluate the effectiveness of this method as a globally distributed context framework.

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Publish/Subscribe Messaging: An Active Networking Approach

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ABSTRACT

One of the challenges in developing a ubiquitous computing environment is transferring information in an efficient way. Peer-to-peer networks are too inefficient for a network with many sensors and devices so we need to find another paradigm for transferring information over a network. Content-based messaging may provide a way of doing this. We propose to develop a distributed, content-based publish/subscribe messaging system designed for a ubiquitous computing environment. It will use an active networks approach to provide efficiency and scalability, reliability in the event of failures and support for mobility.

KEYWORDS

Ubiquitous computing, active networks, event notification, publish/subscribe, content-based, distributed hash tables

INTRODUCTION

Ubiquitous computing embeds computing power in the environment, rather than just on our desktop. These computers should react to the users needs without the user needing to know how the underlying technology works or where the processing is taking place.

An implementation of this approach will involve many different sensors and devices connected together in a network. For example, in a room we might have a microphone to listen to user commands, a video camera to view gestures, an infrared sensor to detect how many people are in a room and a speaker through which feedback is provided. In this room, the output from the camera, microphone and infrared sensor can be sent to a remote server. This data will be processed and the results sent to the speaker, providing the user with feedback.

One of the challenges we face in implementing a ubiquitous computing environment is connecting all of these devices and sensors together. Connecting in a peer-to-peer network will provide many problems. Some of the devices in the network will have a limited power supply, so forcing the sensor to send its data to each of the possible consumers it is not a good idea. There will also be problems with addressing and service advertisement in a network with billions of sensors. Ubiquitous computing requires a new networking paradigm.

A networking paradigm that could be useful in a ubiquitous computing environment is a publish/subscribe system. In a publish/subscribe system, subscribers send messages describing the types of messages they want to receive. When a publisher posts a message, the message is forwarded to any subscribers who have requested it. A publish/subscribe system has a number of useful properties. One advantage is that publishers don't have to know who is interested in the data they are publishing; all they have to do is put the message on to the network. Similarly, the subscribers don't need to know who is generating the data; they only need to know that the data matched their request.

RELATED WORK

There have been a number of attempts at creating a publish/subscribe system in the past. The two main types of publish/subscribe messaging systems are subject-based and content-based. In group-based messaging systems every message belongs to a particular group. Subscribers can then register to receive all messages from a certain group. The main problem with this type of messaging system is that the subscription messages are often not expressive enough.

Another, more flexible, type of messaging system is content-based messaging. In content-based systems, the subscribers ask for messages where the content matches a certain pattern. The subscribers are not restricted to just a subject, they can ask for all messages where the data matches a certain pattern, for example, a user might want all messages where the temperature is greater than 30 degrees. This additional flexibility would be very useful in a ubiquitous computing environment.

There have been a few attempts at making content-based messaging systems in the past, but they all have issues that will make them unsuitable for a ubiquitous computing environment. Elvin [1] implements content-based routing on individual servers. The servers can be connected to some extent, but it is not scalable enough to work over a worldwide network. SIENA [2] and Gryphon [3] are distributed content-based systems, but they don't cope well with mobile publishers and subscribers or network failures. One other issue all of these messaging systems is that they require separate servers to run. Before a user can send a publish or a subscribe message, it needs to locate a server. This is unreasonable for some devices because they can be mobile or they may have very little processing power.

Another more powerful type of content-based messaging would require the subscriber to send its subscription in the form of code. When a message is received by the server, the subscription code could then be executed with the message as input, and the result of the code could be used to determine whether to send the message to a subscriber. This method gives subscribers full control over the messages they receive but has a number of drawbacks in terms of processing power required and security.

The Active Networks approach [4] attempts to place computing power inside network nodes. Active network nodes receive packets containing code which they then execute. With this approach it is possible to upgrade routers 'on the fly' and install new protocols simply by putting the code for them on the network. This approach aims to improve network efficiency and reliability.

PROPOSAL

We plan to investigate how active networking technology can be applied to the problem of content-based messaging and then see how this can be used in a ubiquitous computing environment. We hope this will lead to the development of a messaging system that is efficient, fault-tolerant and able to support mobility.

We plan to view the publish and subscribe messages as code that is to be executed by the messaging system. We will then investigate allowing subscribers to send complex subscription messages to see what implications this has on performance and scalability.

A major advantage of an active network messaging system has over traditional server based messaging systems is that publishers and subscribers will not have to search for a messaging server. Instead, they will simply publish their messages to the network and any active network node that picks it up will be able to execute it. This is a very useful property to have in a network filled with devices with low processing and battery power.

We also plan to investigate the use of distributed hash tables, like Chord [5], in a messaging system. Chord provides a method of locating objects in a distributed network, as well as providing support for fault-tolerance. These are properties should prove useful in a content-based messaging system.

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Workspace Orchestration to Support Intense Collaboration in Ubiquitous Workspaces

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ABSTRACT
The combined social and technological aspect of intense, co-located, collaborative work is a relatively new field of research. There is currently little support for the procedural and cognitive processes that exist in these group workspaces. This work will investigate the concept of workspace orchestration to support intense group collaboration in ubiquitous workspaces.

Keywords
Workspace orchestration, ubiquitous workspaces, cognitive activities, procedural support

INTRODUCTION

The results of recent work [1] have highlighted the need to augment collaborative workspaces with new services, such as an orchestration service, to coordinate and synchronise intense, collaborative activities. The procedural aspects of these work activities need to be automated to allow workspace participants to focus on the cognitive aspects of achieving their goals rather than mechanical aspects such as retrieving files. Many of the cognitive aspects of group workspaces, such as support for shared awareness, also need to be facilitated but few results from previous research are evident. The focus of this work is to investigate the concept of workspace orchestration that addresses some of the cognitive and procedural needs of collaborative activities within ubiquitous workspaces.

This paper characterises ubiquitous workspaces and briefly describes LiveSpaces, the environment that provides the setting for this work. The paper then highlights the types of activities that these workspaces support and identifies some of the components that are needed to support collaborative activities. The concept of workspace orchestration and its requirements are introduced and this suggests a direction for developing the theoretical foundations for orchestration services in future workspaces.

UBIQUITOUS WORKSPACES

Ubiquitous computing research is providing the components and infrastructure for augmenting physical workspaces with devices that will allow people to interact more effectively with each other and with technology. Future workspaces will be augmented with various interactive display devices, personal information appliances and natural language interfaces. Approaches such as augmented reality, virtual presence and conversational agents will help transform the way in which people use information to support collaborative workspace activities.

LiveSpaces is an experimental test bed for exploring the enabling aspects of ubiquitous workspaces. The reference architecture for LiveSpaces, see Figure 1, has at its core a workspace infrastructure that integrates with the broader enterprise by way of an enterprise bus. The workspace infrastructure provides for the coordination and integration of applications, services and devices within a workspace, much like an operating system might provide for personal computers. The current infrastructure implementation is based on iROS [2] and ODSI [3]. The architecture defines two service stacks. Knowledge services provide support for those aspects that make a workspace "intelligent". Workspace support services provide capabilities that directly support collaborative activities. One of these services is workspace orchestration, which is the focus of both this paper and the related PhD project.

UBIQUITOUS WORKSPACE ACTIVITIES

The LiveSpaces project is currently focusing on support for intense collaboration. These are the types of activities described by Mark [4] and others in using project or "war" rooms for intensive design and planning activities in areas such as space missions and software engineering. Intense collaborations can be characterised as being intent (or goal) directed, time critical and involving teams of specialists. This research focuses on workspace support for activities such as disaster relief planning, software reviews and decision making.

Workspaces need to adapt readily to a number of factors such as: the type of activity being undertaken, the setting hosting the activity and the people involved. Moreover, activities need to be orchestrated and managed within individual workspaces to ensure that goals are met within a required timeframe.

Issues such as coordination and synchronisation are critical for teams to achieve their goals. Specialists who are participants in these activities are often co-located in specially designed rooms that foster face to face collaborative activities but often the supporting technological infrastructure adds little to achieving their goals.

Many of these activities have a defined flow of events. For example, an emergency response planning session generally has a formally defined, procedural set of activities. Workflow engines could potentially be used

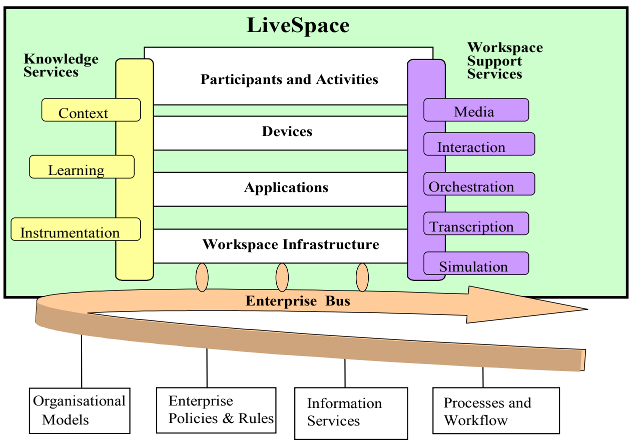

Figure 1 The LiveSpaces architecture in the e-World lab at UNISA

to support these procedural aspects and inferencing engine models may assist when more flexible approaches are required. These aspects will be explored further as part of this PhD research.

In addition to the procedural side of intense collaboration, group cognition also needs to be considered as part of the orchestration process. The aim of this work is to identify, model and automate some of the group cognitive processes such as group awareness and decision making. Approaches to be researched in this regard include Distributed Cognition theory [5], which focuses on changes in cognitive states at a system level, and Activity Theory [6],which focuses on individuals along with the activities they are engaged in.

WORKSPACE ORCHESTRATION

Workspace orchestration services support both procedural and cognitive aspects of intense collaboration and two approaches are required to explore these aspects. The first is to investigate the procedural, structured processes that lend themselves to automation and the second is to identify and model the group cognitive processes that produce the less structured, ad hoc activities.

An orchestration service needs to be partly autonomic and partly interactive. For example, the service may prefetch and load data automatically as required, but a user should also have the flexibility to request ad hoc data sets. This means that the service can coordinate activities according to a preselected sequence of events with the flexibility to change the order as determined by cognitive actions. It should augment the cognitive work activities of the users in the workspace and at the same time provide procedural guidance. The service should monitor workspace activities and context to coordinate devices, displays and applications and it should operate primarily in the background as a ubiquitous service.

Observations of laboratory experiments and ethnographic studies in our candidate domains will help to identify and model the cognitive and procedural processes in collaborative activities and these processes will be mapped to computational artefacts. An experimental orchestration service will be developed to explore implementation approaches based on the use of workflow concepts, an inferencing engine or other candidate approaches. This experimental apparatus will be used within a LiveSpaces environment to evaluate workspace orchestration concepts in two application domains: disaster relief planning and scientific “tiger teams”.

CONTRIBUTIONS

This work will test the hypothesis that “workspace orchestration can enhance a team’s ability to achieve its goals in intense collaborative activities within ubiquitous workspaces”. It will provide a workspace orchestration model for building applications for collaborative workspace activities and it will model of some of the cognitive and procedural properties of intense collaborative activities.

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Visualisations of Digital Items in a Physical Environment

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ABSTRACT
One of the results of the increase in Ubiquitous computing is the addition of a large number of digital items to the physical environment. As more hidden complexity is added to the environment it becomes difficult to understand. This paper presents an abstract of my doctoral research into visualising this environment using a variety of techniques including Virtual Environments.

Keywords: Intelligent Environments, Visualisation, Virtual Environments

1. BACKGROUND
Ubiquitous Computing and context aware computing are increasingly active research areas. As evidenced by the growing number of new journals and conferences in the area such as: UbiComp, IEEE Pervasive Computing, IEEE Transactions on Mobile Computing, IEEE Distributed Systems Online: Mobile & Pervasive section and Middleware section, and ACM Sigmobile.

Researchers have looked at embedding sensors in the environment to measure all manner of information. Examples of this are location and temperature. The Georgia Tech Aware Home [2] project has built a complete house embedded with a wide variety of sensors. The aim of this project is make the home "aware" of the activities and location of its occupants. They use this information to improve the quality of life and allow the occupants to maintain their independence.

The Global Smart Spaces (GLOSS) project[3] aims to provide an architecture for interaction between people taking into account context and movement on a worldwide scale. One example service built on the GLOSS architecture is the Hearsay system. This allows users to leave messages for others in a given locational context.

Researchers at the university of Kent have developed a system for leaving pieces of digital information in a given context [1]. This context is generally the location of the information. They call these digital post-it notes stick-e notes.

2. EXAMPLE SCENARIO
To give motivation for this project lets consider an example scenario of an intelligent office from the perspectives of a normal user (an employee), visitor and administrator.

The office contains all the items one would expect to find in a modern building, such as cabled network, wireless LAN, electronic door locks, fixed computers, printers, fax machines, projectors, video surveillance. There are also items to make the office intelligent such as cameras, temperature sensors, motions sensors, location tracking devices, large communal displays, bluetooth devices and PDA's.

In addition to these physical objects with a digital effect there are also purely digital items. An example of one of these would be a stick-e note, or other information which only appears in particular contexts. An example of a context would be a particular location and specific set of people present) as would occur at a regular department meeting.

When we consider the digital items of interest to a normal employee (regular user of the building) They may be interested to know how / where they control the lights for a particular room. For example unless they are the building administrator they won't be able to turn the lights on or off unless they are in the correct room or it's their own office.

A visitor to the building has a different view of the environment. For example, in needing to access the wireless LAN they may need an easy way to see where in the office there is wireless LAN coverage. Alternatively they may be seeking to print and need a way to find the nearest printer and to determine its capabilities and settings. They will not be interested (and probably shouldn't be able to see) certain digital messages left around for regular employees.

An administrator of the system has a need to understand much more about the environment. They need to be able to see all of the digital information tied to the environment, possibly at the same time. They may wish to see all of the digital items as well as information about when / where / to whom the items are visible.

3. PROBLEM STATEMENT

The continued expansion of Ubiquitous Computing has resulted in the physical environment having a multitude of computational devices and digital items added to it. These additions continue the evolution of the Physical Environment in to an Intelligent Environment. However such computing environments are difficult for people to understand. The question which my research seeks to answer is how to provide a view of the digital information which resides in the physical environment, in a way which is comprehensible.

The motivation for this project is that there is no good way to see / filter all this information. It would be useful to be able to visualise this information and also be able to browse through it or see aggregated views. This should be accessible on a range of devices for example a PC, PDA or mobile phone.

4. PLANNED RESEARCH

My research aims to represent physical and digital items within an intelligent environment. Before examining the representation of these items we first categorise the items of interest, finally we look briefly at the architecture required to show these representations of digital and physical items.

4.1 Physical and Digital Items

Items within an intelligent environment fall into a number of categories. The first category contains physical items with an area of effect in the environment. This includes WiFi access points, bluetooth beacons, proximity sensors (such as those on door locks), motion detectors and video cameras.

The next category is physical items with some digital/physical function. Items in this category include light switches, door locks, projectors.

The final category contains purely digital items. These can vary in the context in which they exist. Their locational context can vary from a single point (for eg. a message only visible at the exact spot) to a large area (eg the area a service is available in). An example in the first category might be digital post-it notes while the second category might contain the logical services of can print or can control lighting.

4.2 Representation to User

My plan is to use a number of different visualisations to present information about the intelligent environment to the user. The first is to generate a virtual environment which mirrors the physical environment. Representations of digital items related to the physical environment are then placed appropriately in the virtual environment.

The level of detail to which the physical environment is modelled can be varied in order to make the digital items more or less prominent. Using this system the user may also be able to interact with the digitally controlled systems via the virtual environment and have the changes reflected in the physical world. Previous work has been done on using virtual reality in control systems but not on a worldwide scale.

Figure 1: An example view using Augmented Reality to show that there is mail waiting.

Another way of viewing the digital items would be using augmented reality systems. In order to work effectively this would require accurate location tracking to be able to put digital information in arbitrary locations. A more restricted option would be to put visual markers recognisable to an augmented reality toolkit [5]. This allows digital information to be display next to physical items tagged and known to the system.

The final way of representing the digital items is on 2 dimensional maps. This approach is more restricted in terms of interaction, but can be displayed on devices with lower computational power.

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Identity Management in Context-Aware Intelligent Environments

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ABSTRACT
This paper briefly defines the concepts of identity management as they relate to intelligent environments and provides some examples of existing research in this area. Several problems within this space such as entity discovery and information classification are also discussed with an aim to make clear several possible research directions.

Keywords
Identity management, nymity, nym, intelligent environment.

INTRODUCTION
As computers become ubiquitous and the notion of intelligent environments (IEs) develops, identity management demands increasing attention. Intuitively, identity management is concerned with controlling the pieces and types of information pertaining to a person that are made available to an environment and other people. More concretely, it can be thought of as the protocols and policies used to access this information.

IEs are often portrayed as "smart" rooms that allow users to connect to various services without manually configuring network settings or interacting in explicit ways. In addition, IEs are generally able to deduce actions and context from basic low-level sensors dispersed throughout the environment.

As with many systems, there exists a tradeoff in intelligent environments between ease of use and security. An example of this is the *Passport* project from Microsoft [6]. This system is intended to provide a single login/password pair for a user across a wide range of web and other services. While appealing in terms of its convenience, such a system has a major drawback; anybody able to determine the username and password of an email account, say, would also be able to access services such as bank accounts or personal log files. Additionally if the right types of information were discovered, it would be trivial to directly associate data found within these systems with an actual person.

NYMITY
An *entity* is defined as a person within an intelligent environment. An *entifier* [1] is a signifier of an entity. The best type of entifier at present would seem to be a *biometric* such as a fingerprint, retinal scan or DNA sample.

The concept of *nymity* realises identity management in an abstract way, dealing in particular with personaes or *nyms* presented to the IE by an entity. Identity management is thus reduced to controlling access to sets of information (nyms) associated with an entity and, in most cases, providing some link by which the IE can communicate with the entity.

Nymity is often thought of in terms of Goldberg's Nymity Slider [4] ranging from *unlinkable anonymity* to fully authenticated *verinymity* with *pseudonymous* possibilities in between. There are several definitions of the terms in existing literature but for the purposes of this paper, I will assume that unlinkable anonymity (or just anonymity) is the case where there is no possibility of linking data to an entity either directly or through combination with other data or nyms [1] and verinymity is the case where data can be directly associated with a particular entity.

Anonymity is often illustrated by the example of using cash to purchase items from a shop that is never revisited. No authentication is required to use cash, and once the transaction is complete it is virtually impossible to discover the involved entity. Verinymity can be illustrated by the example of a retinal scan allowing access to a building. In the cases of such biometrics there is virtually no doubt that a given identifier links to a particular entity [1]. However the absolute ends of the scale should in practice be considered unachievable [2], meaning all nyms fall into the category of pseudonyms.

A nym, then, is a signifier for an entity but it is not necessarily linked in such a way that an entifier for the entity can be found (that is, it is not necessarily possible to discover the actual entity associated with the nym). Consequently, nyms can be used to expose various pieces of information in such a way that they cannot necessarily be linked together or to the entity that created them.

EXAMPLE SCENARIO
Jill, a lecturer at a university wishes to use the projector in a meeting room to present some slides. It is not necessary in such a situation for the environment to know exactly who Jill is; it is sufficient to know that she is a lecturer, and hence allowed to use the facilities of the meeting room. In this case, a 'lecturer' nym exposing a particular agreed password would be sufficient for the environment to provide the desired functionality. Other applications, such as a system whereby Jill could be located on campus would require a different, less anonymous 'name' nym that actually provided her name to the IE. Figure 1 illustrates these relationships.

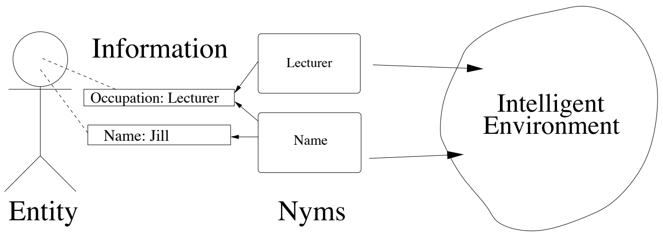

Figure 1: The relationships between an entity, the entity's information, nyms and the intelligent environment.

In general, it seems clear that most people would like to limit the amount of information they provide about themselves to the intelligent environment, or at least provide the requisite information in such a way that it cannot be easily traced back to them unless absolutely necessary.

Although the purpose of nyms is to present very specific sets of limited information to the environment, it is easy to imagine situations where nyms could be maliciously combined either by a single party or by colluding parties to allow the discovery of additional information, or even the discovery of the entity underlying the nyms themselves.

PROBLEM STATEMENT

I am interested in exploring mechanisms for automatically creating or modifying nyms to provide as little information as possible to an IE while still providing enough for applications to be useful.

Further to this, I am interested in finding ways of reducing the probability that an entity can be discovered (or linked to data) based on the nyms they expose.

APPROACH

To understand and develop such nym-based mechanisms, it may be worth considering the classification of types of information referenced by a nym such that automated reasoning can be applied to reduce or eliminate discovery of an entity or deduction of further information. For example, if an entity's address details are classified as extremely sensitive, a nym-based framework may disallow inclusion of them in a nym that is intended for public use.

To take this further, such a framework could disallow the use of multiple nyms which include an entity's address in different contexts so that it cannot be used as a way of tying together otherwise apparently unrelated nyms. Such automated schemes for enforcing containment of information have been explored in specific domains such as cooperative collaboration tools [3] with some success.

The problem can also be approached from a different, though complementary direction, that of *identity fusion* [7, 5]. Similar to *sensor fusion*, this is the concept of constructing probabilities of a nym relating to a particular entity based on the accretion of low-level sensor data such as an entity's location or passage through security doors. Instead of trying to reduce the leakage of information or entifiers, identity fusion is at least partially concerned with exploiting such weaknesses. It would thus be beneficial to explore this concept to strengthen research into reducing entity discovery.

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Towards a Software Architecture for Device Management in Instrumented Environments

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ABSTRACT

An infrastructure for scalable plug-and-play device management in an instrumented environment is presented. A prototype of the system is described and issues of the overall architecture are addressed.

1. INTRODUCTION

The FLUIDUM project (www.fluidum.org) is currently building an instrumented environment in order to investigate interaction techniques for ubiquitous computing. An infrastructure for device communication has to be provided that allows fast prototyping and provides a stable foundation for the projects devices, scalable to desk-, room-, and building-level.
In analogy to the well known concept of a window and driver manager of a conventional desktop computer I am working on such an infrastructure for instrumented environments of various scales.
At the core of this system is a device manager with a dynamic plug and play mechanism for possibly fluctuating devices (e.g. PDAs or laptops) in the environment. A prototype of this device manager is built. Its architecture is described in the following section. Finally, I discuss issues raised during the implementation of the prototype.

2. ARCHITECTURE OF THE PROTOTYPE

2.1 Design goals

The design of the device manager is guided by several constraints. In the FLUIDUM project it will be used in three differently scaled instrumented environments, with a potentially widely varying number of devices and applications. Also, in order to cooperate with other, similar projects at the same office, the device manager has to be reusealbe in other contexts. In order to achieve these goals, there are several important considerations.
Since the architecture has to be open to new applications and new devices, the interfaces have to be well defined and simple. The architecture has to be sufficiently flexible for unforseen future devices. This will be achieved by the way devices are classified, as described in more detail below.

2.2 Overall system design

The core part of our system is a blackboard, called “the pool”. It is used to store and exchange all sorts of important information about the environment. Connected to the pool are several services that provide information for the pool, or offer processing of information and then eventually write their results back to the pool.
The plugboard service is one of those services and deals with the device management. Besides keeping track of all plugged devices and their features, it can trigger actions on the devices based on data stored in the pool. For instance a service might put a request for taking a photo with a digital camera on the pool. The plugboard service then takes the request from the pool, captures the requested photo and places a reference (URL) to this photo back in the pool. The requesting service can take this URL and process it.
The next section discusses the device manager’s approach for device classification. After that, the architecture of the plugboard is presented.

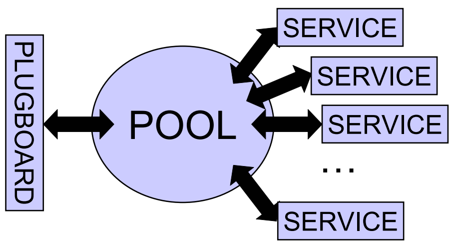

Figure 1: High level view of the system

2.3 Classification of devices

As mentioned above, one main issue in device classification is the uncertainty about future devices. At the current pace of hardware evolvement, it is very hard to tell which kind of devices will have to be integrated in the system in a few years, and next to impossible to find a classification of devices that could handle them.
Therefore, we decided not to classify the devices, but instead to classify the different properties of a device (video capturing, text entering, infrared sensing, etc.) and model a device as a list of those properties.
This approach turned out to be very flexible and useful so far.

2.4 Plugboard architecture and device manager

The architecture of the plugboard reflects the approach of device classification. A device is modelled as an object containing a list of parameter/value pairs (e.g. “name=camera01”) and a list of property APIs. The inclusion of such a property API, e.g. “video in”, means that the device has this property. If a property of this type is missing, we can assume that the device can not perform that task. The advantage of modelling those properties as API is that besides getting information about the device, we also acquire access to its features. The APIs are standardized, so on encountering a certain property API we know which functions can be called.
The central part of the plugboard is the device manager server. It is a lookup service to which devices can connect or from which they can disconnect. On the other hand, services can also connect to the server and request information about devices. Each connected service will be automatically informed if there are important changes in the plugged devices. Some of those services take care of the connection and exchange of data to the central data pool.

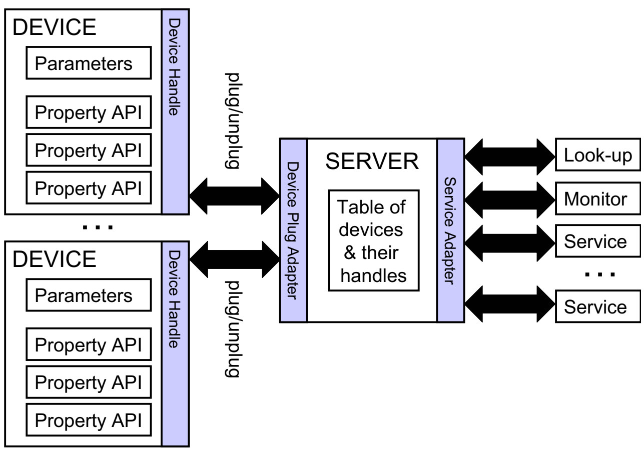

Figure 2: Architecture of the plugboard

3. DISCUSSION ISSUES

There are some unresolved issues in the current system that I would like to discuss.

3.1 Centralized design as bottleneck

Although the central device manager service seems the logical design approach, it is a potential bottleneck and source of instability of the whole system if it fails. At the moment, the services keep a copy of the device manager’s list of all plugged devices and thus could continue working during a device manager failure. Although stable, this solution might lead to performance issues. Alterantive approaches might include self-organizing structures or some sort of peer-to-peer network.

3.2 Reliable recognition of device disconnection

At the moment, the devices connect via remote method invocation to the central server. Although there are some stable mechanisms to detect a failure of this connection, there is no sophisticated mechanism yet to detect failure of a device without previous disconnecting.

3.3 Ressource management

The device manager server is a useful lookup service to find available devices and to find out about their features. A feature and concept for scheduling devices to applications is yet missing. Especially a realiable locking mechanism for devices or device features in use is missing. Also, mutual locking of different properties on the same device is missing. For instance, a camera currently in use in the system is not capable of simultaneously broadcasting a video stream and capturing a high resolution photo. Those dependencies have to be modelled.

3.4 Inclusion of future devices

This is a point which should be solved with our approach of device properties. The author would like to discuss it and gather some more opinions.

3.5 Dealing with virtual devices

Some properties, for instance recognition of visual markers, do not have a hardware equivalent but are overlays of other properties, for instance video capturing in this example. There current solution is implementing virtual devices that plug to the server both as device (marker recognizer) as well as requesting service (looking up devices with video capturing property). Although this approach works, there might be a more elegant way to do this.

4. ACKNOWLEDGMENTS

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Ubiquitous Support for Knowledge and Work

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ABSTRACT
Knowledge management (KM) presents a challenge to human-computer interaction (HCI). Indeed, a reassessment of how knowledge and work distributed across structural and cultural boundaries of organization are supported may be in order. This dilemma can be summarized by stating that the problem concerns how knowledge is conceptualized and at what level of organization interventions are proposed. Consequently, my dissertation draws upon three theories—Communities of Practice, Activity Theory, and Institutional Theory—that emphasize knowledge and work as collective processes to counter this challenge. A case of the collaborative practice of virtual teams in the U.S. Navy is presented to illustrate.

Keywords
Knowledge management, human-computer interaction, Communities of Practice, Activity Theory, Institutional Theory

INTRODUCTION
The U.S. Department of Navy (DON) is in a monumental period of transition. In essence, to counter a radical downsizing in on board personnel and to leverage what has been championed as the critical asset of tacit, expert knowledge as well as advanced information technologies, the DON has formulated a strategy that promotes knowledge management and eGovernment initiatives throughout the enterprise. To emphasize the impact of this transition, an exchange on evolving collaborative troubleshooting practice in the U.S. Navy between two long-time civilian employees follows:

Bill: In the old days that [an exchange between at-sea sailors and shore-based technicians engaged in a troubleshooting action] would have been handled by satellite phone (MRSAT) or message traffic. So the SIPRnet [the *S*ecret *I*nternet *P*rotocol *R*outer *Net*work, used to transmit classified information about ships] has really helped, being able to send email because sometimes it would take a day to get a message out. Even if you're in a priority situation there's (sic) a lot of things going on in a ship; they don't have the time to cut a message with you.

Don: Yeah and, in fact, just to further what BS's saying like again the chat came in to play [in a recent troubleshooting action aboard a ship deployed in the Persian Gulf]. Because what I was doing was I was chatting with LANT [FTSCLANT – Fleet Technical Support Centre, Atlantic Division in Norfolk, VA] almost nightly. Almost every night about what my problem was and, you know, what I mean and then they were in turn calling Richard [at the Naval Surface Weapons Center, Crane in south-central Indiana] and actually doing, you know, calling Richard on the phone saying, "Yeah, you know…[Don's]…got these parts – he can do this, this and this," and then they would get back on chat [to continue troubleshooting with me] and it's all real time.

The above discussion between Bill, an electronics engineer, and Don, a subject-matter expert technician, encapsulates the current, yet evolving practice of maintaining and troubleshooting at a distance the shipboard systems in the U.S. Navy. To review, a subject-matter expert (SME) on a "tech assist" in the Persian Gulf exploits both mundane and advanced information technologies to leverage geographically-dispersed expertise. The mission was to troubleshoot and resolve a critical problem with a complex electronic countermeasure system aboard a ship deployed to defend troops landed in Iraq.

DESIGN FOR DISTRIBUTED KNOWLEDGE AND WORK
The above excerpt and scenario capture nicely the hurdles to be overcome to support sailors, engineers, and technicians servicing complex electronic systems aboard U.S. Navy ships. The matter is more critical given the DON's explicit interest in knowledge management (KM) initiatives.

