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Multi-User and Ubiquitous User Interfaces

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Background and Motivation

The vision of Ubiquitous Computing bears the promise of permanent access to information and computing resources through user interfaces (UIs) accessible to every human in many different situations and contexts. Current research in intelligent and instrumented environments shows that these UIs present quite a number of challenges, such as

- new 'devices' such as tags or everywhere displays
- new UI paradigms, such as tangible, physical and hybrid UIs
- new UI metaphors for bridging the physical and virtual world
- larger and 3-dimensional space of interaction
- spatial and temporal mappings between real and virtual world
- dynamic set of devices (i.e. people moving in and out)
- dynamic adaptation among several dimensions: devices, users, services
- restrictions of technical resources in the environment
- restrictions of cognitive resources of users
- presentation planning for single users vs. groups

Another direct consequence of ubiquitous user interfaces is the fact that they are used by more than one user at a time, more specifically, this implies

- sharing of resources and control
- synchronous and asynchronous collocated collaboration
- conflict resolution such as control over parts of the environment
- supporting and monitoring social protocols for group interaction
- the need for UI metaphors for multiple simultaneous users
- public vs. private services and devices
- large UIs and specialized settings e.g. industrial control centers

The workshop is relevant to several topics from the IUI CFP, namely ubiquitous interfaces and smart environments as well as computer-supported cooperative work. Its relation to CADUI can be seen in the field of automated presentation planning and adaptation to multiple users and devices.

Contents

The better remote control – Multiuser interaction with public displays

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ABSTRACT

The issue of multiuser interaction with a single device is addressed in a typical situation of educational entertainment: the visit to a museum. To allow for these multiuser interactions, the museum is equipped with stationary systems, so called Virtual Windows, which are distributed throughout the museum. While each visitor may rent a mobile information system, based on a personal digital assistant, the number of stationary systems is significantly lower than the number of visitors in the museum. Hence, to maximize the benefit of the visitors, it is necessary to allow several users to interact with a Virtual Window at the same time. Since these multiuser interactions are uncommon to most users, a virtual character is used to support the users in their interactions.

Keywords

Multiuser interaction, mobile devices, stationary devices, virtual characters

INTRODUCTION

Intelligent computing environments, like for example a museum which is well equipped with all kinds of modern technology, pose new challenges on the design of computer-user interfaces. In such environments, the classical input devices like mouse and keyboard will loose importance. In contrast, more human like communication methods will play the key role. Personal devices will help to provide the users with personalized information based on their special interests. Despite this, large screens, that may have to be shared with other users, will still be used to display huge amounts of text and graphics.

We present some novel developments in the ongoing PEACH [16] project, dedicated to the exploitation of cultural heritage. In this project, some of the salient elements are the emphasis on multimodality in the dynamic presentation and the coherent and seamless transition between presentations running on stationary and mobile devices. This article exploits the possibilities to combine both personal mobile devices and public stationary devices, to allow multiple users to benefit of a single stationary device at the same time. This combined use of mobile and stationary devices allows large groups of users to benefit of a single public device, without physically interacting with it (i.e. interacting at a distance, which is necessary to support large groups). The supported method, used to allow several users to interact with a single stationary device, is based on the idea of a remote voting system.

PROJECT OVERVIEW

The PEACH project has the objective of studying and experimenting with various advanced technologies that can enhance cultural heritage appreciation. The research activity focuses on two technology mainstreams, natural interactivity (encompassing natural language processing, perception, image understanding, intelligent systems etc.) and microsensory systems. Throughout the project, synergy and integration of different research sectors are emphasized. Two general areas of research are highlighted: (i) the study of techniques for individual-oriented information presentation and (ii) the study of techniques for multisensorial analysis and modeling of physical spaces to unobtrusively collect information about the visitors and the environment.

The project focuses, as a case study, on a museum with beautiful frescoes (figure 2 shows two screenshots of a presentation run on a mobile device in that particular museum, for further detail, please see [9]). To underline the flexibility of our approach, another experimentation is being conducted in a world cultural heritage site dedicated to iron and steel industry.

RELATED WORK

The main goal within the PEACH project is to go one step further in the development of location-aware adaptive systems similar to the multimodal approaches presented in [14] and [15].

The problem of adapting content for (cultural) information presentations in physical ”hypernavigation” was tackled in Hyperaudio and HIPS [1] [2]. It shares many features with the problem of producing adaptive and dynamic hypermedia for virtual museums (e.g. MPIRO, [4] or dynamic encyclopedias like PEBA-II, [5]). Relevant projects focusing on mobile information presentation for a cultural visit of a town are GUIDE [7] and DeepMap [8]. A fascinating work on wearable augmented reality systems that include localization, vision, graphics and caption overlay for a person moving in a cultural outdoor environment is described in [10]. In [20], a framework allowing users to access multimedia content on a large public display by using a mobile device, is proposed. However, this framework does not support multiuser access to a single public display. In contrast, in [21], a Single Display Groupware is described, supporting collaborative work between people that are physically close to each other.