Consequently, one interpretation of this strategic initiative is to develop a knowledge management and performance support system to aid at a distance the collaborative troubleshooting actions of military and civilian technicians maintaining electronic countermeasure systems aboard U.S. Navy warships. To this end, the Knowledge Acquisition and Projection Lab at Indiana University is attempting to meet this challenge by participating in the Knowledge Projection Project – a joint undertaking with Naval Sea Systems Command (NAVSEA), Naval Surface Weapons Center (NSWC) Crane, EG&G Technical Services and Purdue University. The proposed system is intended to leverage both intellectual capital (i.e., tacit knowledge) and advanced information technologies (e.g., Case-Based Reasoning and High Performance Knowledge Bases) to facilitate the collaboration between shore-based civilian technicians and on board sailors within a network of distributed practice. The goals of the design team at IU are to exploit KM thinking and techniques to impact key organizational variables, including a reduction in total cost of ownership, an improvement in the efficiency and effectiveness of maintenance and troubleshooting, and an increase in fleet readiness.

Understandably, this presents a unique challenge to human-computer interaction (HCI). To meet this challenge the suggestion forwarded here is to expand traditional frames of reference to more fully incorporate social and cultural features of organization that may influence the effective distribution of knowledge and work across enterprise boundaries. As will be illustrated in the case of this collection of military and civilian technicians, social features arise as performance is essentially a collaborative and distributed practice across specialized work units; cultural features arise as this coordination cuts across functional identities, defined both by their status in the organization (military or civilian) and role in the end-to-end process (primary maintainer or first-line support). To assist with accounting for these social and cultural features, I will enlist concepts and principles from three perspectives that are appearing with increasing regularity in the HCI literature — *Communities of Practice* [4], *Activity Theory* [2], and *Institutional Theory* [5]. Juxtaposing these three theories may better permit for the examination of inherent, yet unrecognized, tensions in the concepts of knowledge (object-process) and work (individual-organizational) that knowledge management principles and initiatives present.

THREE PERSPECTIVES ON KNOWLEDGE AND WORK

Almost fifteen years ago, Susanne Bødker [1] wrote:

This article presents a framework for the design of user interfaces that originates from the work situations in which computer-based artifacts are used: The framework deals with the role of the user interface in purposeful human work…I deal with human experience and competence as being rooted in the practice of the group that conducts the specific work activity…The main conclusions are: The user interface cannot be seen independently of the use activity (i.e., the professional, socially organized practice of the users and the material conditions for the activity, including the object of the activity). The standard view in these situations is to deduce an ultimate set of operations from an abstract use activity and apply these to design and analysis. This article argues that the user interface fully reveals itself to us only when in use (p.171-172).

In this dissertation I wish to extend her framework to include Communities of Practice and Institutional Theory. The reasons for this are threefold. First, over the past fifteen years there have been tremendous advances to theoretically-informed analyses of knowledge and work. Nonetheless, few attempts have been made to integrate perspectives. Second, there are shortcomings to Activity Theory, particularly a lack of attention to the issue of power that can be addressed by the other two perspectives. Finally, a brining together of these theories can aid to facilitate the continued interdisciplinary nature of HCI. By incorporating theories that are now used in cognate fields such as educational psychology, performance technology, information science, and organizational theory, this agenda can be further advanced.

CONCLUSION

My aim has been to reveal the challenges that knowledge management initiatives bring to the theory and practice of human-computer interaction. The issue is that distributed knowledge and work inevitably involve the crossing of social and cultural boundaries of organization. What is encouraging is that we now have appropriate, theoretically-based perspectives that can assist in meeting this endeavor.

ACKNOWLEDGMENTS

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Anonymous Usage of Location-Based Services over Wireless Networks

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ABSTRACT

The ability to sense user context, especially user location, and to adapt applications to it, is a central notion in ubiquitous computing. While such information can enable important applications, it also raises significant questions about information privacy. Concentrating on location information—arguably a more sensitive part of context—we investigate novel privacy enhancing technologies between the extremes of relying on goodwill and complete data suppression. By adjusting data precision and ensuring anonymity of the distributed information can mitigate privacy risks while still allowing some applications to gain insights from this data.

1. INTRODUCTION

Improvements in sensor and wireless communication technology enable accurate, automated determination and dissemination of a user's or object's position. There is an immense interest in exploiting this positional data through location-based services (LBS), which we define broadly as applications that automatically receive user location information. For instance, adaptive smart spaces could tailor their functionality to the user's presence and current location [1], or vehicle movement data would improve traffic forecasting and road planning [2].

The success of LBS is intrinsically tied to wireless networks. Wireless networks enable a high degree of user mobility; that is, users can access computing services virtually anywhere. Thus, location becomes an important piece of contextual information for applications. Among wireless networks, the proliferating wireless LAN networks are of particular interest, because they provide high-bandwidth network connections, allow precise locating of stations, and have the potential to cover the highly populated key areas, where people spend most of their lives.

However, without safeguards, extensive deployment of these technologies endangers user location privacy and exhibits significant potential for abuse [3]. Common privacy principles demand, among others, user consent, purpose binding, and adequate data protection for collection and usage of personal information. Complying with these principles generally requires notifying users (data subjects) about the data collection and purpose through privacy policies and implementing security measures to ensure that collected data is only accessed for the agreed upon purpose.

2. SCOPE

Our research concentrates on a complimentary approach based on adjusting the level of data accuracy. In this approach, location-based services and network providers can collect and use only de-personalized data (i.e., *practically anonymous* data). This approach promises benefits for both parties. For the service provider, practically anonymous data causes less overhead. It can be collected, processed, and distributed to third parties without user consent. For data subjects, it removes the need to evaluate potentially complex service provider privacy policies.

Practical anonymity requires that the subject cannot be re-identified (with reasonable efforts) from message contents and characteristics. So far, we see the greatest location privacy challenges in link layer information available to wireless LAN clients and application layer information that is transmitted to service providers.

2.1 Wireless LAN Hotspots

In IEEE 802.11b wireless LANs, signal characteristics allow determining the position of a transmitter with high precision [4]. In addition, the MAC address provides a static identifier that enables an adversary to link multiple messages to the same transmitter. Thus, an adversary can track the movements of the transmitter and potentially identify its user.

2.2 Location-Based Services

For LBS, we consider the primary risk inherent in the location information. While user IDs are not required for all services or could be faked, the transmission of location information is necessary to obtain the service. However, revealing accurate positional information can pose serious identification problems. The Global Positioning System typically provides 10–30 feet accuracy. This information can be correlated with public knowledge to identify a user or vehicle. For example, when a map service is used while still parked in the garage or on the driveway, the location coordinates can be mapped to the address and owner of the house. If queries are sufficiently frequent, they can be used to track an individual. Note that these methods use mostly publicly available information as opposed to the identity behind network (IP) addresses, which is typically only known to Internet Service Providers. Thus, this type of identification attack is available to any provider of a location-based service.

3. APPROACH

The privacy enhancing mechanisms seek to maintain a minimum level of anonymity. Inspired by the k-anonymity concept [5] for databases, we define the level of anonymity as k, where the adversaries observations of an individuals movements must be undistinguishable from at least $k-1$ other individuals. We plan to extend this model to take into account continuous data updates (i.e., location information changing over time).

We address the WLAN tracking problem at the link layer through disposable MAC addresses. Compared to solutions such as directional antennas, this lightweight mechanism that can be deployed without extensive hardware modifications. When addresses are switched frequently enough, it prevents an adversary from tracking the movements of individuals. More sophisticated adversaries, however, may be able to link several addresses to the same individual through monitoring signal-to-noise ratio or traffic analysis. We plan to analyze WLAN traces to judge how frequently addresses must be disposed for a given level of anonymity and how vulnerable this approach is against the more sophisticated attacks.

The system uses cloaking algorithms that change the accuracy of location information, when the system intentionally reveals it to third parties, such as location-based services. To date, we have designed a system architecture and algorithms [6] that adaptively control the accuracy of transmitted location information so that the message could have originated from at least k users. Based on automotive traffic simulations we found that 100–200m accuracy is usually sufficient on city and highway streets to maintain a minimum level of 5-anonymity. We plan to extend this work with algorithms that do support more sophisticated location queries than asking for a single point and with algorithms that do not rely on a central trusted server.

4. RELATED WORK

The design for the Cricket location support system [7] takes privacy into account by determining position the user's trusted client device (as opposed to potentially untrustworthy building infrastructure). This enables the user to take control over his location and decide whether to share it. Our cloaking algorithms, however, can build on such location systems to control the accuracy of revealed information.

Langheinrich's privacy awareness system [8] informs data subjects and users about data usage policies; thus, it increases awareness but does not seek to offer protection. Other researchers [9, 10] describe systems that can enforce data access rules specified in privacy policies; our approach adds the capability of determining appropriate levels of accuracy for anonymous data.

Sweeney [5] proposes the k-anonymity model for anonymizing database tables. Generally speaking, a database table is considered k-anonymous if it contains at least k entries for every quasi-identifier. In other words, there are at least $k-1$ other individuals that any given record could pertain to.

For data mining purpose entries can be perturbed before storage by adding a random value [11]. A reconstruction procedure then estimates the approximate distribution of a large number of values; however, no specific value can be linked to an individual.

Short Bio

Marco Gruteser is currently a Ph.D. candidate in computer science at the University of Colorado at Boulder. His research interests include privacy, context-aware applications, and wireless networks.

During a one-year leave at the IBM T.J. Watson Research Center, he developed a software infrastructure that integrates sensors to support context-aware applications in the BlueSpace smart office project. This work led to four pending patents, a refereed conference publication, and coverage from US news media such as the New York Times and ABC Television News.

Marco received a Master's degree in Computer Science from the University of Colorado at Boulder (2000) and completed a Vordiplom at the Technical University Darmstadt, Germany (1998). He is a student member of the ACM.

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Service Advertisement Mechanisms for Portable Devices within an Intelligent Environment

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ABSTRACT
Personal servers are portable devices with substantial processing and storage abilities, but no user interface. A user carries one on their person while inhabiting intelligent environments, and interacts with the processes and data it contains using nearby devices. The lack of user interface requires a rethink in how this interaction takes place, as the environment now needs to access services available on the portable device, rather than the more traditional method of the portable device accessing the services available in the environment. Through my research, I aim to develop a mechanism which enables a portable device, such as a personal server, to advertise the services it has available to an intelligent environment and to explore what new applications this enables.

Keywords
Ubiquitous computing, intelligent environments, services, service discovery, service advertisement, portable devices, personal servers.

INTRODUCTION

Personal Servers

The personal server [1,2] is a portable device containing high-density storage and low-power, high performance processing, but without any form of direct user interface. Wireless connectivity allows it to communicate with other devices within a local intelligent environment, and it is through these that a user interacts with their personal server. This allows users to interact with their data through whatever interface is convenient, so that the personal server itself does not have to be a trade off between portability and usability. Users can carry a device small enough to clip on a belt with them at all times, access it using a phone or PDA while traveling, but then easily make use of a full size screen and keyboard when it becomes available, such as in a café or their office.

A major strength of the personal server is that, regardless of what interface devices are being used, the user always has access to their own data and applications. This removes the difficulties inherent in accessing personal data within an unfamiliar environment, such as gaining network access, negotiating firewalls and finding a computer running the correct version of an application. All the user needs to access their data is a personal server and a devices that supports the appropriate standardised method of communication

The personal server supplies external devices with access to its resources through services. These services can range from providing simple personal details about the user such as your name or your favourite food, to far more complicated services such as capturing input, outputting screen buffers, running processes or presenting its storage as a mountable volume.

The properties that a personal server exhibits make it the perfect device for a user to employ to interact with an intelligent environment. Similar devices have been created, such as Factoid[3], MetaPad[4] and Minder[5]. However, these tend to either be less capable, particularly in terms of processing ability, or to be more reliant on wired links. This limits their ability to take part in a truly ubiquitous computing environment.

Client-Server Interactions in an Intelligent Environment

Within current intelligent environments, a user commonly carries some form of portable client device with them, such as a PDA, which they use to access services. A service is a logical function that any other device, acting as a server, is willing to offer to the client over a network.

For a client device to access services, it needs to know which ones are available and where they are located. There are two main ways that it can do this. One method is to query some well known directory, such as a Domain Name Service (DNS) [6]. This method encounters difficulties when used by portable devices, as the device may not know where to look to find the directory in the first place. A better way in this situation is deploy a service discovery protocol, such as that found in zeroconf [7] or Universal Plug and Play [8]. These make use of multicast messaging to query the network and allow clients to locate the services directly.

MOTIVATION

Personal servers change the method of interaction between clients and servers. The situation is now reversed, such that the server is the portable device, rather than the client. The user wants applications running on devices within the intelligent environment to access the services available on their personal server. If these external devices are to make use of the services, they first need to know that they exist. Therefore the personal server needs a way to advertise what services it has to offer as it enters a network, so that the client devices will access them upon discovery.

It is this requirement for a reverse discovery method, where the server informs the client, rather than the client querying the server, that forms the basis of my research direction.

EXAMPLE SCENARIO

Take the example of a landline phone in an office, which is equipped with an LCD display. As you approach the phone, wearing your personal server, the phone becomes aware of its presence and the services it is offering. It utilises the phonebook service on offer to present you with a list of your contacts on the LCD display, from which you can easily pick out who you want to call. When you hang up and walk away, the phone knows that your personal server is no longer offering these services, and ceases to use them.

In order to make this work, there are a number of issues that need to be addressed:

- How does the phone know that the personal server is there?
- How does it know what services the personal server is offering?
- How does the phone authenticate itself to get access to the services?
- What data representation do the devices use to communicate?
- How does the phone know when the personal server is no longer available?

It is my intention that my research will lead me to come up with suitable solutions for each of these problems.

RESEARCH DIRECTIONS

Current networking models do not allow personal servers to introduce their services in the ad-hoc fashion that we wish them to. Therefore my research is going to be directed towards finding new mechanisms for client-server interactions and investigating what possibilities they open up.

Firstly, I need to fully investigate existing service discovery and advertisement mechanisms. This allows me to identify what problems they encounter when applied to devices wishing to offer network services. This knowledge can then be used to develop a protocol suite similar to that used by zeroconf, to make it simple to introduce devices and their services to the network.

Consideration needs to be given to how external devices authenticate with the personal server to access services. This would probably involve services available with different levels of clearance, ranging from low-level statistical information open to all, to the most privileged ability to write to all parts of the disk.

An important part of my research will be to recognize how the changes I propose to make to client-server interactions can also change the nature of applications within an intelligent environment. What applications do this new service advertisement mechanism enable that were previously difficult, or even impossible, to implement? For example, what changes will it enable for identity checking, location tracking and personalisation applications? Applications such as these are major areas of research within ubiquitous computing research today, so my research has the potential to offer new ways to approach them.

Finally, I intend to build a working system where personal servers, or devices acting in a similar fashion (such as customised PDAs), can wirelessly join a network and make their services known. These services should include some that the new mechanisms have made possible, as discussed above.

ACKNOWLEDGMENTS

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ME: Mobile E-Personality

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ABSTRACT

More and more services require some personal information about the user in order to work properly. How to get the required personal information to the service with little or no action from the user and still preserve users privacy, is important question. In this research Mobile E-personality (ME) service is presented. In ME approach the personal information is stored on single mobile device. ME service provides this information to those services that request it.

Keywords

Personal information, privacy, mobility, services, wireless.

1 Services and Personal Information

Internet based electronic services have gained more and more customers. At the same time new communication standards have evolved that make it possible to provide new types of services with various types of hardware for example local information kiosks from where information can be fetched by using Bluetooth wireless communication technology. Further on ubiquitous computing aims to provide services automaticly to the user.

As the mobile devices have quite limited user interface the services should be personalised in order to provide better use experience for the user. Personalisation is a technique that allows the selection of the received information according to the preferences of the user. If implemented correctly both the user and the service provider will benefit. The information needed for personalisation can be acquired either by requesting from the user or by following the user behaviour on the services. Personal information is not required only for personalisation reasons. Internet shops, hotel registrations, competitions, conferences and so on, require user's personal information in order to provide their service properly.

Traditionally personal information has been stored in the database of the service. This approach has few significant flaws from the user point of view. First, as the databases of different services do not usually have cooperation, user has to type in the required information every time he decides to use a new service. For example, when taking a trip to three different towns the user has to reserve hotel room for each town. This mean that if the hotels have no cooperation, the user has to type in his personal information three times in a very short period of time. Besides inputing repetitive information, the more services the customer uses, more databases hold his personal information, which brings up two problems. First, more places the information is stored in, bigger the risk is that one of the places has a security flaw and the given information gets stolen. Secondly, if some of the personal information changes it requires lot of work to go and update all those databases.

For internet services these basic problems have been resolved partly on web browsers. For example mozilla wallet can fill web forms automaticly when the form fields are notated properly [1]. This approach is fine as long as the user uses only personal computer at work or at home. For mobile user that uses mainly ubiquitously provided services, which are not accessed by web browser or web café's to access internet services, mozilla wallet helps very little.

There are many frameworks and architectures defined for handling user mobility. For example, Integrated Personal Mobility Architecture [2] defines a framework where user's personal information is requested from "home" network by the network in which the user is visiting. This approach relies on the fact that the service can connect to the user's home network. This may not be possible for services provided ubiquitously. The same problem exists for trusted third party approaches such as Liberty Architecture [3] and Microsoft .NET passport [4]. Connection to the trusted third party is required for personal information retrieval. Third party approach may also require some kind of payment to the third party for it's services.

In this PhD research the personal information is stored in mobile device, where the user has the control over it. The information is delivered to the services on request by Mobile E-Personality service (ME). Therefore there is less need for service to have huge databases of customers personal information.

2 ME and research tasks

The goal of ME research is to define the ways for communicating with the mobile device holding personal information. The access of information in ME is designed so that after configuration user actions are minimised but the privacy is preserved.

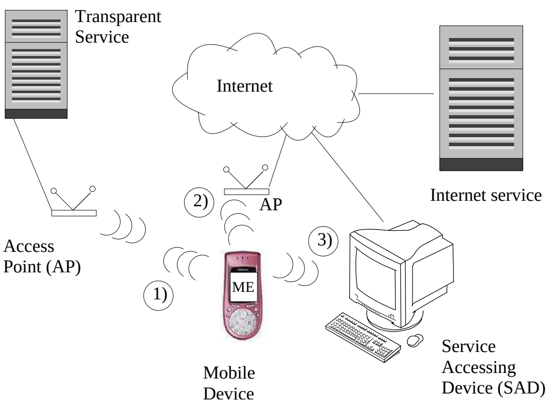

Fig. 1. Mobile E-personality and services

In order to create universally functional Mobile E-Personality there is several questions that need to be addressed. What are the benefits and drawbacks of having single device holding lot of special information? What are the risks? How different types of services can request the personal information or how they even know they can request it? How user privacy can be ensured i.e. how much automation can be provided? How the information is notated so that any service can use it? How user can define what information is available to what service? How is user authenticated for changing the stored data? How does ME affect on business?

The PhD thesis is not going to answer to all of these questions. Since the thesis is done for the computer science department and the laboratory of communications engineering, the focus is on the communication between ME and the services (Figure 1).

Initial evaluation of various personal information properties that can affect to the location where the given piece of information should be stored was first done and published at: [6]. First version of personal information transfer from mobile device to internet service based on vCard transfer between browser plug-in and mobile phone[7]. More generic transfer was defined for transparent services[8]. Next steps for research is to define privacy rules for mobile device and define general structure for Mobile E-Personality service on mobile device.

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User Location and Mobility for Distributed Intelligent Environment

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ABSTRACT
User mobility in an Active Office (AO) represents human activity in a context awareness and ambient intelligent environment. This research describes user mobility by detecting user's changing location. We have explored precise, proximate and predicted users' location using variety of sensors (i.e. WiFi and Bluetooth) and investigate how the sensors fit in an AO to have interoperability to detect users. We developed a model to predict and proximate user location using wireless sensors in the Merino Architecture, i.e.: the architecture for scalable context processing in an Intelligent Environment (IE).

Keywords
Context, Location Awareness, User mobility, Active Office

INTRODUCTION
An AO as an implementation model of a distributed IE is defined to be as a normal office, which consists of several normal rooms with minimal additional decorations (minimal intrusive detectors and sensors). In order for an AO to provide services to the users, AO must be able to detect its current state/context and determine what actions to take based on the context. The AO uses a scalable distribution context processing architecture (Merino service layers architecture) to manage and respond to rapidly changing aggregation of sensor data [1,3].

The key role of a distributed context processing in IE is an IE domain. An IE domain is an administrative domain, which at least contains an IE repository, a resources manager, knowledge based and various sensors.

This paper explores user mobility in an AO. We began from understanding user location, then changing location from a current location to another location. By analysing the history data we can get the pattern of the user mobility. We strongly believe that by understanding user mobility we can better understand user activity.

A location is the most important aspect providing a context for mobile users, e.g. finding the nearest resources, navigation, locating objects and people. Numerous location models have been proposed in different domains, and can be categorized into two classes i.e. Hierarchical (topological, descriptive or symbolic) and Cartesian (coordinate, metric or geometric) [2,4,5].

We believe that accessible resources for users in an AO can be detected based on their proximate location. We also believe that a hierarchical location model will be more relevant than a Cartesian location model because a hierarchical location model could scale room and building, while the technology for gridding/mapping the office using a Cartesian model is not available yet at the time of writing.

In the Wireless LAN (WLAN) environment, the location of mobile devices can be determined by measuring the signal strengths of a few most visible access points [6]. This accuracy is sufficient to support the everyday tasks in the AO.

User Location in an AO implies the ability of IE to understand a user changing location on a 'significant' scale. When the user moves, it means that the user's access to the resources also changes. The AO can be designed to understand 'significant' user change location by using sensor that can measure proximate location.

SENSOR AGGREGATION FOR USER LOCATION
User locations in an AO can be categorised as precise, proximate and predicted locations. The category is based on the sensor capability in covering an area.

The problem is to combine these known location data to determine a user's actual location with sufficient precision for office activity purposes.

PROXIMATE USER'S LOCATION
Proximate location is based on sensor that covers more than a meter range, e.g. WiFi, Bluetooth, WiMedia, ZigBee, active/passive badge, voice recognition, face recognition, smart floor, etc.

Proximate location detected by WLAN is an interesting proximate sensor in an AO because it can be used to access the network and also to sense user location on the scale of a room or an office.

We used the Bluetooth access point as a sensor for several rooms within the range. For example, when a user is close to a certain access point, his location will be proximately close to the access point and it could represent user location from several rooms.

WiFi does not only have a higher speed and longer range than Bluetooth but the signal strength of Wi-Fi also can be used to detect user location. We have two scenarios to determine user location using WiFi. Firstly, by determining the signal strength from the WiFi capable device which stores data in a local IE repository with the server sending the current user location. Secondly by determining the signal strength from the WiFi access points and storing the signal strength data in the local IE repository with the server sending the user location. The difference between these scenarios is that in the second scenario the process of sensing is in the access point, so we do not require a user's mobile device with a high capability.

We used self organizing map (Kohonen map) approach of artificial neural network to cluster the signal strength data. Once we get the signal strength cluster allocation in the local IE, we can directly get current user location.

In our experiment using WiFi, we used 11 access points to measure signal strength in two adjacent buildings, already installed for WLAN access.

The result was good enough to predict current user location. On the 2nd level of one building, we found that most places had a good signal from more than two access points and we could predict accurately (96%) in rooms of 3 meters width. On the 3rd level, where not all locations were covered by more than one access point, we had only a reasonable degree of accuracy (75%) in predicting a user's current location.

PREDICTED USER LOCATION

Since IE is also a ubiquitous and ambient computing environment, we assume that sensors and actuators, and computer access will be embedded and available in every area. We identify the user's location by recording a historical database of events, whenever the receptor/sensor/actuator captures the user's identity in a certain location.

We develop historical data from precise users locations. The history data can be used to predict user location. Probabilistic model also possible to develop to find the most probable location of user based on a certain policy.

We've implemented the policies for user's location checkpoints i.e. the same day of the week (at almost the same time and same day of the week) and all the days in a one week range (almost the same time within a week) [4]. We use simple extended SQL query to implement the above policies to find user location via a Java Speech interface.

DISCUSSION

In figure 1, we show how an AO processes the information to determine user's location by aggregating the relationship between user data and location data.

Aggregate of precise location has first priority and is followed by proximate and predicted locations respectively. This means that when the AO receives information from aggregate precise location, then the current user's location is determined. If not, then we check using aggregate proximate location data.

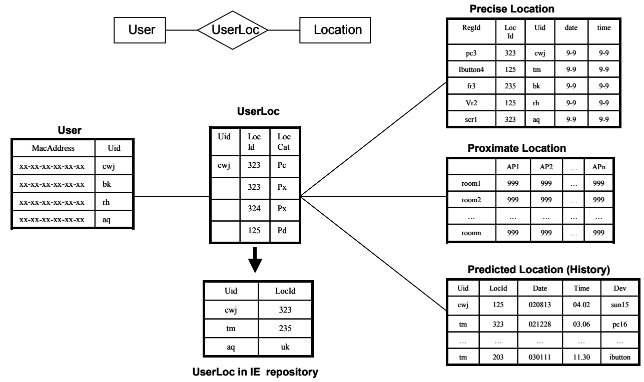

Figure 1. Aggregate users' location in AO

CONCLUSION AND FURTHER EXPERIMENTS

In an AO, a user has a regular work schedule. A user has a routine activity that can be used to predict his location in a specific timestamp. A user's activity can be represented by user mobility, and user mobility can be seen from the user's changing location on a significant scale. So, in an AO once we can capture a user's location then we can map a pattern of user mobility.Our experiment using WiFi and Bluetooth as proximate location in an AO has showed their good results in sensing user location. The result can be improved by developing interoperability between sensors to get aggregate sensor data.

Further experiments that can be considered arising from this work are aggregation smart sensor (more interoperability between sensor) using notification system to notify the difference between current location and previous notification and managing location information in Merino service layer architecture, i.e. format representation, conflict resolution, privacy of location information.

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Towards a Rich Boundary Object Model for the Design of Mobile Knowledge Management Systems

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ABSTRACT

This research proposes a Rich Boundary Object Model as a conceptual framework in the design of knowledge management systems that utilize mobile technologies. An ethnographic study is being conducted of a heating and cooling services company focusing on the exchange of case stories. With knowledge gained from this study, a prototype system is being built that allows *in situ* multi-media data capture. The proposed study will extend our understanding of how to effectively design for *in situ* multi-media data capture so that it is integrated into organizational processes.

Keywords

Mobile Knowledge Management, boundary objects, capture

INTRODUCTION

Mark Weiser in his seminal paper "The Computer for the 21st Century" envisioned a ubiquitous computing world where computational resources are spread into the environment, and people find "using computers as refreshing as taking a walk in the woods" [10]. In recent years various consumer technologies that meet Weiser's definition have become pervasive. The existence of these mobile, reachable devices whose use are personal and near pervasive can clearly be used to provide value to organizations.

With the increasing acceptance of the importance of intellectual capital for businesses and organizations, many information systems have been designed specifically to address knowledge management issues. Pioneers of information systems for knowledge management and organizational memory adopted a simple view of knowledge and a passive memory model. From this perspective, the design of knowledge management systems is similar to database design. These early systems focused on categorizing information into fields for later reuse and retrieval (e.g. Answer Garden [1]). The result was that these systems only shared explicit information in strictly defined domains.

However, advances in cognitive and social theories have shifted the view on knowledge as static and isolated, to knowledge as active, holistic and socially constructed [2, 6]. It follows from this view that to maximize intellectual capital, it is often important to capture much of the *context,* where knowledge and meaning is developed. In the mobile domain, the focus has been the automated capture of the environment for context-aware computing [3], or the automated capture of interaction history for mobile meeting support (i.e. RoamWare [11]). While serving as a useful metaphor, some researchers argue that current "context-aware" computing obscures the centrality of control and intelligence in recognizing context and determining appropriate action [5].

CONTEXT, BOUNDARY OBJECTS, AND MOBILE KNOWLEDGE SHARING

Instead of making systems "aware" of the "context", this research proposes a Rich Boundary Object Model for the design of knowledge management systems. The concept of boundary object was developed through social study of communication and technology to characterize objects that serve as an interface between boundaries of domain knowledge [9]. The theoretical importance of the concept has been studied in a number of studies concerning organizational memory [6,7] and common information space [2]. In all of these studies, boundary objects are necessarily decontextualized on one side of the boundary for storage, and need to be recontextualized on the other for reuse. The recontextualization of the boundary object, for example a personal record, was found to be critical to reuse information in organizations [6]. Serving the purpose of boundary objects, entries in organizational memory and knowledge management systems are usually text that are entered after-the-fact. Contextual information is often lost during the process.

Different from context-aware computing, the rich boundary object model recognizes the importance of the "knower", people who do their job through field practice. Provided with mobile multimedia capture devices, the knower captures multimedia data *in situ*, which can be used to construct rich boundary objects (and thus the name of the model). More “portable context” [2] can be carried with rich boundary objects. The understanding of context is not only from a computational perspective focusing on physical environment [3], but also from social and organizational perspectives incorporating the organizational and social context [4]. The central hypothesis is that rich boundary objects afford multiple levels of contextualization, and enhance tacit as well as explicit knowledge transfer.

METHODOLOGY

To test and refine the model, it is proposed that a series of studies be conducted focusing on the exchange of *case stories*, which are messages that tell the particulars of an occurrence or course of events that is directly related to work processes. Similar to stories, a case story is told for a particular purpose**.** Different from other forms of stories, such as jokes, news, or notifications, case stories focus on work process experiences. Such case stories have been used to share informal information; transfer tacit knowledge; share organizational culture and norms; help form communities of practice; and catalyze organizational change. Orr’s pioneering research, which examined Xerox photo-copier repair technicians in 1986, showed how the exchange of “war stories” could help a community of practice diagnose problems, circulate information, and celebrate identity [8].

Exchange of case stories and the model are being examined through field studies at a company that provides fuel, house boiler and air conditioner repair, and maintenance service to about 3000 customers in central New Jersey. The company has four secretaries, seven technicians, managers and oil drivers. A significant proportion of the technicians’ activities can be described as mobile knowledge work, and a significant proportion of the office activities support the mobile technicians. Three studies are being proposed, each addressing a specific question in the context of the field study site:

1. Study 1 –what are the uses and limitations of boundary objects in current organizational knowledge sharing?
2. Study 2 – what rich boundary objects are considered useful in knowledge sharing?
3. Study 3 – can the rich boundary object model be utilized to effectively guide the design of a mobile knowledge management system?

Part of study 3 involves the development of the CAse sTory capture and Sharing (CATS) system, which will enable capture of rich *in situ* data and the creation and sharing of rich boundary objects. The prototype CATS system being built will use digital pictures and voice recording on pocket PCs with digital camera attachment, and will synchronize data via 802.11-enabled network.

STATUS AND CONTRIBUTIONS

Currently study 1 is being conducted at the field site. A variety of boundary objects and their limitations are being identified in current case story sharing processes among technicians and between technicians, secretaries and customers.

The proposed research is innovative because it operationalizes the conceptually important yet ambiguous idea of *context* in mobile knowledge management systems design, using mobile multimedia data capture technologies. The result is not only a database with information objects and events, but a common information space [2] where meanings of information objects can be interpreted and shared.