Several projects have aimed at developing concepts for combined interaction of large and small screen devices. Two examples are the PEBBLE project [12] that focuses on Computer Supported Collaborated Work with handhelds and a framework described in [13] for the distribution of media on different devices. However, none of those systems so far make use of a lifelike-character to transparently combine small and large screen devices.

TECHNICAL SETUP

In our scenario, each user carries a personal mobile device, while exploring the museum. We make use of infrared technology to locate the users (i.e. mobile devices) throughout the museum. Infrared beacons[1] installed in the museum allow us to detect both position and orientation of each device. Figure 1 illustrates the infrared technology installation.

Figure 1. Infrared beacon and overview on an exemplary infrared installation in a single room (red semicircles indicate beacon positions and ranges).

While these mobile devices are basically used to present localized information, based on the actual position/orientation of the users, they are also used to build up user models, based on the movements and interactions the users perform during their visit. Based on the collected data, a central server is capable of choosing appropriate in depth information, to be presented later on, at a Virtual Window. The communication between mobile devices, the Virtual Windows and the server is realized with standard wireless lan technology.

To improve the computer-user interaction, we make use of so called lifelike-characters [17], which may be used on both stationary and mobile devices, and which are also capable of easily moving from one device to another. User evaluations [18] have shown that the introduction of a life-like character makes presentations more enjoyable and attractive (something that we regard as very important to keep younger visitors engaged). As stated in [6], we believe, that the use of these characters may also help to guide the users attention when following presentations spanning several different devices.

While exploring the museum site, the visitors are accompanied by a personal guide, embodied by one of our lifelike-characters. When approaching a Virtual Window, the guide will automatically suggest to make use of it. However, it might happen, that the Virtual Window is already being used by somebody else. Since the system is aware of the interests of the different users, it will automatically decide, whether it would make sense to have a group of users interact with the same Virtual Window.

Figure 2. Screen shots from a running presentation on a PDA: the life-like character first presents a static graphic and then announces and starts the presentation of a video clip.

In this paper, we give a solution to deal with this situation of a heterogeneous user group, interacting with a single Virtual Window, by introducing a voting system, allowing to maximize the benefit of all users of the system. In the following section, we give a detailed description on how presentations are rendered on the Virtual Windows, and how the characters move from one device to another. Based on this technology, in the subsequent sections, we present our approach for multiuser-interactions with a single Virtual Window.

[1] Provided by the Eyeled Company, http://www.eyeled.de

PRESENTATIONS ON THE VIRTUAL WINDOWS AND TRANSITIONS BETWEEN DEVICES

The Virtual Window is the primary medium to provide the visitors with in-depth information on interesting topics. It has enough resolution to allow the full use of graphics, animations and video-clips of all kinds. If visitors approach a Virtual Window, their personal presentation agent will transit to the Virtual Window, where it appears fully sized (see Figure 5). In order to detect the visitor's relative distance to the Virtual Windows, each of them is equipped with two infrared beacons of different ranges.

When visitors approach a Virtual Window for the first time, the presentation agent proactively informs them about the Virtual Window and how to make use of it.

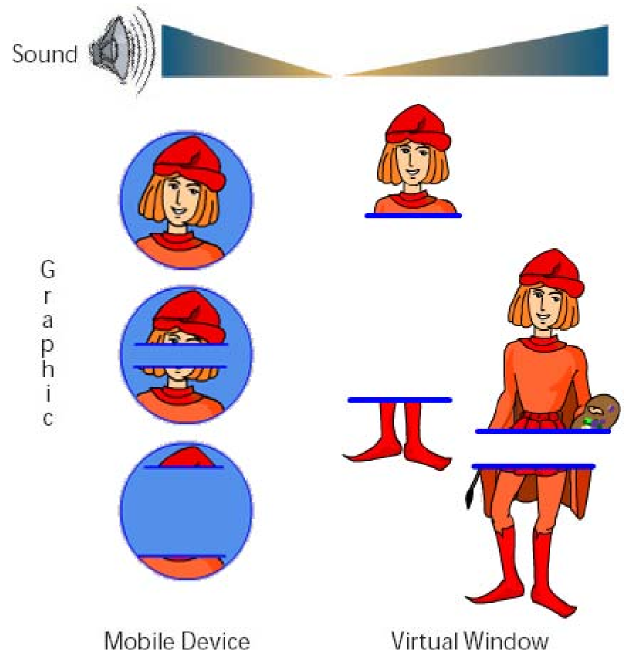

Figure 3. Key frames of the transition between the mobile device and the Virtual Window (the *beam*-effect).

If the visitors are close enough, the presentation agent starts to disappear from the mobile device and to reappear on the Virtual Window. The transition from one device to another is underlined by sounds and an animation. The key frames of such an animation are shown in figure 3. This *beam*-effect is used to guide the visitor's attention towards the Virtual Window, where they find the personal presentation agent continuing the presentation. Once the presentation agent is on the Virtual Window, the visitors can continue to coherently interact both with the agent and the presentation. In the current state of the implementation, this is held fairly simple, but future implementations may make more use of the capabilities of the Virtual Window, for example by providing a multimodal interface (see [11]). Generally, the presentation agent is playing a more active role while guiding the visitor through the presentation on a Virtual Window. Sophisticated gestures and animations thus lead to a much more lifelike appearance.