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Part V

Videos

DigiScope: An Invisible Worlds Window

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ABSTRACT
Smart appliances, i.e. wirelessly networked mobile information devices have started to populate the "real world" with "hidden" or "invisible" services, thus building up an "invisible world" of services associated with real world objects. With the embedding of invisible technology into everyday things, however, also the intuitive perception of "invisible services" disappears. In this video we present how we can support the perception of smart appliance services via novel interactive visual experiences. We have developed and built a see-through based visual perception system for "invisible worlds" to support interactive theatre experience in mixed reality spaces, which we call DigiScope. In the video we shown how e.g. the "invisible services" of our SmartCase, an Internet enabled suitcase, can be visualized via graphical hyperlink annotations

Keywords
Computational Perception, Smart Appliances, MR.

SMART THINGS
"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it" was Mark Weiser's central statement in his seminal paper [8] in 1991. His conjecture, that "we are trying to conceive a new way of thinking about computers in the world, one that takes into account the natural human environment and allows the computers themselves to vanish into the background" has fertilized not only the embedding of ubiquitous computing technology into a natural human environment which responds to people's needs and actions in a contextual manner, but has also caused "hidden" functionality and services volatilize out of sight of humans. "Smart Things" functionality is characterized by the autonomy of their programmed behaviour, the dynamicity and context-awareness of services and applications they offer, the ad-hoc interoperability of services and the different modes of user interaction upon those services. Since many of these objects are able to communicate and interact with global networks and with each other, the vision of "context-aware" [1] smart appliances and smart spaces – where dynamically configured systems of mobile entities by exploiting the available infrastructure and processing power of the environment – has become a reality.

DIGISCOPE
With our work we aim at supporting "human to ubiquitous computer interaction" processes by bringing back visual clues to the user on how to interact. Once computers have disappeared from desks, hiding in the background, their services will most likely still be there. New artefacts and smart appliances [7] are evolving that "carry" invisible services, such that manipulating the appliance controls a service. Even if the service is not integrated into the artefact but merely "linked" to a background system [5], the manipulation of the physical object can manipulate their virtual representative on that background system respectively. To this end it is necessary to link the physical world with the virtual world [2], i.e. the linking of physical objects with their "virtual counterparts" [6]. Tangible interface research [4] has contributed to this issue of physical-virtual linkage by considering physical artefacts as representations and controls for digital information. A physical object thus represents information while at the same time acts a control for directly manipulating that information or underlying associations.

This video presents the use of DigiScope, a 6DOF visual see-through tablet we have developed to support an intuitive "invisible service" – or more generally: "invisible world" – inspection: the invisible services of the smart appliance "SmartCase" – which has been developed as a demonstrator for a contextware framework [2] [3] – are inspected. We exploit the metaphor of digital annotations for real world objects, and display these annotations along the line of sight to real world objects that are seen through a holographic display. The user gets the ability to interact with the virtual object and its digital information by viewing the corresponding real (physical) artefact. With DigiScope, the user is handling a holographic display tablet just like a 6 DOF window that opens a view into the virtual world. The tablet is an optical see-though display which allows for a very natural viewing and scene inspection. To implement correct views into the scene, the angle and perspective of the DigiScope is being tracked, instead of tracking the position and orientation of the user. Thus the user is freed from any system hardware obstacles like HMDs, stereoscopic glasses, trackers, sensors, markers, tags, pointers and the such. To support free navigation in the scene, the DigiScope can be fully tilt and rotated in space by hand. The projecting beamer is fixed in the right projecting angle within a 6DOF mounting frame, and is used to project the computer generated image encoding the scene annotation onto a holographic display. The DigiScope software architecture is based on standard building blocks for AR application frameworks: (i) a 6 DOF tracking library for position and orientation tracking of the DigiScope frame, (ii) Java and Java3D for 3D scene modelling, rendering and implementing user interaction, and (iii) ARToolkit for visual object tracking and scene recognition.

INSPECTING SMARTCASE

In previous work we have developed SmartCase [2], a context aware smart appliance [3]. The hardware for the SmartCase demonstration prototype uses an embedded single board computer integrated into an off-the-shelf suitcase, which executes a standard TCP/IP stack and HTTP server, accepting requests wirelessly over an integrated IEEE802.11b WLAN adaptor. A miniaturized RFID reader is connected to the serial port of the server machine, an RFID antenna is integrated in the frame of the suitcase so as to enable the server to sense RFID tags contained in the SmartCase. A vast of 125KHz and 13,56 MHz magnetic coupled transponders are used to tag real world objects (like shirts, keys, PDAs or even printed paper) to be potentially carried (and sensed) by the suitcase. In addition, the SmartCase is equipped with optical markers so as to enable visual recognition and tracking with the ARToolkit framework.

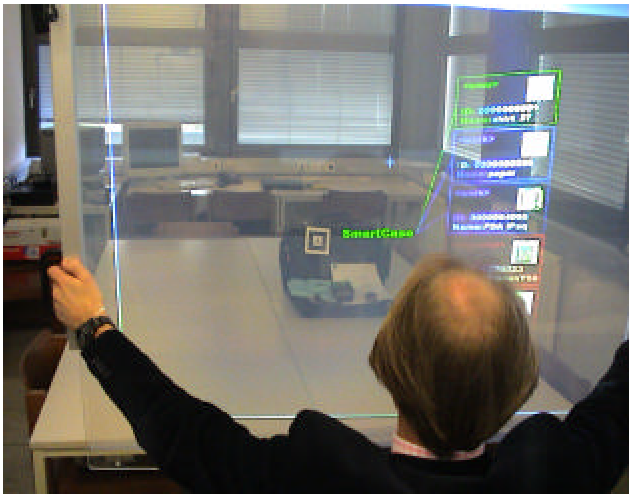

Figure 1: The DigiScope

A unique ID associated with every real world object is the ID encoded in its RFID tag. It is sensed by an RFID reader which triggers a script to update the state information on the embedded Web server. Considering now the inventory of the SmartCase as an “invisible” service, then, once an object (e.g. shirt) has been put into the SmartCase, this service can be queried to check whether the shirt is in the case or not. A straightforward way to access this information would be via a classical http interface to the embedded web-server. Observed via the DigiSpace however, changes to the SmartCase inventory are displayed as a graphical annotation of the real world.

CONCLUSIONS

This video presents DigiScope, a 6DOF visual see-through inspection tablet, as an approach towards emerging problem of developing intuitive interfaces for the perception and inspection of environments populated with an increasing number of smart appliances in the pervasive and ubiquitous computing landscape. DigiScope envisions a new type of MR interface with two main features: (i) a new exploration experience of the physical world seamlessly merged with its digital annotations via a non-obtrusive MR interface, and (ii) an integration of ubiquitous context-awareness and physical hyperlinking at the user interface level. The DigiScope is demonstrated in operation.

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Bumping Objects Together as a Semantically Rich Way of Forming Connections between Ubiquitous Devices

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ABSTRACT

This research explores the use of distributed sensors to form dedicated and semantically rich connections between devices. For example, by physically bumping together the displays of multiple tablet computers that are facing the same way, *dynamic display tiling* allows users to create a temporary larger display. If two users facing one another instead bump the tops of their tablets together, this creates a *collaborative face-to-face workspace* with a shared whiteboard application. Each tablet is augmented with sensors including a two-axis linear accelerometer, which provides sufficient information to determine the relationship between the two devices when they collide.

Keywords

Distributed sensors, context aware, multi-user interaction

INTRODUCTION

Establishing meaningful connections between devices is a problem of increasing practical concern for ubiquitous computing [3][4]. Wireless networking and location sensing can allow devices to communicate and may provide information about proximity of other devices. However, with many devices nearby, how does a user specify which devices to connect to? Furthermore, connections need semantics: What is the connection for? Is the user collaborating with another user? Is the user combining the input/output resources of multiple devices to provide increased capabilities? Users need techniques to intuitively form semantically rich connections between devices.

This research proposes physically bumping two devices together as a means to form privileged connections. Bumping introduces an explicit step of intentionality, which users have control over, that goes beyond mere proximity of the devices to form a specific type of connection. For example, dynamic display tiling [2] enables users to combine the displays of multiple devices by bumping a tablet into another one lying flat on a desk (Fig. 1). Users can also establish a collaborative face-to-face workspace [1] by bumping the tops of two tablets together (Fig. 2).

Bumping generates equal and opposite hard contact forces that are simultaneously sensed as brief spikes by an accelerometer on each tablet. The software synchronizes the data over an 802.11 wireless connection; two spikes are considered to be simultaneous if they occur within 50ms of one another.

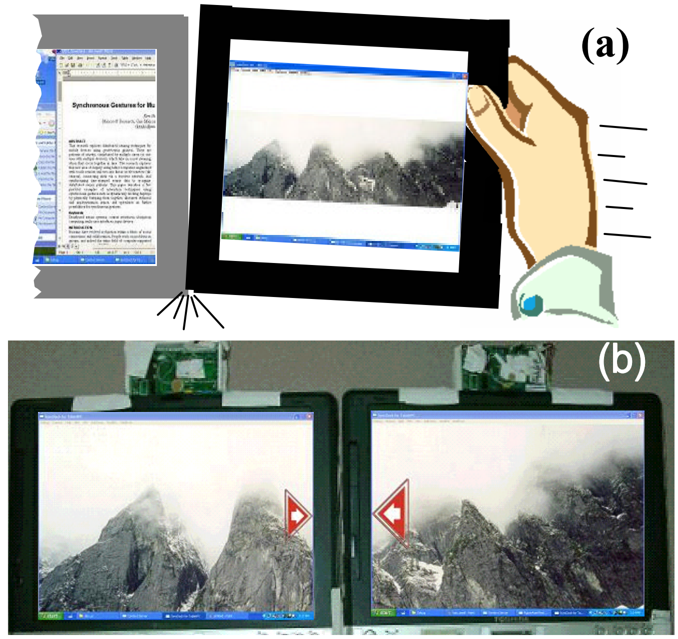

Fig. 1 (a) Dynamic display tiling by bumping together two tablets that are facing the same direction. (b) The tablets form a temporary larger display, with the image expanding across both screens. Small arrows provide feedback of the edges involved in the dynamic display connection.

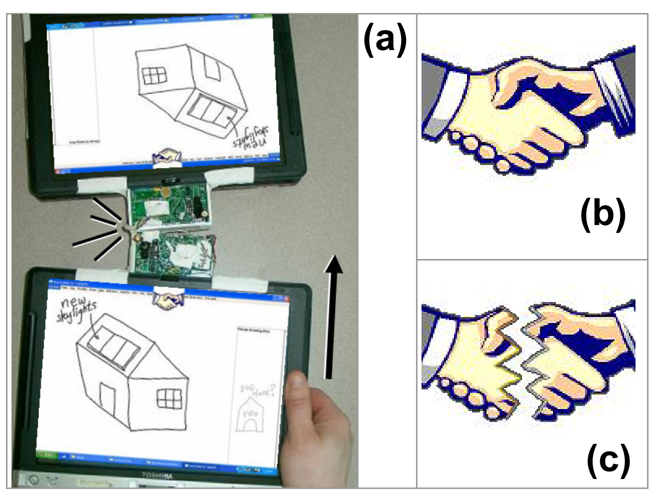

Fig. 2 (a) Face-to-face collaboration by bumping the tops of two tablets together. The sketch is shared with the other user for annotation. Also shown: feedback for (b) making or (c) breaking a collaboration connection.

The two orthogonal sensing axes of each accelerometer provide enough information to determine which edges of the tablets have collided, allowing tiling of displays along any edge (left, right, top, or bottom) or sensing that the tablets are facing one another when bumped together in the case of face-to-face collaboration. Example accelerometer data from bumping two devices together is shown in Fig. 3, as well as simultaneous but incidental handling of the devices. The software can ignore most such sources of false-positive signals. Details of synchronization and gesture recognition appear in [2].

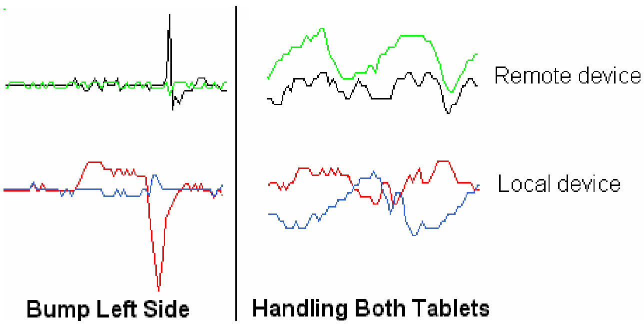

Fig. 3 **Left:** Example accelerometer signature for bumping two tablets together, with forward-back and left-right accelerometer axes for the local and remote devices. **Right:** Incidental handling of both tablets at the same time results in signals that are distinct from intentional bumping.

For dynamic display tiling, one tablet (the *base tablet*) rests flat on a desk surface, and a second tablet (the *connecting tablet*) is held by a user and bumped into the base tablet along one of the four edges of its screen bezel. Note that this creates a hierarchy in the connection. The connecting tablet temporarily annexes the screen real estate of the base tablet. The software currently distinguishes the connecting tablet from the base tablet using capacitive touch sensors to determine which of the two tablets is being held.

Appropriate feedback confirming that a connection has been established is crucial to the techniques. Users are shown the type of connection being formed using overlaid icons on the screen as shown in Fig. 2 (*b, c*) for face-to-face collaboration; analogous "connection arrow" icons for dynamic display docking can be seen in the video. Furthermore, because the techniques involve two users, one user's attention may not be focused on the tablets; hence it is important to provide audio feedback as well. Tiling two displays together makes a short metallic clicking sound suggestive of a connection snapping together. A different sound reminiscent of slapping two hands together occurs when users establish face-to-face collaboration.

For display tiling, picking up a tablet removes it from the shared display. By contrast, for face-to-face collaboration, users may want to move their tablets apart but continue collaborating; hence moving the tablets apart does not break the connection in this case. Instead, users can explicitly break the connection by drawing a slash across the handshake icon (*Fig. 2b*), or the system automatically breaks the face-to-face connection if one of the users walks away (walking can be sensed using the accelerometer [1]).

Users can also exchange information by bumping tablets together just as people at a dinner table might clink glasses together for a toast. This is distinguished from display tiling by sensing that both tablets are being held (as opposed to one being stationary on a desk). Finally, one user can "pour" data from his tablet into that of another user by angling the tablet down when the users bump their tablets together [2]. These variations shown in the video suggest additional ways to enrich the semantics of connections that can be formed based upon bumping objects together.

RELATED WORK

Smart-Its Friends and ConnecTables form distinguished connections between multiple devices. Smart-Its Friends infers a connection when two devices are held together and shaken. ConnecTables [4] are wheeled tables with mounted LCD displays that can be rolled together so that the top edges of two LCD's meet, forming a connection similar to the collaborative face-to-face workspace proposed here. Both [3] and [4] can form only one type of connection, whereas bumping two objects together can support multiple types of connections. Furthermore, bumping can specify additional parameters, such as which edges of two separate displays to join, or determining which tablet is the connecting tablet (as opposed to the base tablet) to provide a direction (hierarchy) to the connection.

CONCLUSION

This work contributes a novel and intuitive mechanism to form specific types of connections between mobile devices. When bumping two tablets together, a connection is formed in the physical world by manipulating the actual objects of concern, so no naming or selection of devices from a list is needed. Bumping can support several different types of connections, including dynamic display tiling, face-to-face collaboration, or "pouring" data between tablets. Here we focus on multiple Tablet PC's, but in the future, dynamically combining multiple heterogeneous devices could lead to compelling new capabilities for mobile users.

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Ubiquitous Computing in the Living Room: Concept Sketches and an Implementation of a Persistent User Interface

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ABSTRACT

This video shows some concept sketches of applications that might be created for a living room with ubiquitous display and laser pointer interaction technology. A fully-functioning prototype of a persistent interface is also described: a language-learning tool.

1. INTRODUCTION

Until recently, researchers creating ubiquitous computing environments were forced to examine the target space, pick a handful of locations where information was most likely to be needed, and then install display devices at those locations. The limitations of display technology have driven user interface design decisions rather than the needs of the end user. Ideally, user interface designers would understand the needs of the end users for any given application *and then* decide when and how to display information to impact the desired tasks.

We have constructed a mock living room that combines non-invasive sensing technology with ubiquitous display technology to create an environment where information can be presented and manipulated on nearly any surface. Our ubicomp environment makes it possible to develop prototype applications. In this video, we show a series of concept sketches illustrating ideas for interfaces that could be developed for a living room with enabling ubicomp technologies. The video concludes with a fully-functioning example of a persistent interface. A persistent interface is one that is designed to be continuously present [1] without creating feelings of information overload [2].

2. THE UBICOMP ENVIRONMENT

Figure 1 shows the ubiquitous computing living room prototype in our lab. This room has, among others, the following capabilities: (1) ubiquitous display of information on most planar surfaces, (2) ubiquitous audio, and (3) ubiquitous interaction with information on most planar surfaces using laser pointer interaction.

We have embedded an ED-projector system [5] into a cabinet in the the living room environment. This relatively inconspicuous device fundamentally alters the display capabilities of the entire living room space, permitting an application designer to display information on most of the planar surfaces in the living room: the floor, ceiling, 3 of 4 walls, furniture, and in some cases even on the interior sides of shelves and furniture. The only limitation is that information can be displayed only in one area of the room at a time.

The primary mode of interaction in the room is laser pointer interaction [4]. The user carries a small laser pointer device. The ED-projector's camera moves so that the projected image is in the field of view of the camera. Image processing algorithms detect the red laser point in the camera view when the user points at the image. That position is mapped back into the image space. Heuristics for "click" events are then created. In the living room, the user clicks on the display using a 1-2 second dwell.

3. LIVING ROOMS "OF THE FUTURE"

The video shows a series of mock-up examples of interfaces that could be developed for a living room with ubiquitous display and interaction capabilities. Although there are many interesting applications one can envision, the ubicomp display and interaction technology is analogous to the computer mouse. There is no single "killer app" for the mouse. It is an enabling technology that was helpful for certain graphical tasks on early computers and which was later adopted as a key component of nearly every application that runs on a common desktop computer. The mouse, once a novelty, is now a necessity for most computer use.

We believe the same will ultimately be true for ubiquitous display and interaction technology. As did the mouse, the use of this tool will require designers to change how they design human-computer interfaces. Particularly challenging is merging multiple applications seamlessly and sharing a single ubicomp resource. The environment itself becomes the "display space" and applications will compete for use of this resource.

The examples in the video illustrate how the technology could be used to enable mobility, augment traditional media, provide just-in-time motivation [3], help people exploit idle time, pull interfaces off devices, and map information at life-size onto the real world.

(a) (b) (c)

Figure 1: (a) The mock living room. (b,c) A user interacting with the language-learning tool: a functioning example of a persistent interface.

4. THE LANGUAGE-LEARNING TOOL

Many of the concept examples are applications that command the user's attention. The video concludes with a fully-operational example interface. Our goal when creating the language-learning tool was to create an interface that (1) could be run continuously in the environment so that it was always available, (2) used the environment and the objects in the environment, and (3) was always ignorable.

The language-learning tool is designed to help home occupants learn the vocabulary of a foreign language. The tool is non-disruptive but ever-present. It can be used by multiple people. It exploits the ability of the ED-projector to present information directly on objects in the environment and the ability of laser pointer interaction to permit selection of information from any part of the space. The application works as follows. Foreign language words (in this case French) appear randomly on different surfaces in the environment. When the user expresses interest in a word, the user can get the English translation. Further, if the user wants, he or she can listen to the pronunciation of the word.

The appeal of the interface is the simplicity, and it shows how the ubicomp environment can be used to create a pleasing, persistent interaction experience. The first challenge was to create a persistent interface that does not cause visual or auditory distraction that would disrupt ongoing activity in the environment, since the application runs continuously. We employ one strategy to minimize perceptible visual distractors: slow change. Overall, the strategy is to design the entire interface so that visual change is imperceptible to the user (change-blind user interface design [2]) unless the user is actively interacting with the application. After a location in the room is randomly selected, the ED-projector is moved to that position. To avoid visual distraction, a word then fades in over 30 seconds, which is too slow to trigger peripheral detection. The visual effect is that of a word materializing out of a surface. No visual distractors are created. If the user does not interact with the word after 2 minutes, the word fades away and the projector moves to another randomly chosen location and displays another word. With a silent ED-projector, this interface would run without creating any cognitive distraction.

If the user happens to notice a word, the user can acquire more information using laser pointer interaction. By simply pointing and dwelling on the word it will change to the English version. At this point, the pace of the interaction increases because the user has expressed an interest in the application, and the application will more proactively provide information that is potentially disruptive. If the user continues to dwell, for example, the pronunciation of the word is heard through the room's audio system. At this point slow fades are not used because the user has expressed an active interest. If the user ignores a word, however, the application switches back to the peripheral mode. Finally, the words that are presented are sometimes associated with the location of the room in which they are presented. The application has hand-coded knowledge of the location of particular objects in the room and is biased to display words related to those objects when projecting near them (e.g. "chaise" when on the chair). Figure 1b-c shows a user interacting with the system. This application can be run continuously in the space even as people have meetings and work in the space.[1]

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STARS - A Ubiquitous Computing Platform for Computer Augmented Tabletop Games

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ABSTRACT
In this video presentation we demonstrate the STARS platform for realizing computer augmented tabletop games within a smart Roomware® environment. STARS dynamically couples multiple types of interaction devices such as personal digital assistants (PDAs) or headsets with an interactive game table. STARS augmented tabletop games provide a number of features like dynamic game boards or private communication channels that go beyond traditional tabletop games, but at the same time preserve the human centered interaction dynamics which makes playing board games a joyful group experience.

Keywords
Tabletop games, ubiquitous computing platform, smart environment, Roomware

INTRODUCTION
During the past decade of ubiquitous and pervasive computing research there has been a growing amount of scientific activity dedicated to the integration of various differently sized and -shaped devices within ubiquitous computing environments.

Our realization of such a ubiquitous computing environment and the integrated 'Roomware®' devices is presented in [4]. Roomware closely follows Weiser's notion of calm computing devices that integrate seamlessly into everyday objects [6]. This means that Roomware components still function like traditional room elements (e.g. tables or walls), but provide dedicated computing services for the people in the smart environment.

In addition to the cooperative work applications previously developed for the Roomware environment [5], we now present a new software platform to support the realization of tabletop gaming applications with multiple input and output devices that integrate with the platform. The STARS gaming environment (STARS stands for Spiel-Tisch-AnReicherungs-Sytem, a German acronym for game table augmentation system) consists of a Roomware hardware setup and a specialized software framework that realizes cross-device interaction through different modes and modalities [3]. The software framework of STARS provides many board-game specific functions such as the administration of the virtual game board that facilitate the development of new games on top of the platform.

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STARS DEVICES
STARS integrates different input and output devices that each have dedicated purposes within game sessions.

Game Table
The game table is the central instance for any tabletop game application. In our setup, it consists of the InteracTable® Roomware component, which is an interactive table with an embedded touch-sensitive plasma display as the table's surface. The plasma display is used for displaying the contents of game boards and for dealing with related interaction objects. Above the table, an overhead camera tracks the positions of arbitrary playing pieces on the table surface.

Below the table's surface, a radio frequency (RF-ID) antenna is embedded to detect RF-ID tags placed on the table. These tags are used to initiate and terminate different game sessions by just placing them on or removing them from the game table.

Wall Display
A large display is located at one wall near the game table. It displays game relevant public information that each player can view at any time. In our setup, the wall display consists of the DynaWall®, which is a Roomware component embedded into one of the walls in our research lab. It is a rear-projected interaction space consisting of three joint segments that allow multiple users to simultaneously interact with the display surface.

Personal Digital Assistants
Players can integrate their Personal Digital Assistants (PDAs) via an 802.11b network connection to administrate private information and to communicate clandestinely with other players.

Audio Devices

A public loudspeaker is available to emit ambient audio samples or atmospheric music. STARS also integrates headsets that allow players to receive computer-generated private messages or utter verbal commands. STARS provides a speech generation and a speech recognition module based on the Microsoft Speech API.

BENEFITS OF THE PLATFORM

Playing hybrid tabletop games in a ubiquitous computing environment offers potential benefits over traditional board games.

Persistency and Game Session Management

STARS game sessions can be interrupted and continued at any time with the current state of a game session being automatically preserved for later continuation. The RF-ID reader unit at the game table assigns game sessions to RF-ID tags, so that the tags operate like physical bookmarks. This makes session management much more intuitive and natural than GUI-based interfaces.

Complex Game Rules

Complex traditional board games such as conflict simulations or role-playing games usually either involve a lot of table reading and dice rolling that hamper game play or they suffer from oversimplified rules to make them more manageable. In STARS, the more complex game rules are put into the digital domain, so that an accurate simulation of the game world can be realized without slowing down the game flow.

Dynamic Information Visualization

The interactive table display allows providing the players with dynamic game boards. This includes alterations to the boards at runtime, e.g. a *fog-of-war* might be lifted when new areas of the board are explored. Also, the presentation of the boards can be automatically adjusted to real-world properties such as the positions and viewing angles of the players.

Generic Development Architecture

The STARS software architecture relieves the game developer from many mundane tasks such as device integration or game board management. Thereby, she can concentrate on creating rules and providing content. So far, we have realized a roleplaying game called KnightMage and a Monopoly clone called STARS Monopoly. Both games make use of the heterogeneous device setup, e.g. in KnightMage the wall display shows a public map of the explored game area, while the PDAs are used for inventory management and character attributes.

CONCLUSIONS

We have presented the STARS platform for computer augmentend tabletop games. Apart from writing new games for the platform, our next steps will include the integration of additional input and output devices and the augmentation of single playing pieces with information technology.

RELATED WORK

Mandryk et al [2] have developed a computer augmented tabletop game called *False Prophets*. Similar to STARS, False Prophets' goal is to combine the strengths of traditional tabletop gaming and computing devices. As in STARS, mobile computers are integrated for private information. However, False Prophets does not attempt to create a general purpose platform for multiple games, but is currently limited to a single exploration game.

Björk et al. [1] presented a hybrid game system called *Pirates!* that does not utilize a dedicated game board, but integrates the entire world around us with players moving in the physical domain and experiencing location dependent games on mobile computers. Thereby, Pirates! follows a very different, but very interesting approach to integrate virtual and physical components in game applications.

ACKNOWLEDGMENTS

We thank our colleagues Norbert Streitz, Peter Tandler, and Carsten Röcker for their helpful feedback on our work. Also, we especially thank our student staff member Sascha Nau for his dedicated efforts to complete the video realization in time.

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A-Life: Saving Lives in Avalanches

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ABSTRACT
We present a novel approach to enhance avalanche companion rescue using wearable sensing technologies. The time to find and extricate victims is most crucial: once buried by an avalanche, survival chances drop dramatically already after the first 15 minutes. Current technology offers only information on the location of a single victim, however statistics show that in many cases there are multiple victims. In our research we show how wearable sensors can further enhance such devices and how this additional information can be visualized. A prototypical implementation offered a basis for participatory evaluation with practitioners in the field.

Keywords
situation-aware, wearable-sensing, personal assistance, avalanche rescue, mobile application, wearable computing

INTRODUCTION

There is an on-going trend towards out of bound (off-piste) skiing. Recreationists go beyond their limits, underestimate the danger of avalanches and risk their lives without the appropriate awareness of avalanche risks. Statistical analysis of avalanche accidents during the last 30 years [1] has revealed that successful avalanche rescue has to aim at rescuing victims within the first 15 minutes. Avalanche survival chances rapidly decrease with time and after 15 minutes there is the biggest decline from 90% to 30%. Accordingly, beacon technology is widely used by recreationists. Worn by the mountaineers these electronic devices enable survivors and witnesses of an avalanche to start immediate search and rescue operations. Microprocessors on the devices can calculate distance and direction to a single victim from the emitted dipole flux pattern of a standardized long-wave signal [2]. Usually, a range of 80m can be achieved. Batteries last up to 300h. In practice, self-organized rescue yields survival chances four times as high as in case of professional rescue [3], which is often too late.

Current devices only provide directions for finding a single victim. However, recent statistical analysis has shown that a surprisingly high percentage of victims get caught and completely buried in avalanches producing multiple burial scenarios [4]: 61% of all backcountry skiers who could not be found by visible parts were involved in a multiple burial situation. Multiple burial scenarios ask too much of most companion rescuers, support with avalanche beacons is not sufficient yet but necessary.

State of the art in wearable sensing suggests more opportunities. We believe that providing information on victims' physical states at an avalanche site to rescuers allows much better resource allocation to the most urgent victims.

OPPORTUNITIES WITH WEARABLE SENSORS

Our approach is to automate prioritization of victims (triage) through sensors. Mountain medicine has developed a so-called triage-scheme for emergency physicists [5]. Based upon different vital sign data, such as heart rate, respiration activity and consciousness, different urgency states can be derived that determine appropriate first aid operations. Currently, triage is delayed until victims have been extricated and rescuers get access to them. Instead, wearable sensing attached to the human body can provide continuous sensors readings and share the awareness of emergency with surrounding rescuers much earlier. Automation could also provide non-professional rescuers with the ability of triage in order to rescue additional victims.

SENSING

According to the triage scheme [5] used in avalanche rescue the primary selection criteria are heart rate and respiration activity. Oximeters offer a non-invasive way of measuring heart rate and blood oxygen saturation.

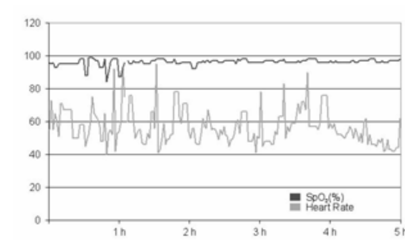

Fig. 1: Oximeter measurements

We tested different placements of the oximeter: forehead, finger tips and toe. Only the toe turned out to be appropriate in mountaineering: Today's ski and hiking boots are well isolated and can shelter the sensor from damage and loss. We have run several tests with skiers and snowboarders and could achieve reasonable measurements of heart rate and oxygen blood saturation (Fig. 1). Further, subjects reported that the sensor would not have disturbed them during their activities, once wrapped around toe or finger, they soon forget about the sensor. However, we are aware of the fact that severe cold may cause retreat of blood from the extremities, referred to as centralization, such that peripheral measurements at the toe may get unreliable under harsh conditions. A more promising way of detecting heart rate, are contact-free measurements through radar based on Doppler phenomena. Currently, this technology has been deployed for people detection in earth quakes and border controls. However, customization for on-body measurements could offer solution which is robust against both centralization and displacement, as this technique works contact less.

Another important source of information is the existence of air-pockets in the snow, closed air bubbles in front of mouth and nose, as they protect victims against asphyxiation up to 90 minutes [6]. As an initial study, we investigated the use of oxygen sensors for air-pocket detection. Unfortunately, oxygen sensors did not appear as the appropriate method for air-pocket detection: even compact snow contains air, such that exhaled air of a victim does not deviate significantly from normal snow.

Knowledge about a victim's orientation can be very helpful for rescuers during extrication. As accelerometers measure all means of acceleration, in the stationary case these sensors can report orientation derived from direction of gravity. We explored how a two-axis accelerometer can be applied to detect the orientation of one's spine.

VISUALIZATION

Avalanche rescue is a situation under immense pressure. Nevertheless, today's devices still require lots of training: Guidance with periodical beeps or support with little arrows and rough distance is rather difficult for untrained users. A visual user interface displaying more appropriate information could help to make usage much easier.