Figure 4. A screenshot of a presentation rendered for two different users sharing a single virtual window

Another functionality that we make use of is the possibility for the visitors to choose a different presentation agent before leaving the Virtual Window. Since each character represents a special interest group (e.g. in our scenario a neutral character and an art historian[2], see figure 4), the newly chosen character changes the stereotype that is used to classify the visitors and hence influences the future presentations generated by the server. Finally, when leaving the Virtual Window, the presentation agent follows the visitors and after another transition automatically reappears on the mobile device.

MULTIUSER PRESENTATIONS ON THE VIRTUAL WINDOW

When using standard devices, like for example a touchscreen, to realize multiuser applications, the first problem is to find out, which user is performing which action. There are specialized devices, like for example the MERL[3] Diamond Touch, which allows multiple users to interact with a single touchscreen. However, interacting with a touchscreen requires the users to stand directly in front of the screen, and hence they obscure part of the display for users standing behind them.

In our scenario, we want to benefit of the fact, that each user has its own mobile device. These devices may not only be used to present localized information throughout the museum, but may also serve as a user-interface when interacting with the Virtual Windows. In [6], several different methods for a combined use of Personal Digital Assistants and large remote displays have been explored.

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[2] both characters, as well as the layout of the application were designed by Peter Rist, http://www.peterrist.de

[3] The Mitsubishi Electric Research Laboratory, http://merl.com

Each Virtual Window is equipped with two infrared beacons, one with a range of about eight meters, the second one with a range of about twenty meters. When entering the area of the long range beacon, the character will either suggest to make use of the Virtual Window (if the Virtual Window is used by someone with overlapping interests, or if it is not used at all), or it will suggest to come back later.

To support multiuser interactions, we adopt the metaphor of a remote control. Users interact with the Virtual Window by pressing on buttons that are displayed on their mobile device. Using wireless-lan technology, this interaction is communicated via a server to the Virtual Window. This server also selects the content to be presented at the Virtual Window, based on the user interaction history. The user may choose different

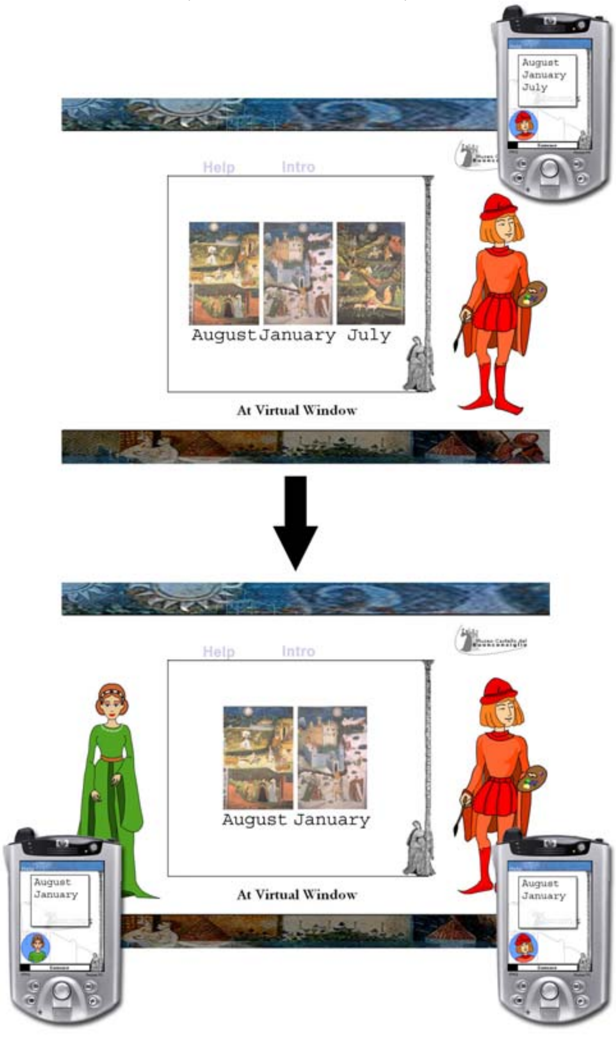

Figure 5. Content adaptation at the Virtual Window, based on the interests of a single user (upper part), and two simultaneous users (lower part)

presentations, which are arranged in a list, sorted in order of highest interest. When another user approaches the Virtual Window, the presentation lists of all users in front of the Virtual Window are combined, to form a new list, which holds only items, which are of interest to all users. In case, this list should be empty, very general presentations are included in the list, which should be of interest to most visitors of the museum. As soon as the running presentation is finished, the newly generated list is shown on each mobile device and on the Virtual Window(see figure 5). To encourage communication between users, the characters (now located on the Virtual Window, and thus visible to all users) aurally inform each other about the special interests of their users. The characters also present the topic list and ask the users to agree on a topic.