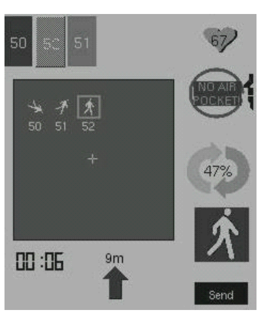

Fig. 2: screen design of prototype

With the introduction of unique identifiers - rather a standardization problem among manufacturers than a technical challenge – multiple victims are discriminated. As putting vital functions, air-pocket existence and orientation of all victims into one interface would be too much, we propose separation in location and urgency (Fig. 2). First, visual map presentation of the victims' spatial distribution enables the user to select victims such that ways can be kept short. Secondly, separation in urgency provides rescuers with a global view on the emergency which allows better focus on the most urgent victims. For that, we introduce a decision tree defined as follows: Heart rate is the primary criterion, air-pocket is second, oxygen blood saturation is third and orientation the fourth. In case of unavailable sensor information the fundamental concept is to always assume the worst case. Now multiple victims can be aligned on a one-dimensional scale where victims' physical states can be easily compared – even under stress conditions. With this user interface, rescuers can select victims either based on location or urgency in order to obtain more details on their vital signs displayed in the right column.

CONCLUSIONS

We motivated the use of sensors in avalanche rescue by the importance of time during avalanche rescue. We discussed and described how sensor technology can be used to provide rescuers with a valuable tool for better planning rescue procedures. For demonstration and evaluation purposes we have developed a first prototype, technical details and experiences can be found in [7].

ACKNOWLEDGEMENTS

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Breakout for Two: An Example of an Exertion Interface for Sports over a Distance

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ABSTRACT
Breakout for Two is the first prototype of a physical, exertion sport that you can play over a distance. We designed, developed, and evaluated Breakout for Two that allows people who are miles apart to play a physically exhausting ball game together. Players interact through a life-size video-conference screen using a regular soccer ball as an input device. In a test of 56 volunteers, the Exertion Interface users said that they got to know the other player better, became better friends, felt the other player was more talkative and were happier with the transmitted audio and video quality, in comparison to those who played an analogous game using a non-exertion keyboard interface.

Keywords
Exertion interface, physical interface, sports interface, social bonding, computer mediated communication, interpersonal trust, funology, sport, video-conferencing

INTRODUCTION
"You can discover more about a person in an hour of play than in a year of conversation" (Plato, 427-347 BC). This quotation conveys the motivation for our work perfectly.

BREAKOUT FOR TWO
How cool would it be if you could play football with your friend, even though he just moved miles away? What about playing tennis with a famous tennis player on another continent who is preparing for a grand slam?

With Breakout for Two, you can. Breakout for Two is the first prototype of a physical, exertion sport that you can play over a distance.

Figure 1: Breakout for Two

It's a cross between soccer, tennis, and the popular computer game "Breakout". The players share a court, but stay on their side of the field, like in tennis. They see and hear each other through a life-size videoconference, which feels like they're separated by a glass wall.

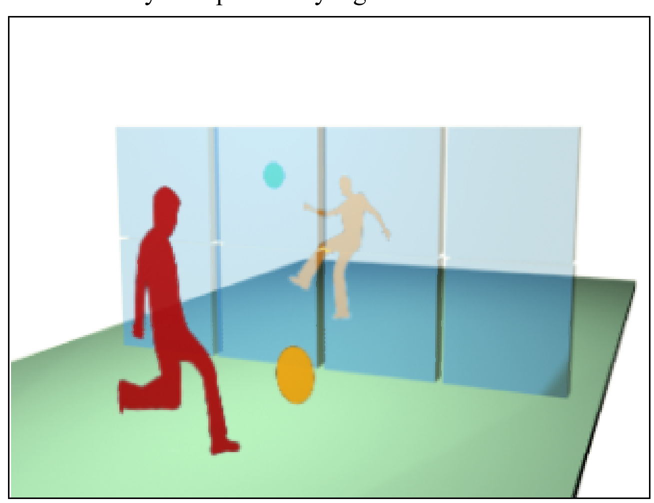

Figure 2: Feels like a glass wall between the players

They both have a ball which they can throw, kick, smash, in whatever sport they agree on – for example tennis.

Figure 3: The system also works with tennis balls

They have to strike semi-transparent blocks, which are overlaid on the video stream. These virtual blocks are connected over the network, meaning they are shared between the locations. If, for example, one player hits the block on the upper left, the block on the upper right is hit for the other player. The goal is to hit all the blocks before the other player hits them. You win if you hit more blocks than the other player.

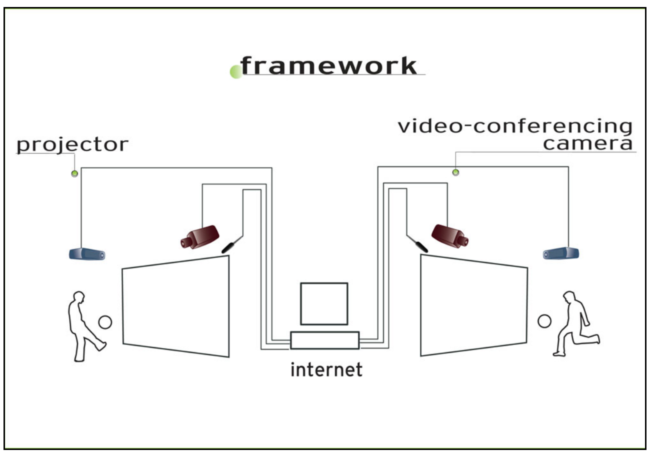

Figure 4: Technical framework

EXERTION INTERFACE

Breakout for Two serves as an example of an Exertion Interface, an "interface that deliberately requires intense physical effort" [1]. It aims to recreate the same bonding and team spirit experience of traditional sports except over a distance; not with email and instant messengers, but with real balls, sweat, and exertion.

EVALUATION

56 volunteers evaluated the system. They did not know each other beforehand, and played Breakout for Two for half an hour. These players reported that they got to know the other player better, became better friends, felt the other player was more talkative and were happier with the transmitted audio and video quality, in comparison to those who played an analogous game using a non-exertion keyboard interface ($p<0.05$ for all these results) [2].

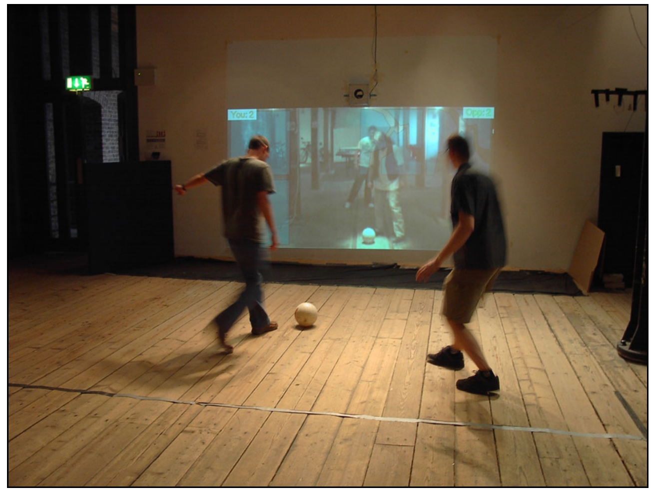

Figure 5: Breakout for Two also supports two-on-two

CONCLUSION

Breakout for Two is only one example of an Exertion Interface, which supports Sports over a Distance.

Augmenting a gaming environment with exertion will greatly enhance the potential for social bonding, just as playing an exhausting game of squash or tennis with a new acquaintance or co-worker helps to "break the ice" and build friendships. You can now have fun playing sports with your local *and* remote friends!

Figure 6: Happy winners

ACKNOWLEDGEMENTS

Thanks to Tom Walter, Beth Veinott and Ted Selker. This project was created in the Human Connectedness group at Media Lab Europe. More information on:

http://www.exertioninterfaces.com
http://www.medialabeurope.org/hc

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Concept and Partial Prototype Video: Ubiquitous Video Communication with the Perception of Eye Contact

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ABSTRACT

This concept and partial prototype video introduces a strategy for creating a video conferencing system for future ubiquitous computing environments that can guarantee two remote conversants the ability to establish eye contact. Unlike prior work, eye contact can be achieved even as people move about their respective environments engaging in everyday tasks.

1. INTRODUCTION

Imagine this scenario: *You are working in your future kitchen. You turn on your video conferencing system and make a call to a friend in a distant city. The face of your friend appears just above your work surface on your kitchen cabinet door. When you look at your friend, he perceives excellent eye contact with you. No matter how you move about your space, when the conversation warrants it you can look at a nearby flat surface, see the face of your friend, and initiate eye contact. Establishing eye contact does not restrict you or your friend to standing or sitting in a particular position, chair, or space.* In this video we show how such a system could be achieved.

2. VIDEO CONFERENCING AND EYE CONTACT

Eye gaze conveys important signals about trust and attention during interpersonal communications [1]. A camera that is placed above or to the side of a display of a videoconferencing system forces the person looking at the display (the looker) to look away from the camera's optical path. The displacement angle, θ, between the optical path of the looker's eyes and the camera will result in a perception of lack of eye contact if θ is sufficiently large.

Chen [4] enumerated the three options previously investigated to minimize or eliminate θ. The first is selectively warping the video so that it appears to be captured from the viewpoint in front of the looker's eyes. This strategy can create unnatural faces and enforce eye contact when it should not be perceived. The second approach to minimize θ is to merge the optical path of the camera and the display, which typically requires two conversants sit in predetermined positions in front of their displays with their heads roughly centered in the respective camera's field of view. The third approach to minimize θ is to simply mount the camera sufficiently close to the display so that the display and camera have nearly the same optical path. This can be effective with small, PDA-sized displays [3] but fails with larger (e.g. desktop) size displays. This video shows a fourth option that combines the positive properties of each of these approaches: manipulating the video (via warping and object tracking) to guarantee that the optical path of the looker's eyes and the observer's face are closely aligned by ensuring that the camera is always positioned *in* the display directly between the observer's eyes.

3. A SYSTEM FOR UBIQUITOUS EYE CONTACT

We introduce a design for a video conferencing system that can be installed in existing environments in a space-efficient manner and that permits ubiquitous video communications with the perception of eye contact. Wireless phones freed people to move about their homes and accomplish cognitively simple tasks as they talk; our proposed video conferencing system would permit this type of casual interaction while maintaining the option of effortlessly establishing eye contact when needed. We achieve this by simultaneously exploiting several technologies: perspective warping of imagery, computer vision head tracking, and miniature (i.e., pinhole) video cameras embedded within walls and cabinetry.

3.1 Concept

Figure 1 illustrates the full concept as it could be implemented in a future home with a high-bandwidth connection. Participant A is located in a kitchen where the walls of the kitchen cabinet doors and the refrigerator have been built with embedded pinhole video cameras centered in each door. Participant B is located in the living room of a remote home where pinhole cameras have been embedded at two different heights, one appropriate for sitting and one appropriate for standing.[1] Both environments have an Everywhere Display Projector (EDP) [6] located at the ceiling of one corner of the

[1]These camera units could eventually be installed by simply drilling a small hole in an existing wall or using component-based architectural wall and furniture systems under development in our group that are designed for such sensor integration [5].

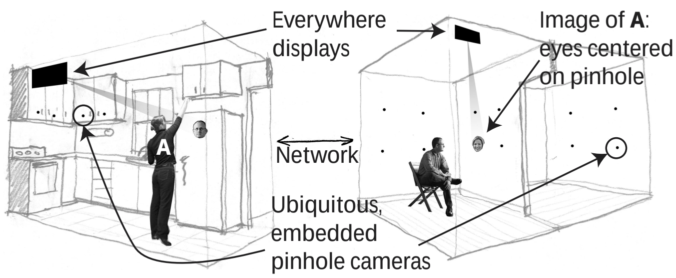

Figure 1: The concept for video conferencing anywhere with sensors embedded in architectural components. Cabinetry with integrated sensing being designed by our group would make such a scenario possible.

room. Each EDP uses a small computer-controlled mirror and perspective warping and can project an undistorted image onto nearly any planar surface in the environment.

The system in person A's space would use face-finding algorithms (e.g. [7]) to detect where person A is located and grabbing the person's image from the closest camera. (2) The system in person B's space would similarly detect where person B's face is located. (3) Based on these locations, the systems would place person A's image in person B's space so that it is near person B. (4) The EDP is used to place the image. The 1.5mm pinhole is barely noticeable on the image of the face. Simultaneously, person B's image appears on the pinhole embedded in the refrigerator appliance in person A's kitchen. As both people move about their respective spaces, the image of the other person will automatically move to the most visually convenient camera position. The system preserves both the ability to make eye contact and the ability to intentionally not make eye contact because the remote participant's eyes are always moved so they are centered directly over a pinhole camera.

3.2 Partial Implementation

We have begun to implement and test the components of this concept. We have two video conferencing stations located in non-adjacent rooms in our laboratory. Each station consists of a flat, white foam core board with a pinhole color camera embedded behind a 1.5mm hole centered horizontally on the foam board. The camera is adjusted so that the optical axis is perpendicular to the board's surface.

Head tracking is performed using the Continuously Adaptive Mean Shift algorithm [2]. The head pixels are translated so that the remote viewer sees the head displayed with the eyes centered over the pinhole camera. A low-pass filter on the face position is used to eliminate jitter motion that would otherwise be visible due to camera noise and sudden flesh changes as people quickly move their heads. The prototype is run using a standard office speaker phone to provide audio. Other mechanisms could be used to improve head tracking (e.g. [7]).

A portable video projector placed to the side of the board uses the same perspective transformation algorithms as the Everywhere Display but permits testing with higher-resolution images than can currently be achieved in the our living room prototype environment with Everywhere Display. When an image of a remote conversant's face is projected with the pinhole centered between the conversant's eyes, the 1.5mm hole is distinguishable but not distracting.

The video also shows our prototype living room with Everywhere Display. Cameras can be embedded directly into surfaces in the space. One is used to create a "magic mirror" effect when used in combination with an Everywhere Display Projector (EDP) [6]. An image from the pinhole camera (flipped) is projected onto the wall centered on the camera itself. The effect is that the user appears to be looking directly at oneself. People who are shown this setup often have a difficult time determining the position of the camera when they are not told about the 1.4mm pinhole in the drywall in advance; only after asking them to "point where the image must be coming from" and pointing out the tiny speck on the wall do visitors typically understand how the effect is achieved.

Eventually we hope to test one half of the full video conferencing system illustrated in this concept video in our prototype living room environment. Resolution limitations of our current Everywhere Display unfortunately prevent an ideal implementation of the concept described. Our group is developing cabinetry components that have integrated sensors networks built in and could easily accommodate the integrated pinhole cameras.

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The Design of a Context-Aware Home Media Space

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ABSTRACT

Traditional techniques for balancing privacy and awareness in video media spaces have been proven to be ineffective for compromising home situations involving a media space. As such, we present the rationale and prototype design of a context-aware *home media space (HMS)*—defined as an always-on video media space used within a home setting—that focuses on identifying plausible solutions for balancing privacy and awareness in compromising home situations. In the HMS design, users are provided with *implicit* and *explicit control* over their privacy, along with *visual* and *audio feedback* of the amount of privacy currently being maintained.

Keywords. Casual interaction, video media spaces, privacy, telecommuting.

INTRODUCTION

A *home media space* (HMS) is an always-on video-based media space used within a home setting. It is designed specifically for the telecommuter who chooses to work at home, but who still wishes to maintain a close-working relationship with particular colleagues in remote office environments. Like all media spaces, the video provides the telecommuter with awareness information about their collaborator's availability for conversation, and a way to easily move into casual communication over the same channel.

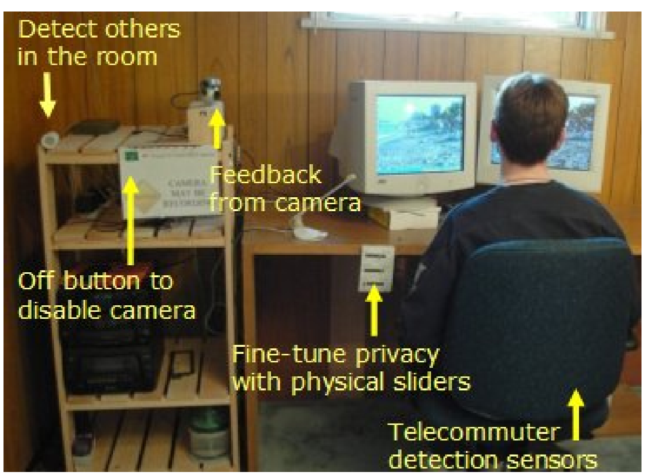

Figure 1: The context-aware home media space.

Unlike office-based media spaces, a home media space has to pay considerably more attention to how the system appropriately balances privacy and awareness, because privacy concerns are far more problematic for home users. Homes are inherently private in nature, and appearances or behaviours that are appropriate for the home may not be appropriate when viewed at the office. As well, individuals in the home other than the telecommuter who gain little or no benefit from the HMS still incur its privacy threat.

These increased privacy risks suggest that home media space systems must incorporate techniques that somehow mitigate privacy concerns. One possibility is to simply adapt techniques already proposed for office media spaces [2]. However, research [3] has shown that traditional image processing techniques do not suffice for home-based video conferencing situations. Image processing techniques are overly simplistic because they do not understand the context of their use. For this reason, our research focuses on designing a home media space using context-aware computing and dedicated physical controls.

OUR DESIGN PHILOSOPHY

Privacy regulation in real life is lightweight and transparent [1]. We replicate this by providing lightweight and transparent privacy regulation in our HMS using context-aware computing as a tool for balancing privacy and awareness through implicit means. We enable one specific location—a home office/spare bedroom shown in Figure 1—with technology that senses who is around and then infers privacy expectations through a simple set of rules.

Context-aware systems can make mistakes and it is important that these mistakes do not increase privacy threats. As a result, we first warn users if an implicit action has initiated a privacy decreasing operation; and second, we provide an opportunity for users to override this operation. Continuous visual and audio feedback makes it easy to know how much privacy is currently maintained and users are able to fine-tune privacy and awareness levels with dedicated physical and graphical controls.

1	2	3	4	5
Attribute Controlled	**Explicit Control**	**Implicit Control**	**Audio Feedback**	**Visual Feedback**
Camera State: Stop to Play	Click play button	None	Camera clicking; Camera rotating	LEDs on; Camera rotates to face you; Mirrored video
Camera State: Pause to Play	Click play button	Telecommuter sits in chair; Family/friend leaves room	Same as above; Camera Twitches	Same as above; Camera Twitches
Camera State: Play to Stop	Click stop button; Block camera with hand; Touch off button	None	Camera rotating	LEDs off; Camera rotates to face the wall; Mirrored video
Camera State: Play to Pause	Click pause button	Telecommuter stands up out of chair; Family / friend enters room	Same as above	Same as above
Camera State: Pause to Stop	Click stop button; Block camera with hand; Touch off button	Telecommuter leaves the room for an extended period of time	None	Mirrored video
Capturing angle	Adjust physical or graphical slider	Change in camera state	Camera rotating	Slider position; Camera position; Mirrored video
Video fidelity	Adjust physical or graphical control	None	None	Control position; Mirrored video
Audio link	Moves hand over microphone base	None	Own voice	None

Table 1**:** Control and feedback mechanisms found in the HMS

Elements of a Context-Aware HMS

Our design contains specific elements that can be used together along with a simple set of rules to balance privacy and awareness. Elements such as the camera state, capturing angle, or video fidelity can be controlled with explicit actions such as touching an off button, or implicit actions like sitting down in a desk.

Table 1 summarizes how design elements are either: controlled, used for explicit or implicit control, or used as feedback. Each row in the table describes how one media space attribute (column 1) is controlled either explicitly (column 2) or implicitly (column 3). The fourth and fifth columns describe the audio and visual feedback that indicate to the users that the attribute in column 1 has changed and what its current value is.

DISCUSSION

This was our "first cut" of a context-aware home media space and as a result we wanted to see what big problems emerged by trying it out ourselves (an evaluation methodology called "eat your own dog food"). In particular, the first author, a frequent telecommuter, routinely used the home media space over several months within his own home office/spare bedroom. We noticed several design faults. First, the control and feedback mechanisms need to be more natural if they are to fit well within a person's everyday world. For example, adjusting a physical slider to regulate privacy is a somewhat abstract notion. Second, a consequence of unobtrusive peripheral feedback of system state is that the person may overlook the information. For example, one may overlook feedback that the camera is recording at high quality (e.g., the LEDs). Third, explicit control mechanisms only work if one can anticipate and react quickly enough to the risk inherent in the current situation, if one is in a location where the system can recognize their control action (e.g., one must be near the camera to block it with a gesture); and if one feels that the effort is worth it. Ideally, the system should automatically sense privacy-violations and control the information it transmits accordingly, but this can be quite difficult to do in practice. Despite these caveats, our experience was positive overall. We were able to control the space for many situations, and indeed just knowing that we *could* control the media space was comforting. Future work will involve formally evaluating our redesigned home media space.

CONCLUSION

While we have concentrated on one specific use of video in homes, our research contributes ideas that have a broader significance for home-based videoconferencing in general. Regardless of the specific use of video in a home, people need and desire methods to regulate their privacy; many video conferencing systems (e.g., Webcam for MSN Messenger, Yahoo! Messenger) ignore these user requirements.

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Hello.Wall – Beyond Ambient Displays

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ABSTRACT
We present a ubiquitous computing environment that consists of the Hello.Wall in combination with ViewPorts. Hello.Wall is a new wall-sized ambient display [4,2] that emits information via light patterns and is considered informative art. As an integral part of the physical environment, Hello.Wall constitutes a seeding element of a social architectural space conveying awareness information and atmospheres in organizations or at specific places. The display is context-dependent by reflecting identity and distance of people passing by. Hello.Wall can "borrow" other artefacts in order to communicate more detailed information. These mobile devices are called ViewPorts. People can also further interact with the Hello.Wall using ViewPorts via integrated WaveLAN and RFID technology.

Keywords
Ambient display, informative art, social architectural space, context-dependent, sensor-based interaction, interactive wall, interaction design, mobile devices, smart artefacts, ubiquitous computing environment, calm technology

HELLO.WALL AND VIEWPORT
Hello.Wall is a piece of unobtrusive, calm technology [3] exploiting humans' ability to perceive information via codes that do not require the same level of explicit coding as with words. It can stay in the background, only perceived at the periphery of attention, while one is being concerned with another activity, e.g., a face-to-face conversation.

Borrowing another Artefact
We propose a mechanism where the Hello.Wall can "borrow" other artefacts, in order to communicate more detailed information. These mobile devices are called ViewPorts and can be personalized using short-range transponders. Due to the nature of the ViewPort's display, the information shown can be more explicit and it can also be more personal. Depending on their access rights and the current situation (e.g., distance to the wall; see below), people can use ViewPorts to decode visual codes (here, light patterns), to download ("freeze") or just browse information, to paint signs on the wall, or to access a message announced by a light pattern. See figure 1.

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Figure 1. Interaction at Hello.Wall using ViewPort as „borrowed display"

INTERACTION DESIGN
Interactions among the different components are supported by two independent RFID systems and a wireless LAN network to enable a coherent and engaging interaction experience. The RFID systems cover two ranges and thereby define three "zones of interaction": ambient zone, notification zone, and cell interaction zone (see figure 2). They can be adapted, e.g., according to the surrounding spatial conditions.

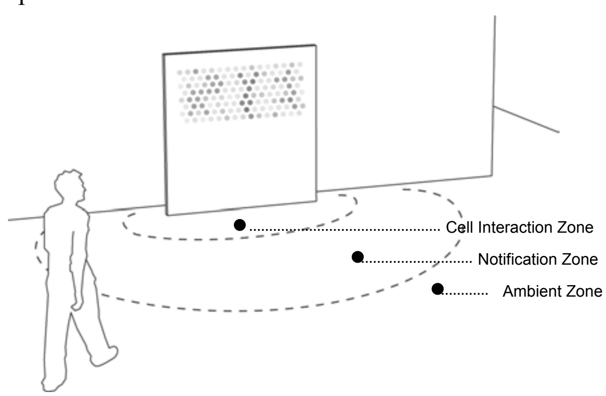

Figure 2. Three zones of interaction

The zones were introduced to define "distance-dependent semantics", meaning that the distance of an individual from the wall defines the interactions offered and the kind of information shown on the Hello.Wall and the ViewPort.

It should be noted that multiple people can be sensed at once in the notification and cell interaction zones.

Interactions

When people are outside the range of the wall's sensors (in the *ambient zone*), they experience the ambient mode, i.e. the display shows general information that is defined to be shown independent of the presence of a particular person.

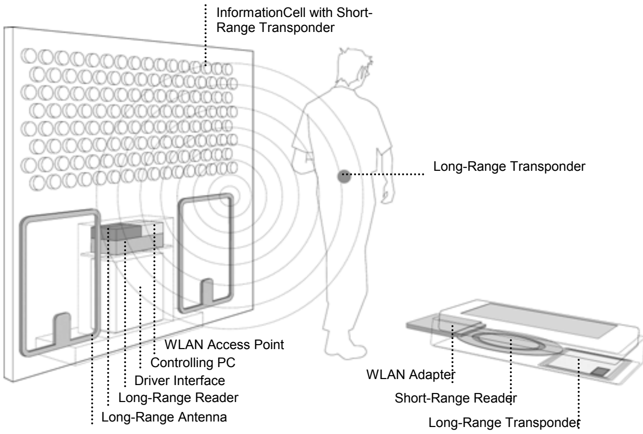

Figure 3. Communication and Sensing infrastructure of Hello.Wall and ViewPort

People within the *notification zone* are detected via two long-range readers installed in the lower part of the Hello.Wall (see figure 3) and people can identify themselves to a ViewPort via the integrated short-range reader. Once a person is detected in the notification zone, depending on the kind of application, data can be transmitted to the ViewPort and/or distinctive light patterns can be displayed for notification. These can be personal patterns known only to a particular person, group patterns, or generally known patterns. Within the *cell interaction zone*, people that are very close to the Hello.Wall can interact with each single cell (= independent interactive "pixel") or several cells at once using a ViewPort to read the cells' IDs. Simultaneous interaction using several ViewPorts in parallel at a Hello.Wall is supported as well. These features allow playful and narrative interactions and there is also a charming element of surprise that may be discovered via single cell interaction.

TECHNOLOGY

Each of the 124 cells of the Hello.Wall contains an LED cluster and a short-range transponder (see figure 4). The brightness of the LED clusters is controlled by a standard PC via a special driver interface with control units using pulse width modulation. This interface also developed by us consists of 17 circuit boards.

The ViewPort is developed on the basis of a PocketPC with 32bit RISC Processor, touch-sensitive color display and 64MB RAM. Its functionality is extended through a short-range (up to 100mm) reader unit and a WaveLAN adapter. Additionally, the ViewPort is equipped with a long-range transponder. Thus, the ViewPort can be detected by stationary artefacts as, e.g., the Hello.Wall, while at the same time identify nearby artefacts through its own reading unit.

Figure 4. From left to right: 1) Rear view with control components 2) Wiring and transponders for each cell 3) Cells with LED clusters

APPLICATIONS

Atmospheric aspects that can, e.g., be extracted from conversations [1] are mapped onto visual codes realized as light patterns which influence the atmosphere of a place and the social body around it. While the Hello.Wall serves a dedicated informative role to the initiated members of an organization or a place, visitors might consider it only as an atmospheric decorative element and enjoy its aesthetic quality.

Communicating atmospheric aspects of an organization includes general and specific feedback mechanisms that allow addressing different target groups via different representation codes. Individuals as well as groups create public and private codes depending on the purpose of their intervention. The content to be communicated can cover a wide range and will be subject to modification, adjustment, and elaboration based on the experience people have.

Sample applications are presented in the video. They include radiating the general atmosphere in an organization or at a place, distributing more specific and directed information, various forms of playful close-up interactions, and support for team building and coherence through “secret” visual codes mediating, e.g., acitivty levels among the team’s members. To learn more about the acceptance of applications, we are currently running user experiments.

ACKNOWLEDGMENTS

This work is supported by the European Commission (contract IST–2000-25134) as part of the proactive initiative “The Disappearing Computer” of “Future and Emerging Technology” (FET) (project website: www.ambient-agoras.org). Special thanks are due to our student Stefan Zink for his contributions to implementing the Hello.Wall hardware.

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Browsing Captured Whiteboard Sessions Using a Handheld Display and a Jog Dial

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ABSTRACT

In previous work we introduced *Total Recall,* a system for in-place viewing of captured whiteboard annotations using a handheld display. To improve on our system we now introduce a method for navigating through time-based whiteboard annotations using a jog dial. By turning the dial, the user can navigate back and forth in time to reach a desired point in the captured session, which is then displayed on the handheld device at the correct location. The tracking system supports drawing as well as erasing, which are both immediately reflected on the handheld display. We argue that our system introduces new application possibilities, e.g. in education.

Keywords

Whiteboard capture systems, ubiquitous computing

INTRODUCTION

During the past few years, several systems have been introduced to augment whiteboards and making them "smart". The reasons are many; being able to keep digital copies of what has been written to the whiteboard, incorporating computer acronyms such as "cut" and "paste" into a non-computer environment, and simplifying drawing in general. Several strategies have been tested to enhance whiteboards. One type of system replaces the entire whiteboard with a digital touch sensitive display. Examples of such system include the *LiveBoard* [4], which was part of Xerox PARC's original ubiquitous computing experiment; and current commercial products such as the *SmartBoard* (www.smarttech.com). Replacing the drawing area with a digital replica provides many possibilities for enhancing the whiteboard, but it is an expensive option that limits its use to specific environments.

An alternative approach is to use a system with pens equipped with built-in positioning systems, such as the commercially available Mimio system (www.mimio.com). To the end-user, using the Mimio system is perceived as using an ordinary whiteboard – the difference is that the coordinates of each pen stroke are captured on a PC, making it possible to create a snapshot of the whiteboard at a specific moment in time. While systems such as the Mimio are portable and can be used in any environment, they do require a separate PC to view the annotations. However, considering the size of an ordinary whiteboard, viewing the notes on a PC usually requires a significant amount of zooming and panning of the captured image.

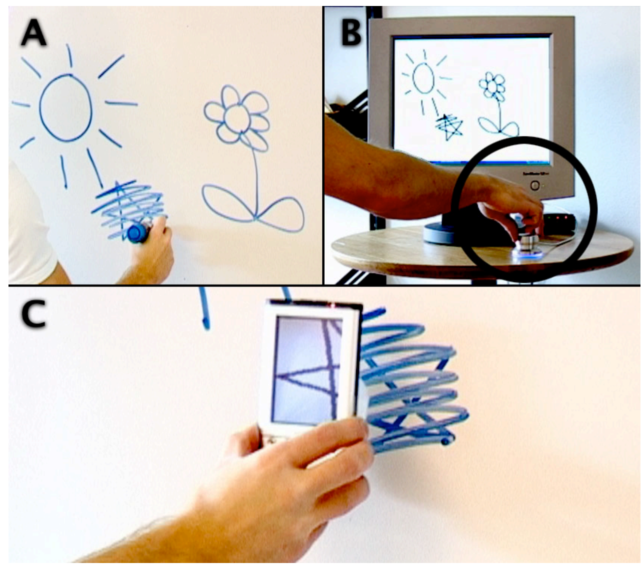

Figure 1. (a) An annotation is created, (b) a jog dial is used to navigate back to a previous position in time, and (c) the session is recalled in its original location.

Total Recall [3] was introduced to provide in-place viewing of captured whiteboard annotations using a handheld display. Using a handheld computer equipped with an ultrasonic positioning system, Total Recall makes it possible to view annotations where they were created – even if they are partially erased! Total Recall can be seen as a physical instantiation of a *Magic Lens*, an operator that is positioned over an onscreen area to change the view of objects in that region [1]; other similar approaches include *Peephole Displays* [5]. We have now extended the Total Recall system by introducing a jog dial (as seen in Figure 1) that can be used to view how the whiteboard state looked at a specific moment in time. By turning the dial, the user can navigate to different point in time during the digitization. The effect is similar to *Time-machine Computing* [2], since the user can always go back in time and for instance easily retrieve previously erased content.

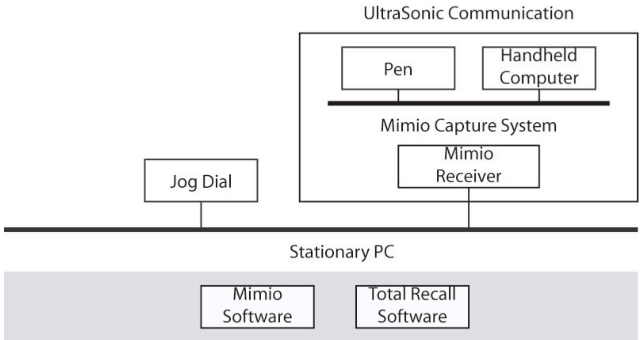

Figure 2. The improved Total Recall architecture.

ARCHITECTURE

The Total Recall architecture comprises two parts: a server software installed on a stationary PC to capture whiteboard annotations, and a client software installed on a handheld computer to view the annotations. The system has two "modes": in one mode coordinates are received as paint or erase strokes when pens or the eraser are used to draw on the whiteboard. In the other mode coordinates are received from a handheld computer equipped with an ultrasonic and infrared transmitter in the form of continuous XY-coordinates. The user switches between these two modes by pressing the top of the jog dial that is shown in Figure 1b. Using our server software, the XY-coordinates received from the pens are sent as drawing coordinates to the handheld computer when the user changes modes. The coordinates received from the handheld computer are sent back to the device in a compressed form over a wireless connection, where the client software periodically redraws the image to reflect the whiteboard using the current XY position.

The jog dial shown in Figure 1B was added to support time-based browsing of the drawing session. In normal use, the stationary PC will continuously send the XY-coordinates it receives back to the handheld device. The handheld display will then draw a brush or erase stroke depending on the current stroke type. When the jog dial is turned counter clockwise, the display of the handheld device is cleared and the entire canvas is redrawn from the beginning up to the coordinate at the current position in time. When the jog dial is turned clockwise, the server software will simply send out the brush or erase strokes that were drawn since the last update.

IMPLEMENTATION

We used the Mimio sensor and pens to get positioning information for both the PDA and the stationary PC. To get the handheld computer to send XY-coordinates to the PC we extracted the interior of a Mimio pen shell and attached it to the back of a handheld computer. Using a switch attached to the back of the handheld computer it is possible to manually enable / disable sending of coordinates.

APPLICATION SCENARIO: DRAWING CLASS

The new system could be used as support in a learning situation, such as a drawing class. Looking at a finished image does not tell the student very much about how it was drawn, nor does it show how much time was spent on each specific detail. Through the ability of time-based browsing, Total Recall could make it is possible for students to first watch a tutor complete a drawing, and then go back in time using the jog dial to study in detail how a specific section was achieved. Unlike on a stationary PC, the student could study the drawing process on the position where it actually happened, using the finished drawing as a frame of reference.

DISCUSSION AND FUTURE WORK

In the current implementation of time-based browsing we experienced issues with captured sessions with large amounts of data. When the jog dial is used to move backwards in time, the stationary pc needs to resend the entire coordinate list up to an exact moment for the handheld computer to redraw the canvas. We are currently working on optimizing the system where the stationary pc is responsible for creating "bitmap snapshots" when a specific number of coordinates have been received since the last snapshot. Using this approach it would only be necessary to transfer the bitmap snapshot together with the coordinates received since last snapshot to the handheld device.

ACKNOWLEDGMENTS

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eyeCOOK: A Gaze and Speech Enabled Attentive Cookbook

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ABSTRACT
While preparing food, cooks often have to manage many time sensitive processes. Because cookbooks require visual and physical attention to use, they may distract, rather than focus the cook on executing the recipe. The knowledge requirements of cooking, concurrent demands for attention and the sensitivity of recipes to proper procedure conspire to make cooking a stressful experience, particularly to novices. We present eyeCOOK, a multimodal attentive cookbook which allows users to communicate using eye-gaze and speech. eyeCOOK responds visually and/or verbally, promoting communication through *natural* human input channels without physically encumbering the user. Our goal is to improve productivity and user satisfaction without creating additional requirements for user attention. We describe how the user interacts with the eyeCOOK prototype and the role of this system in an Attentive Kitchen.

Keywords
Attentive User Interfaces, Gaze, Eye Tracking, Speech, Context-aware, Information Appliance, Sensors.

INTRODUCTION
The attentive cookbook reduces the burden caused by competing requests for physical attention by directing instructions and glossary definitions to the unoccupied auditory channel. Gaze and speech were chosen as input modalities because they do not require physical contact (i.e., mouse, touch screen), which may be inconvenient and unsanitary while preparing food. The dynamic display window automates page turning, allowing users to focus their hands on the process of cooking. Alternative approaches to enhancing the cooking experience include Cook's Collage [7], a passive memory recovery aid, and CounterActive [1], a touch enabled multimedia cookbook. Unlike these approaches, eyeCOOK adapts its behavior and interface presentation based on the user's eye gaze, proximity, and the current cooking task. eyeCOOK qualifies as both an *information appliance* [2], and a *context aware* system [4], but because user attention drives the human interface, it is most precisely described as an *Attentive User Interface* (AUI) [5]. Using knowledge of the user's attentive context, the system applies contextual reasoning to activate localized grammars, working within the user's *attention space* [5].

SYSTEM DESCRIPTION
Our attentive cookbook prototype consists of an electronic recipe database with a hypertext-style interface. eyeCOOK receives input from an LC Technologies eye tracker and a wireless microphone using the Microsoft Speech API (SAPI) for speech recognition and production. The eyetracker is calibrated only once for each user. Since eyeCOOK uses a small context-sensitive grammar, speech recognition calibration is rarely required.

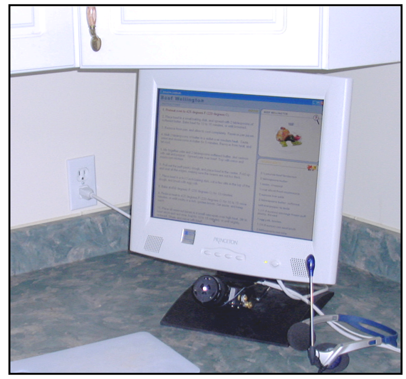

***Figure 1**.* The eyeCOOK System

eyeCOOK can read aloud ingredients and instructions, access additional information such as pictures and definitions of ingredients, terminology, cookware, nutritional information, the history of the dish, and suggest other food items it can be served with. Throughout the process of cooking, the system automatically triggers timed notifications, to remind the user when steps are completed, or require attention. The relationship between the current, previous and future cooking steps and the ingredients they involve is implicit via a simple color-coding scheme. The dynamic colouring, shown in figure 2, situates the current cooking task within the recipe as a whole.

Adaptive Inputs and Display
The display adjusts its presentation based on user presence reasoning. If eye gaze is detected, then the user must be in front of the screen. Thus the entire recipe is shown on one page in Cookbook mode (see figure 2), and deictic references are interpreted using gaze and speech. Alternately, if eye gaze is not present, the display is set to Recipe Card mode. This breaks up the recipe into multiple cards and enlarges the text, thereby allowing a user who is further away from the display to easily read the recipe. Because the user is not providing eye gaze input in Recipe Card mode, the system compensates by adjusting the vocabulary of the speech recognition engine, providing answers to more detailed queries.

Figure 2. eyeCOOK in Page Display Mode

NATURAL INPUTS

eyeCOOK is designed to use *natural* input modalities, or those that humans use in human to human, non mediated communication [5]. Observing and interpreting this implicit behavior reduces the need for users to provide explicit input. Using these cues, interfaces can be designed such that the difficulty lies in the intended task, not the technological tool.

Gaze and Speech

When the user is in range of the eye tracker and looking at the display, eyeCOOK substitutes the target of the user's gaze for the word '*this*' in a speech command. For example, eyeCOOK responds to the spoken command *'Define this'* by defining the word the user is currently looking at. However, because eye trackers are spatially fixed and have a limited range, the user will not always be in a position where eye tracker input is available. Thus, our speech grammar is designed such that system functionality is maintained when users are not in front of the eye tracker. Instead of saying "define *this*" while looking at the word *sauté*, the user simply states "define *sauté.*" The active vocabulary is dynamically generated using context-sensitive, localized speech grammars, allowing more synonyms to be included for a given word. Real world performance may be improved by adding partial terms and colloquialisms that may only be relevant in specific circumstances.

TOWARDS AN ATTENTIVE KITCHEN

Interfaces that recognize and respond to user attention, and understand how it relates to the overall activity can help the user efficiently engage in tasks. To achieve this, we must augment the kitchen with attentive sensors that monitor human behavior [5,6], augment appliances with functional sensors [3,6], improve coordination among appliances [5], and allow appliances to affect the environment [3,5].

Attentive and Environmental Sensors

Increasing the knowledge of users' activities may allow interfaces to engage in less interruptive, and more respectful interactions with users. Visual attention, a prime indicator of human interest, can be deduced by adding eye contact sensors [5,6] to items in the environment. This information can be used to determine the appropriate volume and timing of notifications to the user. Additionally, temperature sensors can be used to keep track of the status of the oven and the elements of the stove and could be synchronized with electronic timers to increase the system's ability to guide the user's cooking experience

Appliance Coordination

Integrating knowledge of the environment can result in improved functionality, taking up less of the user's time and effort. For example, user recipe preferences, timing constraints, as determined by the user's electronic schedule, and currently available ingredients, communicated by food storage areas, can be combined to suggest recipes. Once selected, the ingredients from the recipe can be added to an electronic shopping list stored on the user's PDA.

Active Environmental Actions

The kitchen should not only be aware of its environment, but it should also be able to affect it. Thus, it should be able to take actions which increase efficiency, and reduce the user's action load, like automatically preheating an oven.

CONCLUSIONS

We have presented eyeCOOK, a gaze and speech enabled multimodal Attentive User Interface. We have also presented our vision of an Attentive Kitchen in which appliances, informed by sensors, coordinate their behavior, and have the capability to affect the environment. This can reduce the user's workload, and permit rationalizing requests for user attention.

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Virtual Rear Projection

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ABSTRACT
Rear projection of large-scale upright displays is often preferred over front projection because of the elimination of shadows that occlude the projected image. However, rear projection is not always a feasible option for space and cost reasons. Recent research suggests that many of the desirable features of rear projection, in particular shadow elimination, can be reproduced using new front projection techniques. This video demonstrates various front projection techniques and shows examples of coping behavior users exhibit when interacting with front projected displays.

1. PASSIVE TECHNOLOGIES
Researchers have been working to resolve the occlusion problem by filling in the technological space between standard front projection and true rear projection. We have performed an empirical study comparing the following projection technologies (the first three are demonstrated in the video):

Front Projection (FP) - A single front projector is mounted along the normal axis of the screen. Users standing between the projector and the screen will produce shadows on the screen. This is a setup similar to most ceiling mounted projectors in conference rooms.

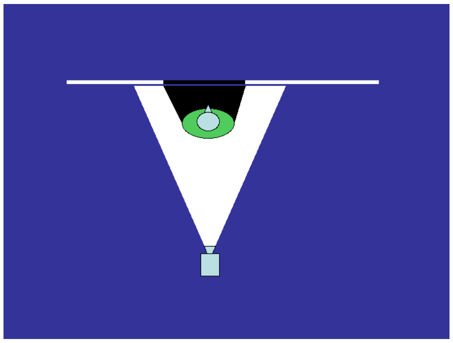

Figure 1: Front projection casts a shadow directly before the user.

Warped Front Projection (WFP) - A single front projector is mounted off of the normal axis of the projection screen, in an attempt to minimize occlusion of the beam by the user.

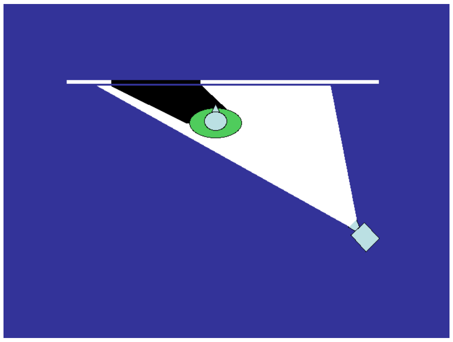

Figure 2: Warped front projection attempts to shift the user's shadow so that they can interact with the graphics in front of them.

The output is warped to provide a corrected display on the screen. Examples are new projectors with on-board warping functions, such as used by the 3M IdeaBoard[1], or the Everywhere Displays Projector[3]. Additionally, the latest version of the nVidia video card drivers includes a "keystoning" function which allows any Windows computer to project a warped display.

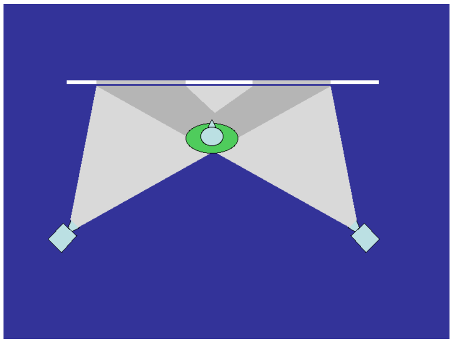

Figure 3: Virtual Rear Projection provides redundant illumination so that the user casts "half-shadows" when they block one of the two projectors.

Virtual Rear Projection (VRP) - Two front projectors are mounted on opposite sides of the normal axis to redundantly illuminate the screen. Output from each projector is warped (as with WFP) to correctly overlap on the display screen. This reduces the number, size and frequency of occlusions. Users standing very close to the screen may still completely occlude portions of the output, but usually only occlude the output of one of the projectors, resulting in "half-shadows" where the output is still visible at a lower level of contrast.

Rear Projection (RP) - Uses a single projector mounted behind the screen, so that it is not possible to occlude the projection beam or cause shadows.

2. USER COPING STRATEGIES

In our study[5], we determined coping behaviors exhibited by users when using front projection (and to a lesser extent with warped front projection) displays. The behaviors demonstrated in the video are:

Dead Reckoning - 1 of 17 participants. This participant would stand in the center of the screen so that he was blocking a particular box. When a box didn't appear (because it was occluded by his body) he would reach to where the box would have been projected and moved it without the visual cue.

Edge of Screen - 7 of 17 participants. These participants would stand at the edge of the screen so that they would not occlude the boxes as they were projected. They would then have to lean inwards to move the box.

Near Center - 7 of 17 participants. These participants would stand near the center of the screen. Whenever a box did not appear (because they were occluding it with their body) they would "sway" by leaning at the waist until the box appeared.

The fourth observed coping strategy, *Move on Occlusion* was exhibited by 3 of the 17 participants[1]. When they occluded a box, they would move (left or right) to uncover it, and stay in their new position until they occluded another box.

Users did not exhibit these behaviors for virtual rear projection and rear projection displays.

3. UNDER DEVELOPMENT: ACTIVE TECHNOLOGIES

As we found that users prefer rear projection (RP) over passive virtual rear projection (VRP), we have continued to develop projection technologies that attempt to close the gap between true rear projection and passive virtual rear projection. Emerging technologies demonstrated in the video are:

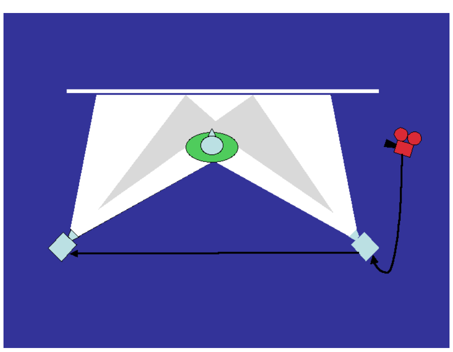

Figure 4: Using feedback from a camera, Active Virtual Rear Projection boosts light in shadowed regions.

[1]These three participants choose not to release their videos to outside observers, so an example is not included in the video.

Active Virtual Rear Projection (AVRP) - Similar to VRP, AVRP adds a camera or other sensor which determines when one of the projectors is occluded. The system then attempts to compensate for this occlusion by boosting output power from the other projector(s) to increase contrast in the "half-shadow" area(s)[2,4].

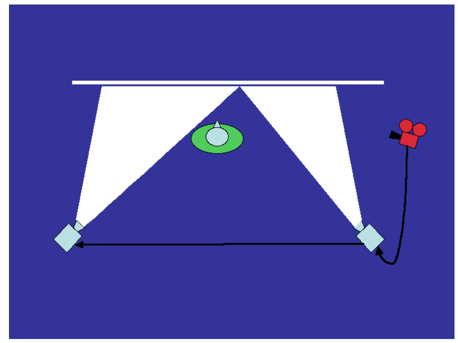

Figure 5: Switched Virtual Rear Projection with Blinding Light Suppression actively reacts by turning off pixels that are blocked by the occluder, which prevents the system from casting light onto the user.

Switched VRP with Blinding Light Suppression (SVRP-BLS) - Similar to AVRP, SVRP-BLS adds the ability to turn off projector output that is projecting on a user or object. This blinding light suppression allows users to comfortably face the projectors without blinding light or distracting graphics being projected into their eyes or onto their bodies.

These techniques are not yet indistinguishable from a rear projected surface, and exhibit some possibly distracting visual artifacts such as "halos" which follow occluded areas. We are continuing to develop improved techniques to simulate rear projection using redundant front projectors.

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VIRTUAL HANDYMAN: Supporting Micro Services on Tap through Situated Sensing & Web Services

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INTRODUCTION

Just imagine a homeowner trying to install a light fixture. It doesn't go smoothly, so he needs expert assistance. What would he do? First, he'd look for help, possibly in a thick phone book or perhaps through a keyword search on the Internet, or ask a neighbor. He'd assess the possibilities (e.g., home improvement and hardware stores, private contractors, handymen) and make a choice. Then he'd make a call, try to describe the problem, and decide what to do. Maybe he'd take notes and go back up the ladder to give it another try. Maybe a repairman would come to the house, lend a hand, and present a bill.

The above scenario represents a typical call for "micro services" – services that come in a finer granularity in terms of duration and cost. These services share three common characteristics. First, they involve a layperson and an expert. The task typically requires asymmetric collaboration between the two parties. While the first step in any service involves finding an appropriate service provider for the problem on hand, the difference is that the discovery cost for micro services is very high relative to the total cost for rendering the service. In the above scenario, for example, it may only take the electrician 10 minutes to show the homeowner show to install a light fixture, but it would take much longer to find a right electrician who is available and willing to provide such a service. And finally, micro services require a high degree of spontaneity. In the above example, if getting the service requires the homeowner to go out of their way, e.g., waiting for 3 hours or learning a new application, chances are that the person would not end up using the service.

To addresses these unique challenges of micro services, we propose the concept of "micro services on tap," which allows spontaneous service delivery by integrating several technologies, including miniature cameras, Web services, wireless networks, and speech interface.

THE PROTOTYPE

VIRTUAL HANDYMAN is a research prototype that supports micro services on tap for home improvement tasks. The prototype consists of three modules: *user*, *provider*, and *market*. These applications run on separate computers connected to a network. The user application includes a wireless microphone and a wireless miniature camera that is measured at .88" x .57" x .92" and with a range of up to 750 feet with line of sight. We also built a customized flashcam (see Figure 1) that combines illumination, wireless video, and pointing device into a convenient form factor that can be used when working in poorly lit areas like craw space or underneath a sink. The wireless camera and flashcam enables the provider at a remote location to see what the user is up to, and to give advice accordingly.

Figure 1. A 900MHz miniature wireless camera (left.) allows hand-free operations. The flashcam (right) has built-in flashlight, wireless camera, and laser pointer.

The wireless microphone (i.e., Sony WCS-999) allows the user to freely roam around the home and still be able to interact with the application via speech recognition and synthesis. Below is a sample dialogue between Krishna (K) and the application (A), when he asks for help for replacing an electrical outlet:

K: *I need some help in installing my electrical outlet.*

A: *Do you want an electrician?*

K: *Yes.*

A: *I've found two service providers: Excel Home Center and Randy's Electrical Shop.*

K: *Tell me more about Excel Home Center.*

A: *Excel Home Center offers virtual installation services for the products sold in its stores free of charge.*

K: *Connect me to Excel Home Center.*

A: *Please wait while I'm binding to Excel Home Center…*

When Krishna's request arrives at Excel Home Center, the provider is alerted through a pager-like device. He then walks over to a store kiosk or an in-vehicle PC. By simply entering the service ID, he immediately gets connected to the user. Figure 2 shows the view from the Excel Home Center. The screen displays the recent history with the customer and a live view of his task environment.

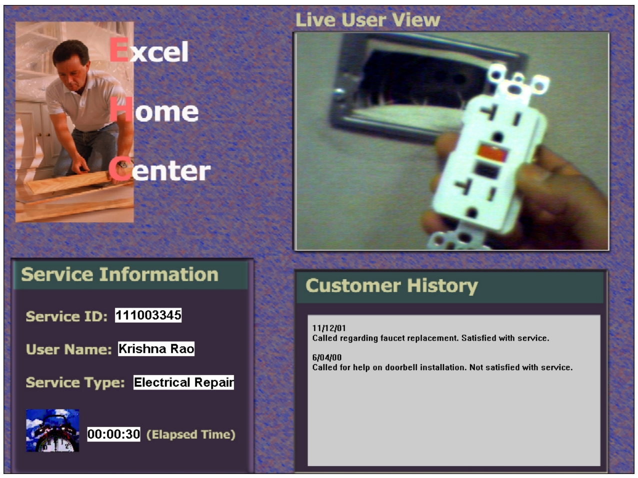

Figure 2. The service provider application shows a live view of the customer's task environment.

At the heart of VIRTUAL HANDYMAN is the market application, which includes a private UDDI [1] registry and a custom taxonomy for home improvement. For our prototype, the registry contains a dozen of businesses and services. The Web services interface is implemented using Microsoft UDDI Server SDK. In addition to UDDI functions, the module integrates speech engines (i.e., IBM Via Voice and AT&T Natural Voices) so the user can use voice to interact with the system, as illustrated in the dialogue above. The module also includes a simple task model about home improvement so that it can map the user task at hand to a specific type of service. For example, when the user mentions the word "electrical outlet" or "light fixture," it knows that he is performing an electrical job, and thus replies, "Do you want an electrician?"

To complement the mobile solution, we also built an online workbench (see Figure 3) with an embedded camera, microphone array (Andrea DA-400), LCD display, and Internet connection. When a user carries out a task on the workbench (e.g., repairing a small appliance or creating a blueprint) and needs help, he can call up a service, just like described earlier. This time, however, he doesn't need to wear a microphone or camera, since both are built into the workbench. As a fixed-location interface to the provider, the workbench can afford much richer experience. For example, if needed, the provider can direct the user to an instructional video or a Web page about a task, which is shown on the LCD display.

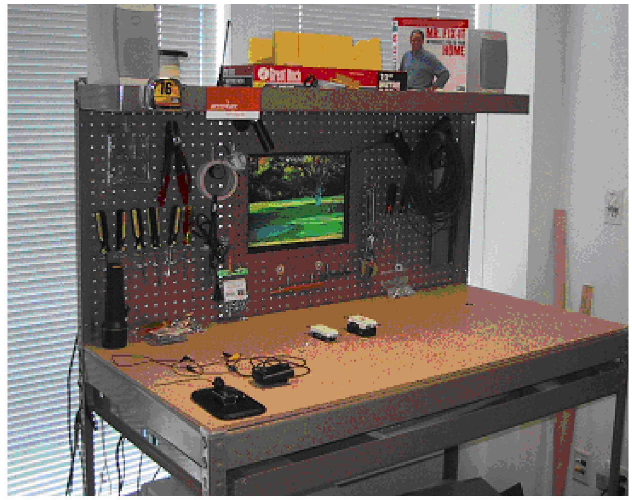

Figure 3. The online workbench (with built-in camera, microphone array, LCD display, and Internet connection) offers a fixed location interface to the service provider.

CONCLUSIONS

While VIRTUAL HANDYMAN focuses on home improvement tasks, the approach is can be generalized to other service areas, such as cooking, fashion, personal security, travel, shopping, and so on, where personal interactions between a novice and an expert is needed. Take personal fashion, for example. With a smart wardrobe like [2] in your bedroom, any time you need advice on what to wear, your wardrobe can, *in real-time,* find and connect you to a live fashion advisor, who may help you select the best outfit for your specific occasion. Since the fashion advisor can see what you're wearing through the built-in camera, and what you have in the wardrobe through the embedded RFID reader, you don't need to waste any time explaining or describing them. The service is fast, personal, and can be called upon any time.

In sum, micro services on tap, as illustrated by VIRTUAL HANDYMAN, are all about being able to easily and spontaneously discover and interact with people who could be helpful for a specific situation. With the proliferation of broadband wireless networks, Web services, and sensors like inexpensive miniature cameras, GPS receivers, and RFID tags, we expect that such services soon become widely available.

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Part VI

Workshops

Ubicomp Education: Current Status and Future Directions

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ABSTRACT

Ubiquitous computing is becoming an increasingly important research area. While experimental Ubicomp courses are taught on a more or less regular basis at several universities there is no common understanding of which ubicomp-related topics should be taught and how to teach them as part of Computer Science and Computer Engineering curricula. This workshop aims to review the current state of Ubicomp education and create a vision for its future. The primary expected outcomes are the definition of Ubicomp teaching modules and the establishment of a permanent collection of Ubicomp educational materials.

WORKSHOP DESCRIPTION

Motivation

Over the last years ubiquitous computing (ubicomp) has emerged as one of the fastest growing research areas in computer science. At its core is the idea of the "disappearing computer" – a vision of computational devices and digital services that blend into the environment where they become an integral part of people's everyday lives and experience.

Ubicomp is inherently an interdisciplinary research area. To be successful ubicomp must balance the creation of new technologies and human-centred, real world evaluation. This requires the integration of essential concepts and methods from a variety of disciplines including computer science, computer engineering, human-computer interaction, industrial design, architecture, psychology, and sociology.

The growing importance of ubicomp as a research area and its potential economic and social impact raises important questions of how to teach ubicomp-related topics as part of computer science and computer engineering curricula. Ubicomp education is currently in the beginning stages of a natural evolutionary process. Experimental ubicomp courses are taught on a more or less regular basis at several universities as part of computer science and engineering curricula. But as of yet there exists no common understanding on what and how to teach ubicomp-related topics. Although this is in part a reflection of the general state of ubicomp as a fast growing and still relatively new research discipline, we feel it is time to review the current state of ubicomp education and to create a vision for its future.

Goals

The goal of this workshop is to discuss where ubicomp education is today and where it should be headed. It is aimed at educators and students who are actively involved in teaching, learning and training ubicomp and who are interested in shaping the future of ubicomp education.

Particular questions to be addressed at this workshop include:

- What should we be teaching? Which, theories, principles, models and frameworks are considered essential for ubicomp?
- How should we be teaching ubicomp? Which educational approaches and learning pedagogies are appropriate for ubicomp education?
- How should ubicomp be positioned in relation to existing Computer Science, Electrical Engineering and HCI curricula? Is there a need for separate ubicomp courses or should ubicomp-related topics be subsumed in existing courses?
- What resources are required and available to enable educators and learners? Which books, course materials, web sites, videos, software libraries and hardware toolkits exist or should exist for teaching ubicomp?
- What is industry looking for? Which ubicomp related skills and knowledge do employers and companies

require now and in the future?

Expected Outcome

The workshop is intended as a forum for the exchange of educational experiences and is focused on the joint development of a common vision statement derived from the experience of each of the participants.

The expected results include:

- A survey of the current state: a (preliminary and possible incomplete) compilation of currently offered ubicomp-related courses and available educational resources
- The scope of ubicomp education: a compilation of important ubicomp topics (research questions, theories, methods, models and technologies). These topics could lay the foundation for the later generation of Ubicomp teaching modules.
- Future agenda: identification of concrete steps that should be taken to improve the quality of ubicomp education.

Dissemination

The results of the workshop will be summarized in a report to be published in an appropriate journal or newsletter. A web site will serve as permanent record of the event. Most importantly, we envision this web site to function as continuously updated public collection of educational materials (lecture notes, assignments, reference list, software toolkits, pointers to web sites etc.).

WORKSHOP FORMAT

Activities

To maximize information and idea exchange and foster collaboration, we plan to spend most of the time on discussions rather than presentations. The primary activities at the workshop will take place in small working groups made up of 3-4 people.

The broad outline of the workshop is:

- Early morning: participants present their background in ubicomp education and compare educational experiences
- Mid morning: discussion of the scope of ubicomp education; identification of important ubicomp topics
- Late morning: forming of break out groups
- Early afternoon: break out groups identify research questions, theories, methods, models and technologies related to individual topics
- Late afternoon: groups report back, drafting of a future agenda to improve the quality of ubicomp education.

Expected Audience

The workshop is directed towards educators, researchers and students from a variety of disciplines (computer science, computer engineering, human-computer interaction, psychology, and sociology, …).

Participation

Participants will be selected on the basis of their ubicomp teaching experience. In lieu of a traditional position paper, participants are asked to complete a Ubicomp education questionnaire.

Workshop Web Site

The workshop web site can be found at http://ubicomp.lancs.ac.uk/workshops/education03.

ORGANIZERS

Gregory D. Abowd is an Associate Professor in the College of Computing and GVU Center at the Georgia Institute of Technology. His research interests include software engineering for interactive systems, with particular focus on mobile and ubiquitous computing applications. He leads a research group in the College of Computing focussed on the development of prototype future computing environments which emphasize mobile and ubiquitous computing technology for everyday uses. He currently serves as Director for the Aware Home Research Initiative. He was General Chair for Ubicomp 2001, held in Atlanta, and is an Associate Editor for IEEE Pervasive Computing magazine. Dr. Abowd has published over 90 scientific articles and is co-author of one of the leading textbooks on Human-Computer Interaction.

Gaetano Borriello is a faculty member in the University of Washington's Department of Computer Science and Engineering. He is currently near the end of a two-year leave to serve as Director of Intel Research Seattle where the focus of research is on new devices, systems, and usage models for ubiquitous computing. His research interests span the categories of embedded system design, development environments, user interfaces, and networking infrastructure. They are unified by a single goal: to create new computing and communication devices that make life simpler for users by being invisible, highly efficient, and able to exploit their networking capabilities. Prior to receiving his Ph.D. in Computer Science at UC Berkeley, Dr. Borriello spent four years as a member of the research staff at Xerox PARC. In 1995, he received the UW Distinguished Teaching Award. He currently serves on the Editorial Board of the IEEE Pervasive Computing Magazine. He is a member of the IEEE Computer Society and the ACM.