At this point, each user chooses a presentation on the mobile device. After a first user has chosen a topic, a countdown is started on the Virtual Window. Each user may make a decision until the countdown is finished, or each user has made his/her choice. In case, all users choose the same presentation, it is simply rendered on the Virtual Window. Otherwise, the server will generate a presentation, which makes use of both mobile and stationary systems, to fit the different interests of this heterogeneous user group in front of the Virtual Window. In general, the mixed presentation modes combine a public and a private audio channel (i.e. speakers at the Virtual Window and earphones connected to the mobile device) as well as a public and private video channel. Since humans are capable of focusing on a single audio source in a noisy environment (the so called cocktail-party effect[19]), it is possible to generate presentations, which "override" certain parts of the public presentation with a private one, to be shown on the mobile device. In order not to confuse the users too much, we make use of the lifelike-character to guide the user's attention. Whenever the focus is moved from the public to the private channel and vice versa, the character moves to the appropriate device. The different methods of generating presentations for heterogeneous user groups have been explored in another project and are explained in detail in [3]. When users leave the Virtual Window (during a presentation, or after a presentation has been finished), without moving their character back on their device, the character will reappear on the PDA, as soon as the PDA enters the range of another infrared beacon (which is the moment the system becomes aware of the fact, that the user is no longer located in front of the Virtual Window), not corresponding to the Virtual Window.

CONCLUSIONS

In this paper, we have discussed a new way to support multiuser interactions with a single public display. By integrating personal mobile devices in our scenario, we were able to distinguish actions performed by different users. To maximize the benefit of all users, sharing a single public display, we took into account the special interests of each user, which were determined by analyzing the interaction history within the museum, to automatically propose appropriate presentations for a particular group of users. In case, the users would not agree on a single topic, a formerly developed presentation planner was used, to generate presentations for heterogeneous user groups, making use of both private mobile devices and a public display. In a next step, we would like to refine our interaction model, so that the system will be able to find out topics, which were of special interest to the user (i.e. topics spanning several different exhibits), instead of simply relating to exhibits the user has visited prior to arriving at the Virtual Window. We also plan to improve the way, the characters encourage the users to communicate with each other, to further improve the overall museum experience.

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Concepts and issues in interfaces for multiple users and multiple devices

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ABSTRACT
In this paper, we identify and discuss several groups of issues that arise in the design of interfaces for multiple users interacting with multiple devices. We analyze in what ways these interfaces differ from traditional single-user single-device interfaces, and identify different characteristics of interfaces. We categorize a possible set of device types that may exist in an environment, and then discuss the fundamental issues that have to be addressed when designing multi-user multi-device interfaces. The focus is on user and device management, technical concerns and social concerns, and some of the topics discussed include coordination, assignment, sharing, load-limits, coverage, privacy concerns, and user alienation.

1. MOTIVATION
The design of interfaces that allow multiple users to interact with multiple devices, at the same time, and with a common set of services, is not an easy task. Users will pursue individual goals that may interfere with those of others. Additionally, many devices have been designed for individual use only. It is thus the responsibility of the user interface to find a balance that facilitates access to complex services for an optimally large proportion of the users, rather than for just a single user.

Consider for example a museum scenario, where visitors are equipped with PDAs to explore the exhibits [8]: not only are they potentially interacting with their own PDA but they may also interact with other users and public displays within the museum. Supporting all this in a consistent and transparent way is a major challenge. Further examples include airports, which nowadays feature a dense infrastructure of various in- and output devices, or the living room of the (not so distant) future, where a multitude of entertainment devices have to be controlled by a number of people. Generally speaking, as we are moving towards a world where computing and sensing devices are ubiquitous, the simultaneous interaction of many people with multiple devices becomes the standard setting.

However, interfaces for single-users have been at the centre of most research in human-computer-interaction, and a large portion of that research has focused on a stationary setting (a single person using a single desktop computer). Although research has covered multi-modal interaction in a stationary setting [12],[17],[3], there has until recently been little interest in interaction with multiple devices [2]. Similarly, interfaces for ubiquitous computing environments are a rather new field of research [4]. Furthermore, while computer-supported collaborative work (CSCW) is a well-established discipline within computer science [1], its main topic lies in the support of a distributed team of people working on a common project, rather than the coordination of possibly independent users that may be collocated but carrying out potentially unrelated tasks.

In the context of ubiquitous and mobile computing, this situation of independent and collocated users performing unrelated tasks is however very likely to occur. In order to create user interfaces that support these types of scenarios, we first need to map the problem space and identify the issues arising in a multi-user multi-device multi-service setting. The goal of this paper is hence to define the entities, events, and relationships inherent in such a scenario, and to then systematically analyse what issues are relevant for each of them. Based on this analysis, we will also present some initial implications for the design of multi-user multi-device interfaces.

2. TERMS AND DEFINITIONS
When discussing issues surrounding users, devices and interfaces, we can distinguish between four different types of interfaces based on the number of people and devices involved. Figure 1 provides an overview of the corresponding matrix. Firstly, there are single-user single-device scenarios such as a person listening to music on a walkman. If there are multiple users using a single device, e.g. watching a (silent) movie or listening to music on a radio, we can identify the scenario as a multi-user single-device setting. The traditional desktop setup – a single user interacting with a keyboard, a display, and a mouse – corresponds to a single-user multi-device setup. Finally, multi-user multi-device interfaces involve several people using multiple devices, e.g. in a ubiquitous computing scenario such as the Active Badge system [13].

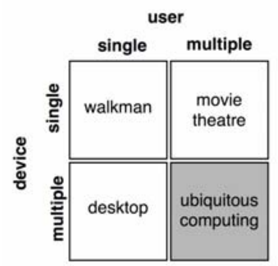

Figure 1 Different types of interfaces

The last type of interface is a very challenging one as each transition from a less complex type of interface to a more complex one introduces further issues that need to be addressed. For example, moving from single-user single-device interfaces to multi-user single-device interfaces entails questions such as who controls the device and how can the device be shared. Similarly, moving from a single-user single-device setting to a single-user multi-device setting may introduce the problem of having to fuse multi-modal input. However, prior to analyzing the key problems of multi-user multi-device interfaces, we have to precisely define what exactly constitutes such an interface and how this differs from traditional interfaces. An *interface* in our context comprises all means employed by one or more *users* to access a service provided by a computer system. Interfaces are embedded in a physical space known as an *environment,* in which interactions take place. *Interactions* represent the actions through which users communicate their goals and intentions to the system, while the physical entities used to interact with a service are called *devices* (see Figure 2).

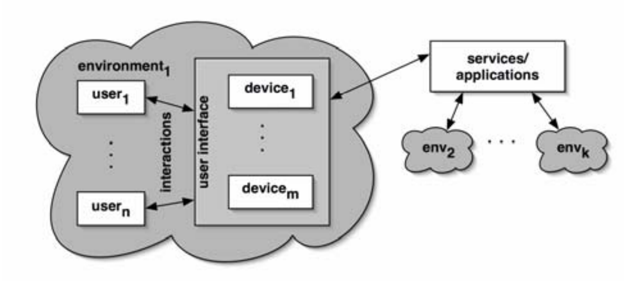

Figure 2 Situated Interfaces

One property that sets multi-user multi-device interfaces apart from other types of interfaces is the relationship they have with the environment. Unlike the traditional setup of a single user interacting with their personal computer, interactions involving multiple users and devices are inherently more closely linked to the state and affordances of the surrounding environment. Figure [2] illustrates this link via a schematic overview of the corresponding relationships, and shows that multiple users interact with a user interface that is comprised of several devices, in order to access one or more services or applications. In contrast to traditional graphical user interfaces, intelligent user interfaces may be largely transparent to the user [4], for example when a user interacts with the service through the use of a microphone. Depending on the nature of the service, additional people from remote locations may also access the services from within different environments.

2.1 Users

A first obvious distinction between traditional and multi-user multi-device interfaces is that of single user and multiple user interaction with a system. In the latter case, we can differentiate among *collaborative* and *independent* interaction. An example of collaborative use would be a small group that interacts with an electronic whiteboard [10] in order to create a project schedule. However, if several people are located in the same room, they could use (and even share) one or more public displays to read their own emails. This interaction could be classified as independent. Mixing both collaborative and independent use results in a third type of interaction, where some people collaborate, while others interact independently with the system, for example in the case where the interactions described above occur in the same room. A further distinction in this context is that users of a system or service may be *collocated*, *distributed* (located at different sites), or again a combination of both. Figure 3 summarises the characteristics of users in a multi-dimensional graph that spans the design space.

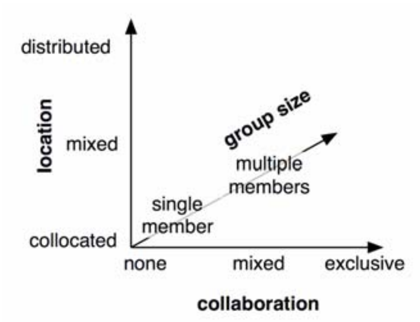

Figure 3 Characteristics of users

2.2 Devices

In order to access a service or application, a user (or group of users) utilizes various devices such as a keyboard, mouse, or display. While we can distinguish between the use of a *single device* and the use of *multiple devices*, the use of multiple devices, (e.g. mouse and keyboard), is far more common. However, it should also be considered that multiple devices are harder to coordinate, and the use of a single device may well still be necessary, for example when a large number of people are all competing for a small number of devices that must ultimately be shared. A device may allow for *input, output,* or both, and provide for *private* or *public* use. For example, microphones only support input while speakers only support output and touch screens can be used for both. Headphones privately transmit their output to a single user, while a public loudspeaker does not. Furthermore, we can distinguish between devices that afford *shared* use and those that do not. A large public display is an example of a device offering shared use, whereas the display on a Pocket PC offers non-shared use.

In a ubiquitous environment, we can distinguish between several classes of *interface devices*, depending on their function and capability. On the one hand, there is a group of devices that are primarily *dedicated* to the handling of input and output such as displays, keyboards and cameras. On the other hand, there are devices (in the sense of the above definition) that fulfil other functions in everyday life such as tables, books and coffee mugs.

This latter group of *non-dedicated* devices can be further partitioned, based on whether or not they have been augmented or *enhanced*. For example, we can attach a sensor [5], such as a Radio Frequency ID (RFID) tag to an object like a book to enable a ubiquitous environment to better perceive it, and to facilitate its identification. If an object is non-augmented, it can be classified as *non-enhanced*, for example a non-tagged coffee mug. Enhanced devices may be *passive* in that they require the environment to detect their presence, such as the book example above. They can alternatively be *active* in that they pursue interaction with their environment such as a weight-sensitive table. Figure 4 depicts this classification of device types, which may interact with a system.