Gerd Kortuem is a Lecturer in the Computing Department at Lancaster University, UK. His research interests include engineering and usability aspects of interactive and collaborative technologies with particular focus on mobile, wearable and ubiquitous computing applications. Dr. Kortuem received his Ph.D. in Computer Science at University of Oregon for his work on Wearable Communities. In the past, he worked as researcher at Apple Computer's Advanced Technology Group in California, the Technical University of Berlin, and the IBM Science Centre in Germany. He is a member of the IEEE Computer Society and the ACM.

2003 Workshop on Location-Aware Computing

Mike Hazas
Lancaster University

James Scott
Intel Research Cambridge

John Krumm
Microsoft Research, Redmond

http://www.ubicomp.org/ubicomp2003/workshops/locationaware/

ABSTRACT

The field of location-aware computing has made great advances recently, with numerous location systems, software platforms, and location-aware applications having been presented by researchers. However, in most environments, including many research labs, location-aware computing has yet to achieve the proliferation and ubiquity envisioned for it.

This workshop will examine the state of the art in location-aware computing, with the objectives of drawing conclusions from existing work, and identifying critical areas for future research. The main themes of the workshop will include location sensing technologies, location representations and sensor fusion, compelling location-aware applications, and factors affecting the deployment of location-aware systems in everyday environments.

THE STATE OF THE ART

Determining the location of people and objects has been the focus of much research in ubiquitous computing. Many location sensing technologies have been devised, resulting in systems which perform sensing using diverse physical media, such as infrared light [22, 23], ultrasound [20, 1], electromagnetic signals [8, 4, 15, 6], ground reaction force [2, 19], physical/electrical contact [10], and visible light [14, 17]. Naturally, these systems have an equally diverse set of properties; each implementation has its own level of accuracy, update rate, infrastructure cost, deployment difficulty, robustness, and capacity for privacy guarantees [9].

Location-aware applications are numerous. Examples include portable memory aids [16], conference assistants [21], environmental resource discovery and control [13], support systems for the elderly [12], tour guides [5], augmented reality [3], mobile desktop control, 3D mice, and virtual buttons [1]. Each demands different levels of service from the supporting systems, for example in terms of location accuracy and update rate.

There has also been a recent focus on location-aware "platforms," which link data-gathering systems and the data-consuming applications in a flexible manner. Such work includes location representation [11], sensor fusion to combine location data from many sources [7], and software frameworks supporting the distributed nature of location-aware computing [18]. Such abstractions are essential for the interoperability, usability and development of location-aware systems and applications.

Unfortunately, many of the promising location systems, platforms, and applications presented have not gone into widespread use in ubiquitous computing research labs, much less everyday environments. Thus, it is important for the diverse groups of researchers interested in location-aware computing to collectively examine the state of the art, with the following goals:

1. Survey the various location-sensing technologies systems presented thus far; if possible, identify trends in existing research leading to generalizations about location techniques.
2. Identify compelling location-aware computing scenarios and applications (especially potential "killer apps"), and assess the nature of their needs (such as accuracy and update rate) for location information and platform support.
3. Examine current location-aware abstractions, platforms and frameworks, and evaluate their suitability for existing and proposed location-aware computing scenarios.
4. Taking all the above into account, consider the factors necessary to facilitate deployment and everyday use of location-aware computing systems in workplaces, homes, and public spaces.

Accomplishing these objectives will help identify the most promising directions for future research in location-aware computing.

WORKSHOP DESCRIPTION

The workshop aims to engage all participants in the exchange of ideas. The morning sessions will consist of short talks from six invited speakers. The speakers in related talks will then act as a panel, with a large allowance for panel-based discussion and debate.

The afternoon sessions will be organized around the use of breakout groups to discuss key issues in location-aware computing. While the exact breakout topics will be decided during the workshop, potential topics include: comparisons and classifications of location-sensing infrastructure and location-aware platforms; "killer apps" and their requirements of location infrastructure; deployment techniques for location infrastructure; and social implications, such as usability, user acceptance, and privacy concerns.

The groups will report back to the workshop in a plenary session, with a short presentation followed by panel-based discussion with the breakout group members forming the panel.

Results of the workshop will be presented as one or more posters at UbiComp 2003.

SPEAKERS

Jay Cadman has over ten years of experience selling and marketing high-tech products around the world. He was one of the founders of the North American operations of Smallworld (a leading Geographical Information Systems company), helping it grow to over two hundred employees, and eventually running global marketing. He then spent two years running commercial and risk management for GE Network Solutions and was appointed marketing lead for Automation and Network Services, and approximately $300 million GE business. Jay now manages North American sales operations for Ubisense, a company that provides location-aware solutions.

Dieter Fox is currently an Assistant Professor at the University of Washington, where he heads the Sensing, Tracking, and Robotics lab which he established in January 2000. Fox obtained his PhD from the University of Bonn, Germany, in the area of state estimation in mobile robotics. Before joining UW, he spent two years as a postdoctoral researcher at the CMU robot learning lab. Over the last six years his research has focused on probabilistic sensor interpretation, state estimation, and their application to mobile robotics. He introduced particle filters as a powerful tool for state estimation in robotics. His current research projects include multi-robot coordination and human activity recognition. Fox received an NSF CAREER award and several best paper awards at major robotics and AI conferences.

Jeffrey Hightower is a doctoral candidate at the University of Washington. His research interests are in employing devices, services, sensors, and interfaces so computing can calmly fade into the background of daily life. Specifically, he investigates abstractions and statistical sensor fusion techniques for location sensing. He received an MS in Computer Science and Engineering from the University of Washington and is a member of the ACM and the IEEE.

Bodhi Priyantha is a fifth year PhD student attached to the Networks and Mobile Systems group at the Computer Science and Artificial Intelligence Laboratory at MIT. He received his BSc degree in Electronics and Telecommunications from University of Moratuwa, Sri Lanka in 1996. He was a teaching instructor at the University of Moratuwa from 1996 to 1998, and received his MSc in Computer Science from MIT in 2001. His primary research area is location awareness in mobile computing and sensor networks. Currently he is working on self-calibration and configuration of location-enhanced sensor nodes.

Bill Schilit is co-director of Intel Research Seattle and is part of a small team chartered with defining and driving Intel's ubiquitous computing agenda. Dr. Schilit's research focuses on ubiquitous and proactive computing applications, with an emphasis on context-aware computing. His research is positioned at the intersection of networking and human-computer interaction. Prior to joining Intel, he managed the Personal and Mobile Computing Group at FX Palo Alto Laboratory, a Fuji Xerox Company. Dr. Schilit also worked at AT&T Bell Labs and Xerox Palo Alto Research Center. At PARC, he championed the notion of location-aware computing and helped invent, design, and build the software and applications for the PARCTAB. He is Associate Editor in Chief of IEEE Computer, an area editor of IEEE Wireless Communications, and is a member of the IEEE Computer Society and the ACM.

Steven A. N. Shafer is a Senior Researcher at Microsoft Corporation working in the area of ubiquitous computing. He received his BA from the University of Florida in 1976, and his PhD from Carnegie Mellon in 1983. He became part of the faculty at Carnegie Mellon for twelve years, working in computer vision and robot navigation. Dr. Shafer joined Microsoft in 1995, where he started the EasyLiving project to develop an architecture for building intelligent environments. His current work is in location awareness and RFID technology.

PARTICIPANT LIST

Twenty-eight participants were accepted to the workshop on the basis of submitted participation statements. The participants, listed below, provide representation from four continents and from both academic and industrial backgrounds.

Jürgen Bohn	ETH Zürich
Jay Cadman	Ubisense Inc.
Derek Corbett	U. of Sydney
Esko Dijk	Eindhoven U. of Technology
Boris Dragovic	U. of Cambridge
Heinz-Josef Eikerling	Siemens
Dieter Fox	U. of Washington
Richard Glassey	U. of Strathclyde
Mike Hazas	Lancaster U.
Jeffrey Hightower	U. of Washington
Albert Krohn	TecO, U. of Karlsruhe
John Krumm	Microsoft Research
Anthony LaMarca	Intel Research
Gaute Lambertsen	Japan Science & Tech. Corp.
John Light	Intel Research
Christopher Lueg	U. of Technology Sydney
Robert Lutz	Sun Microsystems
Nibuhiko Nishio	Japan Science & Tech. Corp.
Bodhi Priyantha	MIT
Steffen Reymann	Philips Research Labs
Kam Sanmugalingam	U. of Cambridge
Bill Schilit	Intel Research
James Scott	Intel Research
Steve Shafer	Microsoft Research
David Ayman Shamma	Northwestern U.
Richard Sharp	Intel Research

ORGANIZERS

Mike Hazas is a research associate at Lancaster University. His primary area of research is sensors and hardware architecture for location systems; he is currently working on infrastructure-free relative positioning technologies. Mike's PhD study focused on indoor location systems, with particular attention paid to investigating the advantages of broadband ultrasound for indoor positioning.

James Scott is a researcher with Intel Research Cambridge, where he is working on location-aware computing research, most recently investigating deployment issues in location-aware systems. His PhD was on Networked Surfaces, a novel type of network using physical surfaces such as desks as the connecting medium, which also provides accurate location and orientation information.

John Krumm is a PhD researcher at Microsoft Research. His experience in location-aware computing includes person-tracking with video cameras, the SmartMoveX RF active badge, and the Locadio system for computing the location of Wi-Fi clients. In addition to work with these location sensors, he has developed various means of enhancing accuracy by respecting prior assumptions about peoples' walking speeds and feasible paths.

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UbiHealth 2003: The 2nd International Workshop on Ubiquitous Computing for Pervasive Healthcare Applications

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SUMMARY

The term 'pervasive healthcare' describes the use of pervasive computing technologies in delivering healthcare services, including making healthcare services more 'pervasively' available across boundaries in time, organization, and place.

Building on the UbiCog 2002 workshop held at the UbiComp 2002 conference, the aim of this workshop is to continue the development of a community of researchers working with pervasive and ubiquitous computing technology and healthcare, and to identify and discuss research themes and methods in order to guide future research.

The workshop will focus on exploring this potential by discussing the constraints and possibilities of existing and emerging technologies for supporting healthcare and patient self-management, and focusing on identifying current and future research directions. These goals will be accomplished through presentation of the participants' visions and research, brainstorming sessions, and small-group breakout sessions.

INTRODUCTION

Pervasive healthcare can be defined from two perspectives. First, it is the application of pervasive computing (or ubiquitous/proactive computing, ambient intelligence) technologies for healthcare, health and wellness management. Second, it is making health care available everywhere, anytime – pervasively.

Weiser stated "the most profound technologies are those that disappear" [1]. Pervasive computing may be considered as the opposite to virtual reality: while in virtual reality the user enters the world created by computers, in pervasive computing it is the computing which enters the physical world and bridges the gap between the virtual and physical worlds. One of the most important application areas for this technology is healthcare, wellness and disease management and support for independent living [2,3,4].

Developments in sensor and measurement technology make it possible to obtain health related information from wearable or embedded sensors in our daily lives. Ubiquitous communication based on mobile telephone networks, (wireless) local area networks, and/or some other wireless technologies makes possible anywhere, anytime transfer and access of all kinds of information – like measurement data, person-to-person communications or health information. Mobile communication devices provide ubiquitous user interfaces for the users (from health care professionals to citizens). The possibilities this technology offers for health care delivery are vast and are only gradually becoming realized, for example [5,6].

Besides this kind of monitoring and transfer of biological data, pervasive healthcare also contains a notion of using pervasive computing – or ambient technology – for social computing. For example, creating technologies for relatives and peers of chronically ill persons to stay in touch with a patient. Pervasive healthcare also contains a notion of helping the patient to better manage his or her own disease, as well as technologies for communication and collaboration among healthcare professionals.

Another central theme related to ubicomp and healthcare is the intersection of ubiquitous computing, cognitive aids, and/or artificial intelligence, as applied to helping people with cognitive disabilities perform daily activities. A primary motivation for developing intelligent "caregiving" systems is the increase in the number of people who have some type of cognitive disability, such as young adults who have learning disabilities, or elderly people who demonstrate (a form of) dementia, such as Alzheimer's disease (AD). Recently researchers and industrial partners in ubicomp and artificial intelligence have come together to envision systems that can act as proactive partners in assisting these special populations, such as [7,8,9,4]. Furthermore, this community has started to facilitate the exchange of ideas and sharing of information through the organization of seminars and workshop, such as the Cognitive Aids Workshop held last year at UbiComp 2002.

The use of pervasive computing for delivery of health care raises numerous challenges. When dealing with personal, sensitive health related aspects of a person's life, this puts forth strong demands for systems that are reliable, scalable, secure, privacy-enhancing, usable, configurable, and many other things. At the same time, one has to consider that the average user of such systems is not the typical early adopter of new technology. This puts special focus on creating technologies that are usable, and can adapt to, and seamlessly melt into, heterogeneous computing environments, like the home of the future.

Pervasive healthcare also contains a fundamental *methodological* challenge. Typical research into pervasive computing uses methods of experimental computer science, where researchers design, develop, program, and evaluate prototypes of new technology. The 'proof-of-concept' is a term often used to denote a prototype, which illustrates and implements the important aspect of a computer system that one wants to demonstrate. Such an 'experimental' approach becomes highly problematic when dealing with health related research – what if the experiment falls out wrong? Modern *evidence based medicine*, in contrast, is based on statistical significance – one has to demonstrate with significance, that a treatment or cure actually works, and with limited side effects. Such clinical trials often involve great number of subjects (i.e. persons) involving various test groups, including a control group. To set up such a clinical trial running over several months or years clearly takes much more that a 'proof-of-concept' prototype. One has to have the resources to design, develop, implement, and maintain a full-fledged computer system, used by thousands of users. Hence, there is a fundamental methodological contradiction embedded in pervasive healthcare, and we would like to discuss this at the workshop as one theme.

The purpose of this workshop is to collect original and innovative contributions in the area of pervasive healthcare and its applications, and to identify and discuss research themes and methods in this area.

TOPICS

The overall topic of this workshop is: *The development and application of ubicomp infrastructures and devices for pervasive healthcare including assisting people with cognitive, mobility, and sensory impairments.*

This includes sub-topics such as (but not limited to):

- How to infer a person's behaviors, intentions, needs, and mistakes from sensory data.
- Deciding on appropriate intervention strategies.
- Wearable computing for health.
- Wireless, wearable and implantable sensors.
- Personal medical devices.
- Applications for personal management of acute and chronic diseases, wellness, and health, including self-treatment (e.g. medication), self-care, self-diagnosis and self-rehabilitation.
- Smart home technology to support independent living and to support peer-to-peer support in health management.
- Pervasive computing in hospitals and care institutions.
- Pervasive applications for caregivers and nurses.
- New services that health care providers, such as pharmacies and physicians, can potentially provide by taking advantage of these emerging technologies.
- Personal, social, cultural and ethical implications of developing and using such technology.
- Methodological issues to evidence based medicine (EBM) and pervasive healthcare – how to create innovative new healthcare technology, which can be clinically tested?

The goal of this workshop is to bring together individuals who are actively pursuing research directions related to pervasive healthcare. This workshop will allow individuals with complementary research experiences to build a collective understanding of the issues surrounding the use of pervasive technologies in healthcare settings. This workshop is timely given the existence of diverse research in the area, and will help to bring together the work of emerging research groups, all working in the area of pervasive healthcare.

WORKSHOP ACTIVITIES AND GOALS

This workshop will be run over a full day and will be structured to provide maximum time for group discussion and brainstorming. Prior to the workshop, each participant will be required to read the other participants' position statements to ensure that he/she is familiar with their research in the area and their visions for pervasive healthcare. All of this will be available from the workshop homepage.

Participants will briefly present their research and vision for future directions in this area. Presentations will be organized according to various themes within pervasive healthcare. These themes will be decided upon after the review of all submissions. Discussion periods will follow after the presentation of each theme. Upon completion of the presentations, participants will be divided into working groups based on the themes identified on beforehand, moderated by the workshop organizers. In a plenary session following the groups' work, each will present their ideas and discuss them with all the workshop participants. In a brief concluding plenary session, all the participants will have the opportunity to provide feedback on the workshop and decide for any continuation at another venue.

The goals of this workshop are the following:

1. To build a network and community of researchers and practitioners working within pervasive healthcare;
2. To identify common research themes in pervasive healthcare;
3. To discuss methodological challenges to pervasive healthcare, especially how to conduct evidence based medicine;
4. To foster collaborative efforts among participants, who might work together in research projects;
5. To create an awareness about research within pervasive computing and healthcare.

PARTICIPATION

We welcome participants from industry, academia, and government. We encourage people who are designing and implementing pervasive computing technologies in medical settings, like in hospitals, in patient's home, in elderly residents, and in the offices of general practitioners. We encourage a broad range of researchers and practitioners to participate due to the multi-disciplinary nature of using pervasive computing in healthcare. We encourage teams of medical and technological researchers to submit work, as well as individuals representing governmental bodies who are enacting related policies, such as those dealing with privacy and ethics of such technologies.

We will explicitly encourage the participation of a number of central research groups working in the area of pervasive healthcare and future health. This includes research groups in Scandinavia, central Europe, and the USA and Canada.

After review of all submissions, 10 to 15 participants will be invited based on the quality and relevance of the position paper. Each position paper should be two to five pages in length and consist of the author's vision of the use of pervasive computing in healthcare, current work, expectations towards the workshop, and the author's research activities including a short bio of the author(s).

Position papers should be formatted according to the standard Springer Verlag format and submitted in PDF format, according to the template submission file, which can be found at http://www.springer.de/comp/lncs/authors.html. Papers should be submitted by email to Ilkka Korhonen (ilkka.korhonen@vtt.fi).

There will be a workshop website accessible from http://www.pervasivehealthcare.dk/ubicomp2003 where both accepted submissions, workshop details (e.g. the program), and the results of the workshop will be posted.

Paper deadline: August 8

Notification of acceptance: August 22

Acceptance of submissions will be decided upon the review of the program committee.

PROGRAM COMMITTEE

The workshop's program committee includes leading academic researchers as well as representatives from industry. The committee has international members from outside North America reflecting the fact that UbiComp is an international conference. To date, the following committee members have been confirmed:

Henry Kautz (Past Chair, U of Washington, US)

Eric Dishman (Past Chair, Intel Labs, US)

Irfan Essa (Georgia Tech., US)

Ken Fishkin (Intel Labs, US)

Peter Gregor (U of Dundee, Scotland)

Edmund LoPresti (AT Sciences, US)

Misha Pavel (Oregon Health & Science University, US)

Martha Pollack (U of Michigan, US)

Rich Simpson (U of Pittsburgh, US)

Ad van Berlo (Smart Home Foundation, The Netherlands)

Liam Bannon (University of Limerick, Ireland)

Morten Kyng (University of Aarhus, Denmark)

Nicos Maglaveras (Aristotle University, Greece)

Niilo Saranummi (VTT Information Technology, Finland)

PUBLICATION

The IEEE Transactions on Information Technology in Biomedicine (IEEE T-ITB) has a call for a special issue on pervasive healthcare (See http://www.vtt.fi/tte/samba/projects/titb). This issue will be edited by the workshop organizers, and participants in this workshop are encouraged to submit their research to this special issue. The deadline for the journal papers is November 30, 2003, which is a nice timing to the UbiComp 2003 conference.

ABOUT THE ORGANIZERS

Dr. Jakob E. Bardram's main research areas are pervasive and ubiquitous computing, distributed component-based system, computer supported cooperative work (CSCW), human-computer interaction (HCI), and medical informatics. His main focus currently is 'Pervasive Healthcare' and is conducting research into technologies of future health – both at hospitals and in the patient's home. Currently, he is managing a large project investigating technologies for "The Future Hospital", which includes (among other things) embedding 'intelligence' in everyday artifacts within a hospital, such as in the walls of the radiology conference room, in the patient's bed, in the pill containers, and even into the pills. He received his Ph.D. in computer science in 1998 from the University of Aarhus, Denmark. He currently directs the Centre for Pervasive Healthcare at Aarhus University [www.pervasivehealthcare.dk].

Prof. Ilkka Korhonen's main research interests are application of pervasive computing on healthcare and wellness, biosignal interpretation, home monitoring and critical care patient monitoring. He received his PhD ('97) in signal processing from Tampere University of Technology, Finland. He is a docent in Medical Informatics at Tampere University of Technology, and a Research Professor in Intuitive Information Technology at VTT Information Technology, Tampere, Finland. He has >70 scientific publications in international scientific journals and conferences.

Dr. Mihailidis has been conducting research in the area of cognitive devices for older adults with dementia for the past eight years. While at Sunnybrook & Women's College Health Sciences Centre in Toronto, Canada, he was one of the first researchers in this field to develop and clinically test a prototype of an intelligent cognitive device that assisted older adults with Alzheimer's disease during a washroom task. He has presented this area of work at many international conferences and has published in key journals related to rehabilitation engineering, assistive devices, and dementia care.

Dr. Wan has been investigating how emerging technologies, such as ubiquitous computing, can be used to help create new consumer experiences and business opportunities for the past seven years. Five years ago, he developed the Magic Medicine Cabinet a popular prototype that integrates biometrics, RFID, and health monitoring devices to provide consumers with compliance support, vital monitoring, and personalized health information. Currently, he is focusing on remote health monitoring using sensors, wireless networks, and Web Services. Dr. Wan has presented his research in various academic conferences. His work is also o widely covered by the media, including Wall Street Journal, Financial Times, BBC, CNN, ABC News, and TechTV.

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2nd Workshop on Security in Ubiquitous Computing

Submitted as a proposal to the organizers of UBICOMP 2003, Seattle Washington

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May 16, 2003

ABSTRACT
A first instance of this workshop was held at UBICOMP 2002 in Göteborg Sweden (see http://www.teco.edu/~philip/ubicomp2002ws/). Only 19 persons were in attendance in 2002, due to space limitations at the Göteborg location; all participants considered it as a successful event, and many expressed the wish to continue at the next conference. This year we intend to repeat it, and seek to dig deeper into the outstanding issues we established during last year's forum.

Keywords
Security

Summary
The last security in ubiquitous computing workshop concluded with a summary of a critical assessment of the state of the art in security, and the requirements of Ubiquitous Computing applications and environments [1]. Most of the contributions were theoretical and were derived based on an analysis of changes in human-to-computer and computer-to-computer interaction and networking. The major challenges identified were:

1) New models for verifying trust, user-controlled privacy and content protection.
2) We cannot assume priori trust in UbiComp environments, as evidenced by developments in ad hoc networking.
3) Basic credential-based authentication and verification is not sufficient for both security and ubiquitous computing goals to be fulfilled.
4) Adaptive, user-based and integrated infrastructures for privacy management are required
5) Context authentication, application of implicit interaction to security mechanisms, and provision of more finely grained factors for trust models need to be developed.

The question for this year's workshop stands as, "is research moving towards meeting these challenges?" We will seek good quality papers that show evidence of these developments, as well as those that refute these claims and make other propositions for research. Submissions to the workshop and the subjects of ensuing discussion will include:

1) Platforms, Architectures and Models
2) Applications and Experience
3) Novel Technologies and Techniques
4) Advances in Networking

The organizers of the workshop are all currently active in security research within this area. However, there are also many interested persons worldwide, as evidenced by the Conference on Security in Pervasive Computing, held in Boppard Germany this year [http://www.dfki.de/SPC2003/]. In this document we propose five topics to be included in the workshop, and suggest how we will organize the correlation and documentation of useful results.

Topic 1: Emergence of New Models for Trust, Privacy and Content Protection
In Ubiquitous Computing, computers are no longer restricted to being physically locked away in large processing centers, being contained within a logically defined administrative boundary, or even being stashed in our pockets or briefcases. Computers are everywhere! They are in the packaging of the groceries we buy, public transportation, our homes, our clothing and perhaps even in the walls we lean on. Therefore, there are so many new interfaces to systems and possible information access mechanisms that are in the hands of the attacker. Perhaps the original story of the "Trojan horse" becomes even more relevant. There's no firewall, there's no constant surveillance and intrusion detection, and there's no full-time administrative staff. Do we rely on high assurance computing? Should mechanisms for degradation or destruction of information be provided? What about trust? Trust decisions have to be made dynamically, be based on continuums rather than discrete models, and go beyond one-dimensional identities – we need mechanisms for

entity recognition. Can the private remain private even without priori trust?

Topic 2: The Absence of Priori Trust

Through the use of X509 certificates and the presence of an online CA (certification authority), PKI (Public Key Infrastructure) has become an adopted model for trust in the Internet. Other models include Kerberos, which is characterized by a centralized KDC (Key distribution center), as well as PGP (Pretty Good Privacy), which creates a web-of-trust that does not require one single signing authority, to whom decisions of trust can be delegated. In any event, all of these models are built on the assumption that some prior registration has been made, and hence a registrar (CA, KDC, web-of-trust) can be referenced when faced with making the ultimate decision - to trust or not. In some ubiquitous computing applications these infrastructures may or may not exist; often the user has to explicitly authorize transactions. Can we still make decisions of trust without making the assumption that such authorities exist? Do all principals and subjects still require a strict identity-based authentication? Are the advantages of separating the identity (secret key) from the permissions, as suggested by SPKI [2], well positioned for ubiquitous computing? Once trust is established, how does it evolve over time, and how can collaboration amongst devices contribute to higher assurance levels?

Topic 3: Beyond Traditional Credential-based Authentication

It has often been said that authentication is the fundamental basis for security and trust. Applications require authentication to determine authorizations, establish constrained channels, infer data integrity, enforce non-repudiation, and complete some form of billing and auditing. Authentication is essentially the proof of identity through a secret, unique characteristics, permissions, or possession. Traditional credential-based authentication includes passwords, biometrics, and signatures.

Topic 4: Adaptive Infrastructures

The origins of Ubiquitous Computing were really concerned with the user. Writers like Weiser [3] and Norman [4] urged that the comprehensive use of computer systems and machines were at times beyond the grasp of the everyday-man. Complicated user interfaces and rules become more of an obtrusion than an aid for completing mental and physical tasks. HCI (Human Computer Interaction) and distributed systems offer research into adaptive interfaces and middleware respectively, to support the goals of seamless integration of technology into everyday life and enterprise systems. How do we fit security into these mechanisms without undoing the flexibility and usability aspects? How do we exploit context information in supporting security infrastructures that are adaptive and complementary?

Topic 5: The use of Context Information

Context is any set of information that can be used to characterize the situation of an entity. It ranges from persisted logs and records of an entity, to the observation and sensing of the physical environment. Context information is a foundation for making security-relevant decisions. A certain context might convey an uneasy feeling about the security of an interaction, while in another situation unknown devices are trusted to carry out a critical transaction. How are such environments characterized, and how do entities adapt when the situation changes?

Organizational Information

Papers will be selected based on their contribution to the understanding of security in ubiquitous computing,originality, and novelty.

Based on the success of last year's program, we will aim to keep a similar format, but are open to change based on the quality and quantity of accepted submissions.

Results of Workshop will be published and exploited initially through the UBICOMP conference, mailing list and on a prepared website. We will consider publication of a special issue, following the evaluation of the workshop.

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Multi-Device Interfaces for Ubiquitous Peripheral Interaction

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SUMMARY

Cell-phones and PDAs are ubiquitous, yet there are limits to the usage they afford. Notably, they aren't always accessible – they're usually carried in a pocket, purse, backpack, etc. This means that people must consciously decide to use a device; furthermore, when a device is used, it becomes the focus of the user's attention.

A new generation of emerging devices does not share these limits. For example, a computationally augmented wristwatch is always visible. It could be used to scroll messages and reminders, and to sound tones or light LEDs for items of special interest.

Such special purpose devices can be combined with PDAs to form *multi-device interface*s, delivering a user experience that offers both the peripheral awareness enabled by (say) a wristwatch, and the more powerful computational, networking, and interactive capabilities of a PDA. This workshop aims to explore candidate devices, interface designs, and information architectures for multi-device interfaces.

BACKGROUND OF ORGANIZERS

Loren Terveen is an Associate Professor of Computer Science & Engineering at the University of Minnesota. He received his PhD in Computer Sciences from the University of Texas at Austin, then spent 11 years at AT&T Labs / Bell Labs. Within the field of Human-Computer Interaction, his specific research interests include recommender systems, online community, web search and information management, location-aware systems, and peripheral awareness interfaces. He has extensive experience in conference and workshop organization, including serving as general co-chair of CHI 2002 and IUI 1998 and organizing multiple workshops at CHI and other conferences.

Charles L. Isbell, Jr. received his PhD from the MIT Artificial Intelligence Laboratory in 1998. He then spent 4 years at AT&T Labs/Research, before joining the faculty of the College of Computing at Georgia Tech in 2002. Charles' research interests are varied, but the unifying theme of his work in recent years has been using statistical machine learning techniques to build autonomous agents that engage in life-long learning of individual preferences. These agents build models of the usage patterns of individuals, rather than discovering trends in large datasets. His work with agents who interact in social communities has been featured in The New York Times, the Washington Post and Time magazine's inaugural edition of Time Digital magazine, as well as in several technical collections.

Brian Amento received his PhD in Computer Science from Virginia Polytechnic and State University. He spent 6 years in the Human Computer Interfaces group at AT&T Labs Research and is currently a member of the Speech Interfaces department. His research focus has been in interfaces that support cooperation between humans and machines by allowing users to interact with agents that mine their environment and associated data sources for relevant content and meta-data. This work has been in areas such as collaborative filtering, information retrieval, speech interfaces and multi-modal systems.

WORKSHOP DETAILS

Maximum number of participants: 15

Means of soliciting participation: messages to relevant online lists and forums (e.g., chi-announcements@acm.org, www.chiplace.org) and personal email to researchers active in the field

Means of selecting participants: Would-be participants will submit a 2-4 page position statement identifying a specific research question or questions in the area of multi-device interfaces and their approach to the questions. Participants will be selected based on the clarity and interest of the research questions and the novelty and interest of their proposed or already implemented solutions.

DETAILED DESCRIPTION: ACTIVITIES AND GOALS

A vision – towards ubiquitous peripheral interaction.

Internet enabled cell-phones and PDAs with wireless networking capabilities enable continuous access to information for mobile users. A PDA can access information from a server, thus (potentially) keeping users current. However, users cannot be expected to hold their cell-phones or PDAs in their hands, constantly checking them for new information or messages. In other words, these devices support a "pull model" of information access, in which users have to make an explicit decision to seek information.

In contrast, wearable devices like wrist computers enable peripheral awareness of information, a "push model". With a wrist computer, for example, information such as messages, reminders, and news stories could be constantly streamed to the device and displayed as a scrolling "ticker". The information is at the periphery of users' attention, and there is no guarantee that any particular item will be noticed. However, from time to time a user may glance at his watch and notice an item of interest. When this occurs, he can follow up on that item simply by pressing a button on the wrist display. This will initiate a program to view that item in detail on the user's PDA. The user then can take out his PDA and interact with the information as desired.

This workshop will explore the theme of multi-device interfaces for ubiquitous peripheral interaction in depth. It has a number of specific goals, including identifying requirements for ubiquitous peripheral awareness devices and considering specific devices that can meet these requirements, exploring software techniques and architectures that drive the interaction, and examining designs for interfaces that divide their functionality across several wearable devices. We consider each of these goals in some detail.