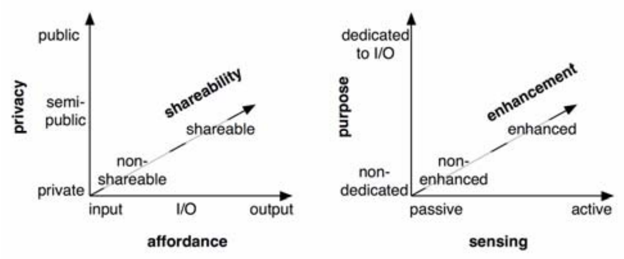

Figure 4 Device properties

2.3 Interactions

In comparison to single-user single-device scenarios, the actual interactions themselves may also have to be much richer, for example, to enable multiple users to interact simultaneously. This may require the use of different modalities such as the auditory, tactile or haptic channel, as well as the need to fuse multi-modal input in order to make sense of the users' input [14]. Furthermore, there are novel types of interactions compared to a single-user setting – such as two users jointly performing a gesture or action.

The interactions may take place *directly* with environment entities (e.g. picking up an object in the room), *indirectly* (e.g. selecting the same object represented digitally on a display), or through a combination of both (e.g. selecting some objects represented on a display, while pointing to other objects in the real world). Direct and indirect interactions are displayed in Figure 5.

Figure 5 Direct and indirect interaction with environment entities.

Tied to this notion is the idea that entities can accordingly be represented *physically*, or *digitally*. In [7], a continuum of coherence is proposed to categorize the relationship between digital and physical representations of the objects. Coherence in this sense refers to the extent in which physical and digital objects are perceived as being the same thing. When coherence is weak, there is no link between a physical and digital representation of an object, whereas when the coherence is strong, the user can no longer differentiate between digital or physical representations of the object.

As a result, interactions must be defined to uniformly and intuitively span communication with objects represented in different ways. The interaction may (as described above) be with the same object represented at one time physically and at another time digitally, or even with different objects, some represented digitally, while others represented physically, for example "read me this book [physical pointing gesture] through these speakers [stylus gesture on a display]".

Human interactions are fairly complex. Along with spanning differing object representations, interaction must also span the use of differing types of input mediums, such as speech and gesture. A person may in one instance interact solely through speech, while at another instance through gesture. Each input medium requires its own interaction library. For speech, this would be the language model, while for gesture it would be the gesture model (e.g. 'point', 'pick up', or 'put down'). Similar to above, different modalities may also be combined, and this can often lead to more natural and more robust levels of interaction [16].

3. DESIGN ISSUES

There are a number of concerns that are specific to multi-user multi-device interfaces. While we can roughly group these into *management, technical and social* issues, they are often hard to classify due to overlapping categories. For example, while the assignment of a specific device to a user is a management problem, it also has a technical component (e.g. how to represent the assignment internally) as well as a social one (e.g. who is authorized to claim a device for personal usage). Therefore, our grouping of issues under the categories of management, technical and social should not be perceived as being mutually exclusive.

3.1 Management issues

In a highly dynamic environment, a very fundamental problem is that of the initial *registration* and later *identification* of users and devices as they enter and leave the environment. This is vital for a system if it is to have an overview of its own composition and current capabilities. Registration and identification may be further complemented by *verification* (especially for sensitive services), which may provide information on the user's accessibility to devices and services, their group membership, and their individual communication preferences.

Device assignment is another aspect that impacts multiple user settings far more than single user settings. Firstly, the devices present in an environment have to be assigned to a specific service and/or user. This is not a simple 1:1 relationship, since multiple users may use the same device to access several services at the one time, and a single service may require the use of multiple devices to operate at another time. Furthermore, the ratio of assigning devices to users is not only dependent on the type of service and the number of users, but also on the type of device, and environment settings such as the location and the level of surrounding background noise. In contrast, a single-user scenario is usually fairly static with regards to the relationship between devices, services and the user. A second difference is that it is harder to assign the resulting observations made by various devices to a specific user and/or service, because there are a greater number of possible relationships and the number of devices and/or users may change dynamically, thus requiring continual reassignment.

Another key issue not found in single-user setups is that of *device control* [15]. Conflicts in control occur for example, when users compete for the same device that is either non-shareable or which one user does not want to share. A system handling multi-user multi-device interactions must not only provide a means for conflict-resolution but must do so without patronizing its users. This may require a model of social hierarchies and/or interactions as well as the continuous monitoring of intra-human interactions. Even if a device is shareable, conflicts may still arise through the type of services being used, for example surfing the Internet and watching a movie, in which the foreground noise in watching a movie may result in an excessive level of background noise for surfing the Internet.

The number of available devices is a limiting factor on the number of users an environment can support. If the number of users rises faster than the number of available devices, the services will ultimately be bound by a *load-limit*. As an example, if no additional devices are added to an environment, services will become unavailable to new users when all of the devices become engaged. If users were to supply their own device(s) in addition to those already existing (e.g. a PDA), the number of users able to interact with services would increase. An issue relating to user's supplying their own devices, is that these devices must then support a communication protocol compatible with the underlying services of that environment, and that the user will then also be burdened with the need to carry their device around with them while interacting.

3.2 Technical issues

A further difference that arises through interacting with multiple devices is that of *device handling*, which allows for the control of specific device features, and also defines how a service should respond when a device is suddenly introduced or removed from an interaction. When an interaction spans several devices, as is in the case of media fusion (i.e. combining multiple input types) and media fission (i.e. combining multiple output types) [[12],[17]], the *synchronization* between these devices also becomes important. A further issue is that of device *interference*. This is not only important on an interaction level, for example when many different public audio channels are actively presenting media to a small space, but also on a hardware level, in which interfering radio signals may affect the control of several wireless devices.

C*overage* also constitutes a relevant factor, as users can only interact and communicate if they are in range of an adequate and available device. The level of coverage varies per device, for example speakers will provide better access to a crowd of people compared to a single display. Coverage also depends on the physical placement of devices (e.g. high up, low down), and on the expected density of users for a given physical space, for example well-known paintings in a museum would attract many more users.

In situations that are more mobile than the traditional desktop, the *localization* of users and devices also becomes relevant. This is seen in the example "play me that [gesture] CD", in which localization information may aid in the identification of both the user and the CD. Identification (as introduced in section 3.1) may be biometric-based (e.g. face recognition), or hardware-based (e.g. wearable devices), and the process may be either automatic (e.g. active tags [13]) or manual (e.g. Dallas Semiconductor's iButton [6]). It may furthermore be intrusive to other users (e.g. speech), or non-intrusive (e.g. smart floor [8]), and the robustness of identification may be affected by environment conditions such as low-light, or high levels of noise.

Depending on the type of device, *energy consumption* will also be relevant, and finally *system performance* will become an issue as the overall complexity of an environment grows through increased multiple user and multiple device interactions.

3.3 Social issues

Social issues constitute another major difference between traditional interfaces and multi-user multi-device interfaces. There are certain *social rules* for example that a system has to be aware of when collocated people are interacting with a system, such as turn-taking in conversations, and respecting the sensory space of people that form a closed working group. Another social issue that may influence factors such as device allocation for input and output, is whether users are *collaborating* or performing *independent* and unrelated tasks. *Detecting a switch* from collaborative to independent work can also be problematic as it can be gradual or interwoven, for example a person that reads email but occasionally participates in a collocated collaborative task. If objects such as coffee mugs are enhanced, the *disambiguation* between everyday use and system interaction also becomes important. Furthermore, since people often interact with both services and other users, it may be relevant to keep track of the *interpersonal communication* or underlying semantics in their user history. For example, people may discuss several alternatives that the system is displaying and rule out some of them without explicitly communicating it to the system.

Privacy is another important social issue that must be considered when multiple users are collocated and are interacting independently with one another. Some devices are inherently unsuitable for supporting privacy, such as microphones, speakers and public displays. The correlation between the type of service and the privacy required must also be considered, as well as the users' personal desire to be given their own space to interact in. One disadvantage arising from privacy is that the social impact of multi-user multi-device interfaces is hard to foresee, and may lead to alienation and isolation. For example, if members of different groups (parents and children in a family), are forced to wear headphones due to half the family watching the news while the other half watching cartoons, interaction between the different groups and even members within each group will be severely limited through the lack of commonality between users, and the type of presentation devices being used.

4. DESIGN IMPLICATIONS

The issues we discussed in the previous section provide some initial guidelines of what to look out for when designing a multi-user multi-device interface. However, we can derive some further implications from these observations that can inform the design process.

Firstly, the multitude of new issues compared to single-user (single-device) interfaces implies that the problem space is larger by an order of magnitude. Consequently, the scalability of an interface plays an important role not only because more problems may be encountered but also because effort required to interpret interactions may increase very rapidly as the number of users and/or devices grows. Hence, designers should pay extra attention to the scalability of the interface.

Secondly, multi-user multi-device interfaces introduce new ways of how things can go wrong. For example, in multi-modal interfaces employing speech recognition, not only the content of an utterance has to be recognized but also the speaker. It may even be necessary to do so while several people are talking at the same time. Also, intra-human interaction has to be distinguished from human-computer interaction. Consequently, interface designers have to emphasize robustness and consistency even more than in traditional interface design.

Thirdly, a multi-user multi-device scenario is likely to be more dynamic than, for example, a traditional desktop setting. This implies that the design of a suitable interface should include specifications on how to react to changes such as the addition/removal of devices. In order to avoid disruptions in the interface, a sophisticated representation format incorporating for example spatial and temporal constraints may be necessary.

The implications listed above are but a few examples for what to derive from the issues we identified in the previous section. However, they may serve as a starting point for further research.

5. CONCLUSION

In this paper, we provided a first mapping of the problem space for designing interfaces for multiple users and multiple devices. We defined the fundamental terms and entities as well as their relationship in this scenario: users, devices, and interactions. We then identified key problems in several core areas, namely management, technical, and social issues. Based on these issues, we provided a few examples for design guidelines that can be derived from the issues pointed out previously. The research presented in this paper can serve as a starting point to further explore the problem space of multi-user multi-device interfaces in a systematic way.