Devices for ubiquitous peripheral awareness: requirements and candidates.

A wearable peripheral awareness device must be always on, always accessible (that is, a user must always be able to receive information from it), and must not demand explicit user attention (that is, it is accessible without a user explicitly "taking it out to use", as one must with a PDA or cell-phone). It would be very helpful if some version of the device already enjoys widespread use (as do wristwatches, for example). And, since in our vision, this device is intended to work together with a PDA, it must be networked. We believe that wireless devices are much more acceptable to users, which means that the networking should be wireless.

There are various promising devices that meet some or all of these requirements. One is a computationally augmented wristwatch. There has been a lot of activity in this area recently, both in commercial and research contexts. Companies such as Suunto make sophisticated wrist computers tailored for sports like golf and skiing. Fossil and onHand make wrist PDAs that runs Palm OS. Swedish researchers prototyped a simple 'Reminder Bracelet' (CHI 2001) – LEDs were added to a wrist band, and they were lighted to show several types of information of varying levels of importance. Most notably, IBM and Citizen are prototyping a general purpose wrist computer that runs Linux.

Another interesting possibility is the use of audio for peripheral awareness. For example, Sahwney and Schmandt's Nomadic Radio used small, neck-mounted, directional speakers to deliver audio. Headsets that are relatively unobtrusive and still allow users to engage in normal interaction are another possibility;. Grinter & Woodruff (CHI 2002) did a pilot user study that showed some preference for single ear headsets; ear buds also are worthy of more exploration.

Other wearable devices also are worth investigating, e.g., computational jewelry or eyeglass displays.

When it comes to the networking requirements for a multi-device interface, Bluetooth seems well-suited. It works over short distances, but the peripheral awareness device and the PDA will be well within the working range. While Bluetooth is appropriate for networking the components of the multi-device interface, the PDA will need to connect a server (more on this below). This will require a long-distance wireless networking technology such as WIFI or GSM/GPRS.

Another important issue we will explore is how much can be done with off-the-shelf devices. The IBM/Citizen 'Watchpad' is not yet available; if it were, it would fulfill most or all the requirements mentioned above. However, it currently still may be necessary to do some simple hardware prototyping along the lines of the Reminder Bracelet.

In general, the workshop will address this goal by trying to reach agreement on appropriate requirements, developing a comprehensive list of candidate devices, and evaluating the extent to which each candidate satisfies the requirements.

Enabling software techniques and architectures.

For any information delivery system, ensuring that information is *relevant* to an individual user is a key goal. This is even more important in our context. Networking may be relatively slow, unreliable, and expensive. Most of the time, users' attention will not be focused on their peripheral awareness device, so the system should be careful not to distract users from their current tasks.

These considerations pose challenges for the information management software that runs on the server. This software is responsible for monitoring events in a user's computational environment (e.g., email, voicemail, calendar), deciding what information to send to a user's wearable system, prioritizing that information, dealing with user responses, and learning from those responses so its decisions can improve over time.

One challenge for the design of this software is to identify the factors it can use to make these types of decisions. One such factor is *timeliness*. New email or voicemail, upcoming appointments, and changes to web-based information services such as stock tickers or sports scoreboards are some examples of timely information. For mobile use, *location* also is important in determining relevance. GPS is one technology that enables devices to be location-aware. Location-aware devices could notify people of nearby stores with items they need to purchase, or of nearby friends whom they'd like to contact.

A system also should provide users with information that is *important*. For a simple example, it should avoid streaming spam email to its users. Ideally, it should be able to prioritize all the types of information (messages, reminders, news items, etc.) and use these priorities to guide its presentation of the information. Initial priorities may be based on the type of the information: for example, getting notified that one of your friends is in the same mall or library as you is likely to be more important than most news stories.

Finally, an effective system will be *adaptable*. No two users will have the same notion of importance. A system should learn from user responses what that particular user considers important. For example, if a user frequently reads email messages from particular addresses, messages from these addresses should gradually receive higher priority.

Thus, the key enabling software techniques come from areas such as information filtering and artificial intelligence, particularly machine learning. The workshop will explore the range of techniques that are relevant, discuss lessons to be learned from existing research prototypes, and identify open problems where new research is needed.

Design of multi-device interfaces.

There are several challenges here. One is the general problem of designing for devices with i/o capabilities that are quite different from, and relatively impoverished compared to desktop user interfaces. Devices may have very small displays – or, in the case of audio devices, no displays at all. And their input capabilities may be very limited, in the case of a wrist computer, or inherently error-prone, as with a speech interface. Designing an interface for a PDA or cell-phone is hard; designing for a wristwatch will be even harder.

Another issue is when it is appropriate to 'promote' information beyond the periphery, that is, when the system should attempt to notify the user about some information at once. When this is necessary, a wristwatch computer might be able to flash its display, vibrate, or even sound a tone. Of course, the decision whether to seek the user's attention must be guided by the prioritization techniques mentioned above.

It's also important to consider how users might respond to items on the peripheral awareness device that catch their attention. One way would be to support brief "canned" responses. For a message, in particular, it should be possible to send a response like "OK" or "I got your message – will reply in detail when I'm back at my desk" without having to take out one's PDA. One research question worth exploring is how to define a small set of generally useful canned responses. Another issue is how to design an interface for a device with very limited input capabilities (like a wristwatch) that makes it simple for users to select a response.

Of course, the most interesting and novel interface design challenge is how to divide functionality across multiple devices. The simplest case to envision is one where a user notices something on the peripheral awareness device, gives a single command (e.g., a button press) to indicate interest, then takes out a PDA to explore the information in detail. This model assumes that one first uses the peripheral awareness device alone, then the PDA alone. It also requires very simple coupling between the two devices. We think this model is well worth exploring; however, we also will attempt to identify situations when a more complicated model for combining the devices is necessary. For example, when a user has his PDA out and is using it, should information and notifications still be going through the peripheral awareness device? Or should they now go through the PDA? This suggests that the division of functionality across the two devices may have to be dynamic.

Workshop activities.

We will attempt to achieve these goals through a combination of activities, both prior to and at the workshop. Would-be participants will submit 2-4 page position statements, identifying one or more of the workshop goals that they want to address, at least one specific research issue associated with the goal, and their current or planned work that addresses the issue. The organizers will select participants based on the interest and clarity of the research questions and the novelty and interest of the proposed or completed solutions. Position papers of all accepted participants will be posted on a website for the workshop.

Well in advance of the workshop, we will group participants into sessions, and assign a discussant for each session. The discussant's job will be to bring additional relevant knowledge to bear on the work to be presented in the session, e.g., to compare and contrast the different approaches, compare them to previous work, or suggest alternative approaches. This process will begin through email exchanges prior to the workshop.

At the workshop, presentations will be organized around the workshop goals and kept short, no more than 15 minutes. This will allow plenty of time for discussion. The discussion will be initiated by the assigned discussant; we expect discussants to present their perspective for about 15 minutes before opening up to general discussion.

Ubicomp Communities: Privacy as Boundary Negotiation

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ABSTRACT

Ubiquitous computing conjures visions of big and little brother, and ever-diminishing privacy. But it also opens up new forms of communication, collaboration and social relations. Full participation in communities involves exchange of information, and maintenance of a visible, public persona. Privacy is often regarded as an imperative in its own right, but this perspective ignores the countervailing need for disclosure in social settings. This workshop takes a balancing perspective: it treats community participation as a goal, and balances the need for disclosure against the need for privacy. Privacy is not an abstract consideration, but a practical process of *negotiating and managing boundaries*. The workshop will explore both social perspectives and technical approaches to this issue. It builds on last year's ubicomp workshop on "Socially-informed design of privacy-enhancing solutions in ubiquitous computing".

Keywords

Privacy, Communities, Ubiquitous Computing

INTRODUCTION

In normal social situations, we are aware of what we say and do, who can hear and see us, and what are appropriate norms for disclosure for the community we are in at the time. Our awareness of where information is going (and should go) helps regulate the information flow and give us a good level of privacy protection. When we rely on ubiquitous computing to mediate our interactions, we may lose many or all of these cues. In the worst case, information about us may be flowing to other actors without our knowledge or consent. The ease and invisibility of electronic communication in ubicomp greatly increases the risk of unchecked information flow and consequent loss of privacy. Concerns about privacy in the ubicomp community are understandable. But addressing privacy alone ignores the needs for community participation. How do we support and enhance normal social disclosure in ubicomp settings? How do we establish and expose norms for disclosure within communities? Can we support gradual, mutual disclosure for trust-building? These are typical questions we would like to address in the workshop.

This workshop aims to provide a forum for ubicomp system developers and researchers, security researchers, and social scientists to collaboratively explore the future of trust-sensitive and community tools in ubicomp. Areas of interest to this workshop include (but are not limited to) the following topics:

1. **Community models and Ubicomp:** What are the emerging and anticipated forms of community supported by ubiquitous computing? What are the communication modes? How are norms established and maintained? What design principles can be discovered?

2. **Communities and Privacy:** What forms of disclosure and discovery are appropriate for ubicomp communities? How is disclosure mediated? What kinds of disclosure boundary are appropriate? How can this be exposed and supported by technology? How can disclosure boundaries be negotiated? Are there asymmetries that need to be mitigated? This topic has both social and technical dimensions.

3. **Communities and Trust:** With respect to privacy and disclosure, how is "trust" manifest in ubicomp

communities? How are reputations, reliabilities, and risks established, measured, and represented? What forms of information or other exchange occur in the community? How might ubicomp systems handle differences in power, access, and expertise within a community?

Format of the Workshop and Timetable

This workshop will last for 1 full day and will be limited to 20 participants (not including the workshop organizers) to enable lively and productive discussions. Participants will be invited on the basis of position papers. Such position papers should be no longer than 4 pages excluding references, and they will be selected based on their originality, technical merit and topical relevance.

The workshop will be organized into panels and breakout sessions. Depending on the submitted position papers, the workshop will consist of 3 to 4 panels. Each panel lasts about an hour, and includes presentation of 5 or 6 position papers that share a similar topic, followed by organizer-moderated discussions. The morning panels are devoted to community-oriented ubicomp systems, while the afternoon panels are devoted to trust issues manifested in those systems. Also in the afternoon, there will be breakout sessions lasting about 1.5 to 2 hours, followed by reports to a plenary session. In addition, coffee breaks and lunch will serve as opportunities for informal discussion. To the extent possible, participants will have lunch together within short walking distance of the workshop location.

09:00 – 09:30	Registration & welcome
09:30 – 10:00	Introductions
10:00 – 11:00	Panel 1 and discussion
11:00 – 11:30	Coffee
11:30 – 12:30	Panel 2 and discussion
12:30 – 02:00	Lunch
02:00 – 03:00	Panel 3 and discussion
03:00 – 04:30	Breakouts
04:30 – 05:30	Breakout presentation
05:30 – 06:00	Wrap-up & coffee

Desired Outcome

We expect that this workshop will have concrete results that will advance the development of trust-sensitive community-oriented ubicomp systems. We will put together a poster summarizing the activities of the workshop, and report back to the conference.

Submission, Selection Process and Publication

The workshop organizers will select participants based on review of submitted position papers, taking into account scientific quality and relation to the workshop topics. We will also invite selected prominent ubicomp researchers, security experts, social scientists and privacy advocates to submit to the workshop.

The workshop proceedings will be published as a technical report available online. Also we will seek cooperation with ACM to archive the workshop outcomes in the ACM digital library.

Update on Selected Workshop Papers

Michael Boyle “A Shared Vocabulary for Privacy”

James Fogarty “Sensor Redundancy and certain Privacy Concerns”

Jonathan Grudin, Eric Horvitz “Presenting choices in context: approaches to information sharing”

Jason Hong, Gaetano Boriello, James A. Landay, David W. McDonald, Bill N. Schilit, J. D. Tygar “Privacy and Security in the Location-enhanced World Wide Web”

Charis Kaskiris “Socially-Informed Privacy-Enhancing Solutions Economic Privacy and the Negotiated Privacy Boundary”

Saadi Lahlou “Constructing European Design Guidelines for Privacy in Ubiquitous Computing”

Marc Langheinrich “When Trust Does Not Compute - The Role of Trust in Ubiquitous Computing”

Scott Lederer, Jen Mankoff, Anind Dey “Towards a Deconstruction of the Privacy Space”

Carman Neustaedter, Saul Greenberg “Balancing Privacy and Awareness in Home Media Spaces”

Chris Nodder “Say versus Do; building a trust framework through users’ actions, not their words.”

David J. Phillips “The information environment as text interpreted by communities of meaning: implications for design of ubicomp systems”

Organizers

John Canny, Paul and Jacobs Distinguished Professor of Engineering, University of California, Berkeley

John Canny is a Professor of Computer Science at UC Berkeley with a background in robotics, AI and algorithms. His recent work is on privacy-preserving collaborative algorithms, including collaborative filtering and location-based services. He founded the group on Human-Centered Computing at UC Berkeley in 1998, a group of technical and social sciences interested broadly in the impacts of IT on society. In 2001, he co-founded the Berkeley Institute of Design, a new interdisciplinary program in socially-informed design of informational environments.

Scott Mainwaring, Senior Researcher, People and Practices Research Lab, Intel Research

Scott Mainwaring is a senior researcher in Intel's ethnographic research and design group in Hillsboro, Oregon, conducting fieldwork in settings of technology use ranging from U.S. and Korean households to Chinese businesses. Current interests include social, cultural, and place-based constraints and opportunities for ubicomp. Prior to joining Intel in 2000, Scott was a member of research staff at Interval Research Corp., working on media spaces, lightweight communication, interactive television, and video ethnography.

Paul Dourish, Associate Professor, School of Information and Computer Science, University of California, Irvine

Paul Dourish is an Associate Professor in the School of Information and Computer Science at UC Irvine. He has held research positions at Xerox PARC, Apple Computer, and Rank Xerox EuroPARC. His principle research interests are in the areas of Human-Computer Interaction and Computer-Supported Cooperative Work. In particular, he has a long-term interest in the relationship between information system design and social analysis. Most recently, he has been exploring the foundations of embodied interaction, which seeks to apply phenomenological approaches to understand encounters between people and technology.

Jens Grossklags, Ph.D. student, School of Information Management and Systems, University of California, Berkeley

Jens Grossklags is a Ph.D. student in Information Management and Systems at UC Berkeley, and has been visiting research student at NASA. Jens also has been research guest at the Max-Planck Institute for Research into Economic Systems in Germany. His current work spans the domains of computer networks, economics, and human factors/psychology research. He has been honored with two conference best paper awards: for research on behavioral studies in privacy, awarded by the German Informatics Society, and for architectural design of large-scale ad-hoc sensor networks, conferred at the ACM/ACS MDM 2003.

Xiaodong Jiang, Ph.D. Student in Computer Science, University of California, Berkeley

Xiaodong is a Ph.D. student in Computer Science at UC Berkeley, where he is currently a Mayfield Fellow and Hitachi Fellow. Xiaodong's research focuses on ubiquitous and context-aware computing. He has worked on the information space model and infrastructure for context-aware computing, and applications that assist firefighters in their emergency response practice.

At the Crossroads: The Interaction of HCI and Systems Issues in UbiComp

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ABSTRACT

Two key research areas in ubicomp are human-computer interaction (HCI) and systems. Both have unique challenges, and constraints from each field affect what can be achieved in the other. Despite this, researchers too often focus on one research area while spending only the minimum necessary time addressing the issues in the other. For example, an HCI researcher might focus on multi-modal interaction for ubiquitous computing environments, but be stymied because they did not pay attention to whether or not the underlying system could support the latencies needed by the users of the system. This workshop will focus on how researchers from both HCI and systems have noticed the impact of constraints from the other field on their own efforts.

Keywords

Human-Computer Interaction, Systems

WORKSHOP OVERVIEW

UbiComp research can be seen as both the study of the way future users will interact with the sea of computers through which they move, and also the systems technology that will allow these computers to interact with one another in meaningful ways. Thus, the field needs to deal both with issues of human-computer interaction (HCI) and systems technology. Systems issues always impact the types of user interactions that are feasible, and user interaction should influence the design of underlying systems, but in UbiComp the two disciplines are even more interdependent than on current desktop platforms where interaction modalities and techniques are less diverse and mostly predetermined through the desktop metaphor.

This workshop will look at the fundamentals of HCI and how they affect the design of UbiComp systems, as well as the limits and tradeoffs in system design and how those restrict the types of interaction and interfaces that can be supported in the world of ubiquitous computing. The workshop will include overviews of these issues, presentations from participants about their experiences with interactions between HCI and systems issues in their own work, and a final group discussion session where we will try to extract themes and principles from the workshop for future presentation to the UbiComp community at large.

In the remainder of this proposal we present some more detailed background information on the topic of the workshop, followed by a preliminary schedule.

Workshop Topic Details

Fundamental constraints from the fields of systems and HCI both have an impact on how well an application designer can do in the UbiComp domain. On account of this, it is important to have a good understanding of the fundamentals from both fields.

There are four general areas of relevance on the systems side: hardware platforms, peripherals, system infrastructures, and applications. At the *hardware level*, the speed of processors and networking technologies place upper bounds on how feature-rich and responsive any given system can possibly appear to the end user. Of course, faster processors and networking technologies are continuously appearing, but ultimately performance is constrained by the inherent latencies incurred by the need to obey the speed of light. Today's networks range up to gigabits/s in transfer speed and down to about 10 Mb/s for wireless. Processors range from the gigaops/s range used in desktop workstations down to the low megaops/s range driving many embedded devices.

The *peripheral level* consists of the sensors and actuators deployed in UbiComp environments. These promise to be the basis for novel interaction mechanisms and may even fundamentally change the way humans interact with a ubiquitous computing environment. However, limiting factors such as the accuracy and rate of capture or actuation, interpretation ambiguities, and processing speed and latency of these devices may become the bottleneck and constrain the way the user perceives the system and its performance.

Given the underlying hardware and peripherals (and in some cases, operating systems), a *system infrastructure* or middleware can be constructed. In creating these systems designers must make tradeoffs between flexibility and features and the maximum performance the system infrastructure will make available to application developers. In the UbiComp field, these infrastructures include Gaia OS [4], one.world [6], BEACH [10], BASE [1], iROS [9], and others.

Finally, application designers create *applications* which present user interfaces to their end users. In doing so, designers must understand the underlying system framework they are using to ensure that the user interface is sufficiently responsive, flexible, and intuitive. It is common practice to run applications through cycles of design and testing to optimize the user interface, but Edwards et al. [5] point out that it is probably also valuable to feed what is learned in application design back into the design process of the underlying infrastructure so that it will evolve to be able to better support the types of applications being built on the system infrastructure.

Just as the underlying system constrains the types of interfaces that can be built, the fundamentals of HCI place bounds on any system that wishes to support human-computer interaction. Some of these fundamentals are cognitive and involve how quickly humans can respond to their environment and how fast their environment must react to them. For example, humans cannot see any detail in motion faster than around 60 Hz, and users expect a system to react to a trigger within 1 s before they feel they are waiting. Many of these fundamentals are documented in classic HCI literature such as [3].

More recently, HCI has begun to develop “post-cognitive” theories for human-computer interaction. These broaden the previous focus on *one* user interacting with *one* device to accomplish a *single* task, to the larger context of *multiple* people, tasks, and devices. Examples of such theories include Activity Theory [8], Distributed Cognition [7], and Speech Acts [11]. While work on these theories is ongoing, their results will help define the characteristics and performance needed for systems infrastructures supporting coordination and collaboration between multiple users and machines in device-rich UbiComp environments.

Of course, HCI and systems issues have been intertwined before on desktop computers, and some of the lessons learned in that domain may be applicable or extensible to the UbiComp domain. In particular in the days of slower desktop computers many coping mechanisms (some still in use today) had to be developed to create a more pleasant user experience. For example, hardware cursors were used to insure the direct-feedback loop between user input and cursor display occurred without noticeable delay. Other mechanisms include hourglasses and progress bars, window drags as outlines, and jump scrolling. At the same time, many of the well-established metaphors that today's desktop user interfaces deploy simply do not work in UbiComp environments—for example, what are concepts such as "pointer focus" and "selection" supposed to mean in a space augmented with multiple machines, input and output devices, and used by many people simultaneously?

Proposed Workshop Format

We would ask members of the UbiComp field to submit papers either on their personal experiences with the interaction of HCI and systems constraints in UbiComp, or reasoned analyses of how the two interact and guidelines for choosing appropriate design points. Ten to twelve papers would be selected from those submitted, and those authors would be invited to participate in the workshop. The papers would be made available as a booklet at the workshop, and permanently on a web site associated with the workshop.

We propose a one-day long workshop with the following schedule:

- Anchor Talks (9-10:30am). Initial suggestions, to be fixed by workshop:
    - HCI Fundamentals
    - Systems Fundamentals
    - Overview of performance constraints of existing UbiComp systems infrastructures
- Break (10:30-10:45am)
- First Paper Session [15 min presentations] (10:45am-12:15pm)
- Lunch (12:15-1:30pm)
- Second Paper Session [15 min presentations] (1:30pm-2:45pm)
- Break (2:45pm-3pm)
- Discussion, Debriefing and Attempt to Draw Conclusions from Presented Materials (3pm-4:30pm)

After the workshop, the organizers and interested participants would try to move from the ideas generated in the final debriefing towards a set of principles or design patterns [2] for designing user interfaces and systems and infrastructure in the UbiComp world that take into account both systems and HCI issues. Participants would be offered the opportunity to continue with this synthesis work after the workshop with the goal of presenting it back to the community in the form of one or more future papers, possibly collected in a special issue of an appropriate journal.

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System Support for Ubiquitous Computing – UbiSys

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SUMMARY

We propose a workshop that focuses on developing an understanding of the challenges faced by system and middleware researchers in supporting ubiquitous computing environments on a large scale. We aim to identify the fundamental services and paradigms necessary to support the move from focused prototypes to wider scale coordination and deployment.

Keywords

Middleware, system support, ubiquitous computing, operating systems, interoperability.

DESCRIPTION OF THE WORKSHOP

This workshop offers the opportunity to bring together researchers and practitioners involved in the development of systems support for general purpose ubiquitous computing environments. It aims at exploring most recent research and findings in this area, comparing results, exchanging experiences, and promoting collaboration and cooperation among researchers in the field. The workshop aims to identify the common abstractions and patterns found in the existing systems, as well as the core low-level services that are needed to build general-purpose ubiquitous computing environments. The workshop will focus on different aspects of system and middleware research and the challenges involved when applying them to support ubiquitous computing. Special emphasis will be placed on presenting state of the art and emerging research as well as experience reports from the following topics and related research areas:

- System support infrastructures and services
- Middleware for ubiquitous computing
- Architectural structure, design decisions and philosophies
- Interoperability and wide scale deployment

Mobisys 2003 hosted a panel about metrics to evaluate ubiquitous computing systems. The results were overwhelmingly positive and the two and a half hours were insufficient to host the number of discussions. The panel organizers decided to cover a specific well-defined subject instead of fostering discussion on a number of different topics. This approach proved highly successful and we plan to follow the same format. The workshop will explicitly concentrate on the three aspects listed above.

In order to ensure a high quality technical session, paper submissions will be 3-5 pages long and will have to cover one of the topics listed above. Furthermore, we will prioritize experience papers describing lessons learnt from built systems, including information about approaches that did and did not work, unexpected results, common abstractions, abstraction mapping among different systems, common building blocks present in different architectures, and metrics for evaluating ubiquitous computing infrastructures.

Ubiquitous computing environments are envisioned as being populated with large numbers of computing devices and sensors to the extent that the physical and computational infrastructures become fully integrated, creating a dynamic programmable environment. To realize this vision, several projects have developed prototype environments, typically focused on a particular ubiquitous computing scenario or application. System support is often pragmatic, problem oriented and difficult to generalize to other domains. To fully realize programmable ubiquitous computing environments it is essential to provide services that coordinate software entities and heterogeneous networked devices and provide the low-level functionality needed to enable ubiquitous computing in the general case. Systems software provides a homogeneous computing environment where applications are supported with resource management (i.e. resource and service discovery), and common abstractions that leverage the implicit heterogeneity in such environments. The work of independent researchers has revealed patterns of service usage, indicating that systems software for ubiquitous computing may converge to a set of necessary core services. If such a set of requirements could be identified, applications could then be more easily ported across different implementations and interoperability would be simplified.

One of the key issues for debate is the underlying structure of ubiquitous computing middleware. Current prototypes are characterized by three different architectural organizations. In the first case, the environment provides an infrastructure that coordinates the resources present in a specific geographical location. Applications can discover and access such resources only via the infrastructure. Furthermore, all communication between devices is mediated by the infrastructure. Additional information, such as large amounts of application data which for instance cannot be stored on small devices, can be maintained in the infrastructure. Direct interaction between devices is not considered and the infrastructure typically provides services localized to a specific geographical area such as a room, or a building, covered by one or more network types. The second architectural organization relies on spontaneous interaction among the devices present in the environment as a federation of peers. There is no common infrastructure per se – applications have to store and maintain application data cooperatively. Such an organization is typically based on an underlying ad-hoc configuration. The third model is a hybrid that relies on a centralized system support infrastructure, but relies on peer-to-peer communication among entities. So far, the three approaches seem to offer benefits in distinct application domains and it is likely that they will continue to co-exist and complement each other. These three approaches lead to a variety of research questions concerning interoperability, architecture, service organization, application models, and application support in general.

We strongly believe that the proposed workshop will provide a unique opportunity to foster discussion and interaction among researchers working on this new area. We expect the workshop to be the first step towards the creation of a discussion group and future workshops and conferences working on the formalization and standardization of basic building blocks for Ubiquitous Computing.

ORGANIZERS

- *Roy Campbell, Ph.D., Department of Computer Science, University of Illinois at Urbana-Champaign.* Roy Campbell is a professor of computer science at the University of Illinois at Urbana-Champaign. His research interests include operating systems, distributed multimedia, network security, and ubiquitous computing. Prof. Campbell is the head of the Gaia project, a ubiquitous computing infrastructure under development that is investigating systems support and applications for ubiquitous computing environments. He received his B.Sc. in mathematics from the University of Sussex, and his M.Sc. and Ph.D. in computing from the University of Newcastle upon Tyne.
- *Armando Fox, Ph.D., Department of Computer Science, Stanford University.* Armando Fox is an assistant professor at Stanford University, and is the faculty leader of the Software Infrastructures Group (SWIG). He received a BSEE from M.I.T., an M.S.E.E from University of Illinois at Urbana-Champaign, and a Ph.D. in Computer Science from UC Berkeley. His primary research interests are systems approaches to improving dependability (the Recovery-Oriented Computing project) and system software support for ubiquitous computing (the Interactive Workspaces project).
- *Paul Chou, Ph.D., IBM T.J. Watson Research Center.* Paul is a Research Staff Member and the manager of the Emerging Interactive Spaces department at IBM Research. His present research focus is on pervasive computing, in particular, the technology and usability challenges in bringing physical objects and digital infrastructure together to address social and business issues. His recent projects include intelligent vehicle, telematics data privacy protection, and office of the future. Paul received his Ph.D. in Computer Science in 1988 from the University of Rochester.
- *Manuel Roman, Ph.D., DoCoMo Labs, USA.* Manuel Roman recently completed a Ph.D. in Computer Science at University of Illinois at Urbana-Champaign. His research interests include ubiquitous computing, middleware, and operating systems, and how to

combine ideas from all these areas to create interactive/programmable active spaces. His research interests include also handheld devices and how to integrate them in active spaces. He received his BS and MS degrees in Computer Science from La Salle School of Engineering (Ramon Llull University) in Barcelona, Spain.

- *Christian Becker, Ph.D., Institute for Distributed and Parallel Systems, University of Stuttgart, Germany.* Christian Becker is a senior researcher and lecturer at the University of Stuttgart. He received a PhD in Computer Science from the University of Frankfurt and a Diploma in Computer Science from the University of Kaiserslautern. His primary research interests are ubiquitous computing systems. Currently he is involved in middleware support for spontaneous networking (the BASE platform) and support of context-aware applications though global augmented world models (the Nexus project).
- *Adrian Friday, Ph.D., Computing Department, Faculty of Applied Sciences, Lancaster University, UK.* Adrian Friday graduated from the University of London in 1991. In 1992 he helped establish the mobile computing group at Lancaster University, completing formative work in the area of mobile distributed systems, leading to the award of his PhD in 1996. In 1998 he was appointed as a Lecturer in the department of Computer Science and is an active member of the Distributed Multimedia Research Group. During his research career, Adrian has been involved with over 9 research projects in the areas of mobile computing, context-aware systems and advanced distributed systems, including the Equator IRC, GUIDE II and CORTEX projects. He has a consistent track record of publishing in high quality peer-reviewed international conferences and journals, having authored and co-authored over 50 publications to date. His current research interests include: distributed system support for mobile, context-sensitive and ubiquitous computing.

WORKSHOP TITLE

"System Support for Ubiquitous Computing – UbiSys"

PARTICIPATION SOLICITATION

We plan to invite key researchers and practitioners who work in this area to submit papers and give oral presentations on their research. We also plan to put out a call for papers that solicits research papers describing current and on-going research and experience reports related to the three aspects described in this proposals. All submissions will be reviewed and selected based on their originality, merit, and relevance to the workshop. All accepted papers should be presented orally during the workshop.

MAXIMUM PARTICIPANTS

We expect to have up to 15 participants giving short presentation about their submissions. We are also expecting 30-50 attendees to participate in the discussion session.

First International Workshop on Ubiquitous Systems for Supporting Social Interaction and Face-to-Face Communication in Public Spaces

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ABSTRACT
This workshop will bring together researchers involved with the development and deployment of ubiquitous systems to support social interaction and face-to-face communication in public spaces (e.g., museums) or semi-public spaces in campus-like environments of large organizations (e.g., companies, universities) and at public gatherings, such as conferences, and tradeshows. The workshop presentations will focus on the underlying technology, applications, and social challenges presented by the technology.

Keywords
Ubiquitous systems in public spaces

INTRODUCTION

Audience of the workshop
This workshop will bring together participants who would like to help define, design, develop, deploy, evaluate, and use ubiquitous systems for supporting social interaction and face-to-face communication in public spaces and at public gatherings. It aims at providing a forum for designers, developers and users of ubiquitous systems deployed in public spaces to exchange experiences and contribute to the elucidation of research challenges and directions.

Origins of the workshop
Every year thousands of conferences and professional trade shows take place worldwide, attracting millions of attendees. Likewise, millions of people go to museums and attend various public gatherings. Such events represent important venues for social interaction and the informal exchange of knowledge, providing a place to find others who share common or complementary interests. However, poor event management and missed opportunities for communication continue to be vexing challenges for organizers.

How do attendees find others who share their interests? How do they identify and communicate with others whose expertise they seek? How and where does the interaction between attendees happen? How can organizers understand the dynamic profile of participation at the sessions and be more responsive to the participants' emerging interests? In the absence of good answers to these questions, many attendees do not benefit from the events as much as they could, resulting in many person-years of wasted human resources.

State of the art
In recent years, attempts have been made to provide public gatherings attendees with various value-added services based on the ability to either track individual attendees as they go from one location to another or detect when they interact with each other or with various "smart" objects

embedded in the space. One of the earliest experiments, Meme Tags project, used electronic nametags capable of exchanging short messages (memes) via IR. The tags also stored information about the interaction between tag wearers and shared it with the centralized database. The cumulative data was shown on large displays (Community Mirrors).

Digital Assistant developed at ATR Media Information Science Lab aimed to enhance communication among conference participants by tracking them as they attend various locations and providing access to a content-rich personalized environment either via web kiosks or interactive displays. Users were required to wear IR badges that could be detected at some locations within the conference space. The resulting data was used to create the user's touring diary and to provide personalized real-time services.

Georgia Tech's Social Net system required attendees to carry a portable device (Cybiko) that uses RF to help mutual friends connect strangers (who were co-located for a considerable amount of time). In order for these mutual friends to identify who among their friends are not connected (but should be, because they tend to be co-located), the system requires each user to provide a list of all their friends – a task that turned out to be challenging for some in a field test of 10 users at a 3-day conference.

MIT Media Lab's Sociometer prototype captures social interaction among individuals who use wearable computers with microphones. While the system tracks and subsequently analyzes communication patterns, it does not use the data to provide any real time value-added services to the users.

NCSA's IntelliBadge™ project implements location tracking by proximity to RFID location markers installed at the points of interest. All the user services are built around tracked location information and a prior knowledge about the attendees and the conference events. These services include the ability to locate other people, view events attendance statistics, and interact with visualization applications.

nTag by nTAG Interactive, LLC (www.ntag.com) uses semi-passive Radio Frequency IDentification (RFID) tag operating in the UHF band which enables a conference organizer to use it for security, to record how many people attended certain sessions, or to track how many people visited certain areas of an exposition floor. When people meet, their tags exchange information about their interests and preferences, thus facilitating social interaction among the attendees. Tags also store and provide convenient access to the conference program.

CharmBadge by Charmed Technology, Inc. (www.charmed.com) uses IR-based tags programmed with attendees' individual business card information. This information is exchanged between attendees as they interact with each other and the interaction is logged and subsequently uploaded to a private website accessible by each user.

SpotMe system by Shockfish SA (www.spotme.ch) requires participants to carry a cell phone-size device through which they can find out who is standing within a 30 meter radius from them. Participants can be notified if a person with shared interests comes within 10 meters, and they can send messages to each other or exchange electronic business cards.

More recently, research investigates also the combined use of public displays integrated in the architectural environment with mobile devices carried by visitors of public spaces or semi-public spaces in campus-like environments of large organizations (e.g., companies, universities). The AMBIENTE-Team at Fraunhofer IPSI developed smart artifacts as the GossipWall (a large wall-sized ambient display) and the ViewPort (a mobile device) in order to support informal communication between people and convey atmospheric information (www.ambient-agoras.org).

Justifications for the workshop

Although the above-described projects attempt to solve the same class of problems and use relatively similar set of basic techniques, the developers do not have a common venue for sharing the results of their work. For example, papers describing this type of systems are scattered across several barely-related journals, which makes it difficult for a novice developer to assess the state of the art in the field. *The proposed workshop therefore is a first attempt to bring together like-minded researchers and practitioners who focus on the area of ubiquitous systems for supporting social activities and social interaction in public spaces and at public events.*

An interdisciplinary approach is required in order to develop a successful application for supporting social interactions. Without an interdisciplinary team, the application is likely to overstate some issues and completely miss other important topics. However, this is not an obvious detail for most novice developers. *This workshop therefore will bring together researchers from different disciplines, such as sociology, psychology, art, computer engineering, computer graphics, and interface designers with the goal to point out the place and importance of each of these disciplines in the overall scope of a successful system design.*

The final goal of the workshop is to identify and clarify the research challenges and directions that the researchers involved with this type of work are likely to face.

WORKSHOP TOPICS

The main subject of the proposed workshop is the development and use of ubiquitous systems to support social interaction in public spaces and at public events, such as museums, conferences, trade shows, etc. Topics relevant to this subject include:

- Applications: existing commercial and experimental applications, e.g., ubiquitous systems in museums, at public gatherings, etc.
- User interface: how to provide a simple and intuitive user interface for novice users to a complex system.
- Presentation: how various types of information acquired by the ubiquitous system can be effectively presented to the end users.
- Scalability: how to accommodate a large number of simultaneous users at a potentially unlimited number of locations.
- Deployment: how to package the system so that it can be easily deployable in an environment that is not prepared for such type of applications.
- Reliability: how to build robust and reliable systems that can guarantee at least some minimal number of services.
- Privacy: if the system "knows" everything about everybody currently present in the tracked ubiquitous environment, what are the privacy concerns and how best to address them?
- Security: what happens if the system is defatted and the intruders gain access to all the accumulated knowledge. How to prevent this from happening.
- Social aspects: how the technology can be used to help forming social networks and how it can be used to study them.

WORKSHOP GOALS

The goals of this workshop are

- to examine the state of the art of an emerging area of ubiquitous computing research,
- identify relevant projects and technologies and build up a taxonomy
- identify challenges and issues that need to be resolved in order for this technology to proliferate in the future,
- provide a venue for the like-minded researchers to meet and end exchange ideas.

WORKSHOP ORGANIZERS

Rick Borovoy has a Bachelors Degree (1989) from Harvard in Computer Science, and a Masters (1995) and Ph.D. (2001) from the MIT Media Lab. In 1995, he co-created the Thinking Tags: interactive name tags that gave people talking to each other at a conference a simple measure of how much they had in common. This led to several more prototypes, including the Meme Tags and i-balls, and a Ph.D. thesis on "Folk Computing: Using Technology to Support Face-to-face Community Building". He recently started a company -- nTAG Interactive -- to deploy advanced versions of this technology in commercial settings.

Harry Brignull is a research fellow at Sussex University's Interact lab, where he is also finishing his Ph.D. His specialist area is user-experience design for public situated displays. Harry currently works on the Dynamo project, on which they have developed a system which provides a communal surface for the sharing and exchange of information in face-to-face scenarios. On another thread of the Dynamo project, Harry has looked at the use of large displays to encourage socialising, and the issues involving enticing users to progress from passer-by to participant.

Shahram Izadi is a research fellow in the Communications Research Group at the University of Nottingham. He is actively involved in a number of research projects at Nottingham including Equator, a six-year Interdisciplinary Research Collaboration (IRC) supported by the EPSRC that focuses on the integration of physical and digital interaction; and Dynamo a public multi-user interactive surface that supports the cooperative sharing and exchange of a wide range of media. Shahram has also had the opportunity to work on the Speakeasy project at PARC, where he has helped engineer an interconnection technology for enabling digital devices and services to easily interoperate over both wired and wireless networks. He has published at international conferences on ubiquitous computing, CSCW and mobile computing, and written several journals articles. He is currently working on a book chapter for the Handbook of Mobile Computing.

Volodymyr Kindratenko graduated in mathematics and computer science from the State Pedagogical University, Kirovograd, Ukraine, in 1993. He received a Ph.D. degree from the University of Antwerp, Belgium, in 1997. His research involved the development and application of image analysis techniques for Scanning Electron Microscopy imagery. From 1997 to 1998, Volodymyr Kindratenko was employed by the National Center for Supercomputing Applications (NCSA) at the University of Illinois as a Postdoctoral Research Associate in the Virtual Environments group where he worked on the development of a distributed virtual reality system for collaborative product design. From 1998 to 2002, Volodymyr Kindratenko was employed by NCSA as a Research Scientist in the Visualization and Virtual Environments group where he worked on the development of industrial virtual reality applications and high-end visualization systems. He is now a Research Scientist at NCSA in the Experimental Technologies Division where he is involved with ubiquitous systems, interactive spaces, and sensors research and is the Technical Lead on the IntelliBadge™ project.

Alex Lightman is a leading writer and speaker on the future of technology and communications. He is the author of the first book on 4G wireless, *Brave New Unwired World: The Digital Big Bang and the Infinite Internet*, published by John Wiley in 2002 and has published nearly 100 articles for technology, business, and political publications including Red Herring, Chief Executive, and Internet World.

Lightman is the CEO of Charmed Technology, (www.charmed.com) which makes wearable computers and achieved world-wide acclaim for producing 100 wearable technology fashion shows in 20 countries. He is the founding director of The 4G Society and the first Cal-(IT)2 Scholar at the California Institute for Telecommunications and Information Technology, a joint program of UCSD and UCI. (http://www.calit2.net). Lightman has nearly 20 years of high technology management experience and, in addition, has experience in politics (including work for a US Senator), construction, consulting, the oil drilling industry, and the renewable energy industry. He also created, managed and received accreditation for the Nizhoni Institute, a small school and college, and produced the 100 Brave New Unwired World fashion shows featuring wearable and pervasive computing, which included many of Lightman's own inventions and designs, such as the patented Charmed Viewer display and the first Internet jewelry. Harvard Business School featured Lightman and Charmed in case study that recognized Lightman's pioneering innovation of presenting computers as fashion. Both the show and Lightman's designs are now widely copied worldwide.

Norbert Streitz holds a Ph.D. in physics and a Ph.D. in psychology. He is the head of the research division "AMBIENTE – Workspaces 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..

He is the Chair of the Steering Group of the EU-funded proactive initiative "The Disappearing Computer", a cluster of 17 projects, and, more recently, the co-chair of CONVIVIO: the EU-funded Network of Excellence on People-Centred Design of Interactive Systems. He was and still is active in various special interest groups in different scientific organizations, e.g., GI (Gesellschaft für Informatik), DGP (Deutsche Gesellschaft für Psychologie), ACM (Association for Computing Machinery), EACE (European Association for Cognitive Ergonomics).

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 walls and furniture with information technology and the design of Smart Artefacts. The roomware components that were developed in close cooperation with an office furniture manufacturer won several design prices. In the EU-funded project "Ambient Agoras: Dynamic Information Clouds in a Hybrid World", he is now working on situated interaction and services employing wall-sized ambient displays and handheld mobile devices in the context of Cooperative Buildings.

He has published/edited 15 books and more than 90 papers presented at the relevant national and international conferences or in journals in his areas of interest. He serves regularly on the program committees of these conferences and on several editorial boards. In the context of his interest in design and architecture, he was also appointed as a design competition jury member. He is often invited to present keynote speeches to scientific as well as commercial events in Europe, USA, South America, and Japan.

Intimate (Ubiquitous) Computing

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ABSTRACT

Ubiquitous computing has long been associated with intimacy. Within the UbiComp literature we see intimacy portrayed as: knowledge our appliances and applications have about us and the minutiae of our day-to-day lives; physical closeness, incarnated *on* the body as wearable computing and *in* the body as 'nanobots'; and computer mediated connection with friends, lovers, confidantes and colleagues. As appliances and computation move away from the desktop, and as designers move toward designing for emotion and social connection rather than usability and utility, we are poised to design technologies that are explicitly intimate and/or intimacy promoting. This workshop will: critically reflect on notions of intimacy; consider cultural and ethical issues in designing intimate technologies; and explore potential socio-technical design methods for intimate computing.

Keywords

Intimacy, computing, emotion, identity, body, play, bioethics, design methods, socio-technical design

INTRODUCTION

Intimate. adj. Inmost, deep seated, pertaining to or connecting with the inmost nature or fundamental character of the thing; essential, intrinsic ... Pertaining to the inmost thoughts or feelings, proceeding from, concerning, or affecting one's inmost self, closely personal.

We inhabit a world in which the classic computing paradigm of a PC sitting on your desk is giving way to a more complicated and nuanced vision of computing technologies and power. This next era is predicated on a sense that the appliances and algorithms of the future will respond better to our needs, delivering 'smarter' more context-appropriate, computing power. Underlying such a vision is the notion that computers in their many forms will be pervasive and anticipatory. Arguably, to achieve this, computing appliances will have to become more intimate, more knowing of who we are and what we desire, more woven into the fabric of our daily lives, and possibly woven into the fabric of our (cyber)bodies.

In this workshop we address the notion of 'intimate computing'. We invite designers within the area of Ubiquitous Computing to: address and account for people's embodied, lived experiences; explore the ways in which computing technology could and should be *more* intimate; and join us in considering possible pitfalls along the design path to such intimacy.

Intimacy as a cultural category/construct

What might intimacy have to do with technology and computers, beyond the obvious titillation factor? In the United States in particular and the west more broadly, there is a persistent slippage between intimacy and sex, which is not to say that there isn't a place to talk about the relationship between sex, intimacy and technology [see 15]. However, in this workshop, we want to cast our net more broadly. We are interested in other constructions of intimacy; intimacy as something that relates to our innermost selves, something personal, closely felt. Such a construction could include love, closeness, or spirituality. Or perhaps it is in the way we understand, feel and talk about our lives, our bodies, our identities, our souls. In all these ways, intimacy transcends technology, and has a role to play in shaping it. As we move towards designing for communication, emotion, reflection, exploration and relationship, we need to critically reassess our reliance in design on outmoded conventions and old models of computation and connection. We need to employ new metaphors and create new models.

A BRIEF HISTORY OF (INTIMATE) UBIQUITOUS COMPUTING

Having said that, there has been an idea of intimate computing for as long as there has been a vision of ubiquitous computing. The two are inexorably linked in the pages of the September 1991 issue of *Scientific American*. In that month's issue of the magazine, Mark Weiser, articulated his vision of ubiquitous computing – "we are trying to conceive a new way of thinking about computers in the world, one that takes into account the natural human environment and allows computers themselves to vanish into the background" [25]. In the article that follows, Alan

Kay used ‘intimate’ as a modifier to computing in an essay reflecting on the relationship between education, computers and networks [10]. He wrote, “In the near future, all the representations that human beings have invented will be instantly accessible anywhere in the world on intimate, notebook-size computers.” This conjoining of intimate computers and ubiquitous computing within an issue of *Scientific American* dedicated to Communications, Computers and Networks is perhaps not a coincidence – both represents complementary parts of a future vision.

How has this conjunction been expressed more recently? Broadly, there are 3 manifestations in the (predominantly) technology literature. 1. intimacy as cognitive and emotional closeness *with* technology, where the technology (typically unidirectionally) may be aware of, and responsive to, our intentions, actions and feelings. Here our technologies know *us* intimately; we may or may not know them intimately. 2. intimacy as *physical closeness* with technology, both on the body and/or within the body. 3. intimacy *through* technology: technology that can express of our intentions, actions and feelings toward others.

In the first category, Lamming and Flynn at Rank Xerox Research Center in the UK in the mid-1990s invoked ‘intimate computing’ as a broader paradigm within which to situate their ‘forget-me-not’ memory aid. They wrote, “The more the intimate computer knows about you, the greater its potential value to you. While personal computing provides you with access to its own working context – often a virtual desktop – intimate computing provides your computer with access to your *real* context.” [12]. Here ‘intimate computing’ (or the ‘intimate computer’) refers to the depth of knowledge a technology has of its user.

‘Intimate computing’ has also occasionally been used to describe a different kind of intimacy – that of closeness to the physical body. In 2002, the term appears in the *International Journal of Medical Informatics* along with grid computing and micro-laboratory computing to produce “The fusion of above technologies with smart clothes, wearable sensors, and distributed computing components over the person will introduce the age of intimate computing” [20]. Here ‘intimate computing’ is conflated with wearable computing; elsewhere intimate computing is even subsumed under the label of wearable computing [2]. Crossing the boundary of skin, Kurzweil paints a vision of the future that centralizes a communication network of nanobots in the body and brain. He states “We are growing more intimate with our technology. Computers started out as large remote machines in air-conditioned rooms tended by white-coated technicians. Subsequently, they moved onto our desks, then under our arms, and now in our pockets. Soon, we'll routinely put them inside our bodies and brains. Ultimately we will become more nonbiological than biological.”[11]

Finally, intimate computing has also referred to technologies that enhance or make possible forms of intimacy between remote people that would normally only be possible if they were proximate. Examples include explicit actions (e.g. erotically directed exoskeletons [19]), non-verbal expressions of affection or “missing” [22], and computationally enhanced objects, like beds, that offer “a shared virtual space for bridging the distance between two remotely located individuals through aural, visual, and tactile manifestations of subtle emotional qualities.” [5]. These computationally enhanced objects are all the more effective because they themselves are rich (culturally specific) signifiers. Dodge states of the bed, it is “very "loaded" with meaning, as we have strong emotional associations towards such intimate and personal experiences”[5].

INTIMATE COMPUTING TODAY AND TOMORROW

So where are we to go with intimate computing in the age of ubiquitous and proactive computing and the tentative realities of pervasive computing [23]? Clearly, as we move to the possibility of computing beyond the desktop and home office, to wireless hubs and hotspots, and from fixed devices to a stunning array of mobile and miniature form factors, the need to account for the diversities of people’s embodied, daily life starts to impose itself into the debate. We already worry about issues of privacy, surveillance, security, risk and trust – the first accountings of what it might mean for individual users to exist within a world of seamless computing. And then there are issues of scale – ubiquitous computing is a far easier vision to build toward. It promises a sense of scale and scalability, of being able to design a general tool and customize it where a local solution is needed. But intimate computing implies a sense of detail; it is about supporting a diversity of people, bodies, desires, ecologies and niches.

THE WORKSHOP:
Outlining A Research Agenda for Intimate Computing

In this workshop, we address the relationship of people to ubiquitous computing, using notions of ‘intimacy’ as a lens through which to envisage future computing landscapes, but also future design practices. We consider the ways ubiquitous computing might support the small scale realities of daily life, interpersonal relations, and sociality, bearing in mind the diversity of cultural practices and values that arise as we move beyond an American context.

We perceive four interrelated perspectives and strategies for achieving these goals: (1) deriving understandings of people’s nuanced, day-to-day practices; (2) elaborating cultural sensitivities; (3) revisioning notions of mediated intimacy, through explorations of play and playfulness; and (4) exploring new concepts and methods for design. Below we elaborate on these perspectives:

1. Nuanced practices

A sense of intimacy made its way into Wesier’s thinking about ubiquitous computing. In collaboration with PARC’s anthropologists, he and his team became aware of ways in which people's daily social practices impacted their consumption and understanding of computing. They looked at the routine, finely grained, and socially ordered ways in which people use their bodies in the world to see, hear, move, interact, express and manage emotion and pondered "how were computers embedded within the complex social framework of daily activity, and how did they interplay with the rest of our densely woven physical environment (also known as the "real world")?"[27] This consideration of social frameworks and physical environments led Weiser's team to propose "calm computing" as a way of managing the consequences of a ubiquitous computing environment. Calm computing is concerned with people in their day-to-day world, with affective response (beyond psycho-physiological measures of arousal), with the body, with a sense of the body in the world, and with the inner workings and state of that body. This notion of calmness and calm technology thus echoes the sense, if not sensibility, of intimate computing. [26]

2. Culture Matters

Weiser also credits anthropologists with helping him see the slippage between cultural ideals and cultural praxis as it related to the use of computing technology in the work place. One of the issues that is very clear when we engage in a close reading of ubiquitous computing is how very grounded it is in Western practices, which makes sense given its points of origin and the realities of resource and infrastructure development. However, there have been several significant, unanticipated changes in the last decade, in particular the leapfrogging of developing countries into wireless networks and whole-sale adoption of mobile phones. It is important then to explore some of the ways in which intimacy is culturally constructed, and as such might play out differently in different geographies and cultural blocks [3;9]. We also need to explore cultural differences in the emotional significance and resonance of different objects.

3. Can Ubiquitous Computing come out and Play?

"You can discover more about a person in an hour of play than in a year of conversation" (Plato 427-347 BC). Play provides a mechanism to experiment with, enter into, and share intimacy. The correlation of play and intimacy is so strong that elements of one rarely occur without the other. It is during play that we make use of learning devices, treat toys, people and objects in novel ways, experiment with new skills, and adopt different social roles [16, 17, 18]. We make two important observations about play: (1) humans seamlessly move in and out of the context of play and (2) when at play, humans are more exploratory and more willing to entertain ambiguity in their expectations about people, artifacts, interfaces, and tools. Such conditions may more easily give rise to intimacy. Such a scenario represents a different design scenario from designing for usability and utility [6].

As ubiquitous computing researchers, we must be aware of this human tendency to play, and use it to our advantage. When does play occur? How does it begin and end? When is it appropriate or inappropriate? What elements give rise to play? The understanding of play may affect our views about the origin and experience of human intimacy.

4. New paradigms for design

It is hard to imagine that the computer, an icon of modernity, high technology and the cutting edge could in some ways be behind the times. However, its association with modernity marks it as old fashioned; as a product of modernity the computer is highly functional with a minimalist aesthetic. It approaches the modernist ideal of pure functionality with little necessity for physical presence. Computer chips become smaller and smaller black boxes offering more and more functionality, but not necessarily more intimacy.

Bergman states modernity has been admired for its "high seriousness, the moral purity and integrity, the strength of its will to change", but he also goes on to note "At the same time, it is impossible to miss some ominous undertows: a lack of empathy, an emotional aridity, a narrowness of imaginative range."[4]. Modernity in art, design, architecture and fashion are associated with aesthetics and design principles from the first half of the twentieth century [7]. Since then, movements in pop art, deconstructivism, and postmodernism have invited us beyond functionalism to new ways of thinking about how to make the impersonal computer more intimate. There are lessons in consumer product design; the founder of Swatch focused on the emotional impact of the watch to start his business, designing the watch as a fashion accessory and invoking the ideals of pop art "fun, change, variety, irreverence, wit and disposability" [21]. What might it mean to apply such lessons to the design of ubiquitous computing systems?

Goals of the workshop

Taking the above perspectives as a springboard for discussion, this workshop has the following aims:

- To bring together a multi-disciplinary group of practitioners to discus what it might mean to account for intimacy in ubiquitous computing and to consider issues like: How do notions of intimacy change over time and place? How do notions of intimacy differ as we engage in different social groups and social activities? When does intimacy lead to or become intrusion? Invasion? Stalking?
- To elaborate new methods and models in design practice that can accommodate designing for intimacy.
- To develop an agenda for future collaborations, research and design in the area of intimate computing and identify critical opportunities in this space.

Workshop Activities

We will balance presentations and discussion with collaborative, hands-on creative activities. These activities will include:

- Cluster analysis, including questions like what does intimacy cluster with semantically (ie: identity, uniqueness, personalization, friendship, connection)
- Designing intimacy within, upon and beyond the skin: build your own membrane/skin; designing supra-skin technological auras; designing for a reflective ethics

Workshop Organizers

The organizers of this workshop come from a wide range of backgrounds, including cultural anthropology, computer science, psychology and design. Together they have considerable experience in workshop organization across several disciplines.

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Ubicomp 2003 Workshop Proposal on Ubiquitous Commerce

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ABSTRACT
Ubiquitous computing offers many varied applications but will probably have its most significant impact on day-by-day living. "The most profound technologies are those that disappear," wrote Mark Weiser. "They weave themselves into the fabric of everyday life until they are indistinguishable from it." Over the past decade, researchers have sought to understand the ways ubiquitous technologies would affect different aspects of everyday activities including learning, entertainment, collaborative work and the home environment. But ultimately, new technologies will be used for conducting business. This workshop will bring together researchers and practitioners interested in the uses as well as the implications of ubiquitous commerce.

Keywords
Ubiquitous computing, pervasive computing, electronic commerce, mobile commerce

WORKSHOP THEMES
The rapid proliferation of e-commerce technologies over the past decade has fundamentally transformed the way we conduct business. This trend is expected to accelerate in the coming years due to a number of different factors, including the introduction of new mobile and ubiquitous computing technologies; the wider recognition by business of the strategic advantages offered by the implementation of ubiquitous computing and communications infrastructures; the emergence of novel business models which become possible only through this technology; and last but not least the development of new economics that can be used to understand and value ubiquitous commerce activity. There are thus, several areas of contestation that must interact to produce the conditions for the successful implementation of ubiquitous commerce. Indeed, recent experience has shown that the concerns of these (traditionally distinct) areas are intimately interrelated and thus have to be co-developed in parallel. Moreover, researchers and practitioners from all fields need to be informed of the concerns and the priorities of each other so that they can include each others requirements in their models. We propose to hold this workshop to provide a forum for the expression of this collaborative ethic across disciplines.

To this end, we have identified both vertical and horizontal axes to describe the particular areas of interest that we would like to see expressed in this workshop. At the horizontal axis we have:

- Technologies: Smart home, radio frequency identification, ubiquitous payments and value transfer, location and context awareness, agents.
- Legal: intellectual property protection, access to intellectual property, privacy protection, ownership of personal data.
- Social: effects on structures, emergent social practices, effects on roles within social organization units, identity and anonymity.
- Economics: pricing of ubiquitous services, valuation of goodwill and information goods, fair pricing for personal data and privacy.
- Business: ubiquitous business models, supply chain management and optimization, industrial design, process design, ubiquitous product development, customer relationship management.
- Experience design: appliances, architecture and building, ubiquitous commerce spaces.

At this vertical axis we have:

- Entertainment, infotainment, retailtainment and gaming.
- Tourism and experience recording.
- Ubiquitous assistance through valets and personal agents.
- Pervasive Retail.
- Remote shopping with smart home infrastructures.

- Health- and home-care.
- Industrial applications
- Automotive telematics

WORKSHOP GOALS

Ubiquitous computing has been recognized as an inherently interdisciplinary research field, requiring the collaboration between several technical disciplines including but not restricted to computing, telecommunications, human computer interfaces and industrial design. In addition to these, ubiquitous commerce requires contributions from the product development, finance, business process management, standardization, law, consumer experience design and social science points of view, to produce useful results. However, researchers with the required expertise do not have a forum to exchange ideas and concerns and develop common agendas and roadmaps for research.

The proposed ubiquitous commerce workshop will aim to bring together researchers with diverse background to:

- Share understandings and experiences as well as recognize each other's concerns.
- Foster collaboration across research communities.
- Create effective channels of communication to transfer lessons learnt from one community to the other.
- Co-develop a roadmap for future research directions.

WORKSHOP ORGANISERS

The workshop organizers have worked previously on the design and development of ubiquitous commerce systems and recognize the importance of interdisciplinary research and development teams. They have found that interaction between their respective disciplines is critical in their previous work and propose this workshop to promote this type of interdisciplinary cross-fertilization. The three organizers have a broad range of international experience and complementary expertise: GR is conducting research in the various technical aspects of ubiquitous commerce with emphasis on retail and identity management; AG is developing prototype ubiquitous commerce systems aiming to transfer the technologies to practitioners; and PK is concert with the implications of ubiquitous commerce for businesses.

George Roussos

George Roussos is a Lecturer in IT Applications at the School of Computer Science and Information Systems, Birkbeck College, University of London, U.K. Before joining Birkbeck he was the Research and Development Manager of Pouliadis Associates Corporation, Athens, Greece, where he was responsible for the strategic development plan for new IT products, primarily in the areas of knowledge management and the mobile Internet, as well as for international collaborations in new technology fields. He has also held positions as an Internet Security Officer at the Ministry of Defence, Athens, Greece, where he designed the Hellenic armed forces Internet exchange and domain name systems, and as a research fellow at Imperial College, London, UK, where he conducted research in distributed systems and algorithms.

His current research interests include ubiquitous and pervasive computing and commerce with particular emphasis on ubiquitous narratives, trailblazing and retail as well as active rules for sensor networks. George is also a director for Netsmat Technologies Ltd a start-up providing home care applications over Digital TV infrastructures to the NHS. He is a member of the ACM and an associate of the IEEE and the IEEE Computer Society. He holds a B.Sc. in (Pure) Mathematics from University of Athens, Greece, a M.Sc. in Numerical Analysis and Computing from University of Manchester Institute of Science and Technology, UK, and a Ph.D. in multi-resolution computer-aided geometric design from Imperial College, University of London, UK.

Anatole Gershman

Anatole Gershman is a partner at Accenture, one of the world's largest consulting companies and Director of Research at Accenture Technology Labs. Under his direction, the laboratory has been conducting extensive applied research in ubiquitous commerce across many industries. Anatole Gershman holds a Ph.D. in Computer Science from Yale University and has been conducting or directing applied research for over 25 years.

Panos Kourouthanassis

Panos Kourouthanassis is a Research Officer at ELTRUN the eBusiness Center hosted at the Athens University of Economics and Business (AUEB), Athens, Greece. His research interests include information systems design, ubiquitous computing and mobile business. Panos holds a B.Sc. in Information Systems and a M.Sc. in Decision Sciences both from AUEB and is preparing his Ph.D. thesis in pervasive retail information systems at the Department of Management Science and Technology, Athens University of Economics and Business (AUEB), Athens, Greece.

WORKSHOP ACTIVITIES

This workshop will attempt to attract participants with technical, business, legal and economics backgrounds as well as with experience in consumer culture research and the social implications of changes brought about from new methods to conduct commerce. The workshop will be organized around position statements and panel discussions. Participation will be invited on the basis of relevance and originality of contributions and so as to represent the multidisciplinary nature of the workshop.

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AIMS2003: Artificial Intelligence In Mobile Systems

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SUMMARY

Today's information technology is rapidly moving small computerised consumer devices and hi-tech personal appliances from the desks of research labs into sales shelves and our daily life. Various platforms from low performance PDA, embedded computers in cameras, cars, or mobile phones, up to high performance wearable computers will become essential tools in many situations for private and professional use. These systems require new interaction metaphors and methods of control. Well-known interaction devices, such as mouse and keyboard are not necessarily available, rendering user interfaces that rely on them inappropriate. Other resources such as power or networking bandwidth may be limited or unreliable depending on time and location. Moreover, the physical environment and context are changing rapidly and must be taken into account appropriately. In the future the focus will shift from single users, using single services on single artefacts towards groups of users collaborating using a combination of different services in physical spaces equipped with personal as well as public dynamically configured artefacts (ubiquitous computing or ambient technology).

Therefore, the main challenge for the success of mobile systems is the design of smart user interfaces and software that allows ubiquitous and easy access to personal information and that is flexible enough to handle changes in user context and availability of resources. Artificial intelligence has investigated the problems of making user interfaces smart and cooperative for many years and is attacking the challenges of explicitly dealing with limited resources lately. AI methods provide a range of solutions for those problems and currently seem to be one of the most promising tools for building location and situation aware mobile systems that support users at their best and behave cooperatively in unobtrusive ways.

AIMS 2003 will be the fourth workshop in a row as a successor of AIMS 2000 (with ECAI 2000, Berlin), AIMS 2001 (with IJCAI '01, Seattle), AIMS 2002 (with ECAI '02) organised by the same persons and institutions. In order to foster the investigation of AI methods in ubiquitous computing scenarios AIMS 2003 will be held in conjunction with Ubicomp 2003. A combination that we believe will be very fruitful for both research areas.

SCOPE

In the AIMS 2003 workshop we intend to bring together researchers working in the sub-fields of AI described above and those working with the design of mobile applications and devices (wearable as well as environmental). The scope of interest includes but is not limited to:

- **Location awareness**
- **Context awareness**
- **Interaction metaphors and interaction devices for mobile /ubiquitous systems**
- **Smart user interfaces for mobile /ubiquitous systems**
- **Multi-modal interfaces for mobile /ubiquitous systems**
- **Situation adapted user interfaces**
- **Adaptation to limited resources**
- **Fault tolerance**
- **Service discovery, service description languages and standards**

We encourage submissions from researchers and practitioner in academia, industry, government, and consulting. Students, researchers and practitioners are invited to submit **papers (max. 8 pages)** describing original, novel, and inspirational work. The submissions will be reviewed by an international group of researchers and practitioners.

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Author Index