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Enhanced Reality Live Role Playing

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ABSTRACT
Live role-playing is a form of improvisational theatre played for the experience of the performers and without an audience. These games form a challenging application domain for ubiquitous technology. We discuss the design options for enhanced reality live role playing and the role of technology in live role playing games.

Keywords
Enhanced reality, interactive artifacts, context-adaptive narrative

INTRODUCTION

Rapid technological developments in recent years have made computers common and available in various different forms, including being embedded into everyday things. However, it is not obvious how the potential of such complex computational environments are to be presented and used by humans. Researchers have started to address this issue during the last few years in research programs such as the EU-funded Disappearing Computer Initiative.

Live Action Role Playing games (referred to as LARPs hereafter) have been proposed as a fruitful environment to explore how pervasive or ubiquitous computing can augment social interaction [11]. We believe that live role play offer several additional motivations for being used as a context for researching ubiquitous computing systems.

- This application area is a highly demanding design space where any technological affordances of a device must be totally hidden or disguised. To have the players accept an artifact, it has to completely blend in with the setting or it will be rejected.
- The use of these systems is varied as they can be both used by people organizing games and people orchestrating interactive experiences [8]. Through the study of augmented LARPs, new technology is exposed to extreme use situations in order to more easily identify potential problems that are also present, but not as evident, in an everyday, mundane use scenario.
- Both the actual games, and the technology used in the games, are chosen and modified by the participants. To support LARPs, technology must be usable and explainable in non-technical terms. It must also be highly configurable in equally simple and purpose-oriented ways.
- Games are often played outdoors, putting real-life design challenges on the system to handle environmental conditions such as lighting and weather, as well as problems with power consumption, design robustness, system coverage (tracking and wireless networks), mobility and deployment.
- LARPs can function as a testing ground for exploring methods for interpreting and using sensors (see [1,3,7] for non-roleplaying game examples) due to the willingness of participants to have an active suspension of disbelief.

LEAVE BLANK THE LAST 2.5 cm (1") OF THE LEFT COLUMN ON THE FIRST PAGE FOR THE COPYRIGHT NOTICE.

Figure 1. "The Conquest of the Galtar Cliff" a Carrousel staged by the Swedish King Gustav III 1778, based on a Celtic fairy-tale.

BACKGROUND

Historical Live Role Play

An early example of a type live role play are the 'carrousel' games, a form of live role play often performed at the European courts during the 17^{th} and 18^{th} centuries in connection with coronations and other ceremonies. Under the monarch's supervision, the members of the court, the noblesse and the servants wearing valuable costumes and full-scale stage settings, reconstructed ancient battles, tourneys or mythological tableaus. The 18th century carrousels were very expensive events with budgets that would correspond to millions of dollars today.

Psychodrama

The second birth of Live Role Playing occurred in Vienna in the 1920s when the psychoanalyst Jacob Levy Moreno made his patients collectively treat their traumas by improvised role-playing [6]. This has since become an established therapeutic method, both in the so-called "psychodrama" and in conventional psychotherapy.

Psychodrama employs guided dramatic action to examine problems or issues raised by an individual (psychodrama) or a group (sociodrama). Using experiential methods, sociometry, role theory, and group dynamics, psychodrama provides a safe, supportive environment in which to practice new and more effective roles and behaviors.

To provide a safe environment for the experience, that sometimes can be quite dramatic, psychodrama employees an organized structure in which the experience is contained. In a classically structured psychodrama session, there are three distinct phases of group interaction: the warm-up where theme and protagonist is selected, the action where the problem is dramatized and the protagonist explores new methods of resolving it, and the sharing where group members are invited to express their connection with the protagonist's work.

Contemporary Role Play

Contemporary live role-playing consists of two additional variants besides the therapeutic: educational role-playing and role-playing for leisure and entertainment.

The use of role-playing within education is similar to that of therapeutic role playing, and aimed at giving the participants a understanding of their own and others actions in new or critical situations. The participants act out a scenario where the prerequisites are determined before the event, but the development of the scenario is influenced by the participants and directly changed by the event leader. Afterwards, the leader and the group analyze the cause of actions together in order to explore what alternatives existed and what could have been done differently.

Modern live action role-playing for leisure and entertainment stems from two origins. There have existed reenactment groups in the U.K and the U.S. for a long time, focusing on the detailed study and reenactment of a historical event or time period. One such example is the US-based medieval recreation organization SCA, Society of Creative Anachronism, which was started in 1966. This society has grown to a world-wide organization including over 24,000 paying members and with many more participating in events. The other origin is the development of table-top role-playing games during the 1970ies. In the early 1980's some players, influenced by improvised theatre, started to perform their adventures with their physical bodies in a real surrounding, thereby inventing the current form of LARPs.

The development of modern role play activities has been very rapid. During the 1980ies, LARPs was a very narrow sub-culture playing almost completely in the world of Tolkien fantasy. Today, especially in Scandinavia and UK, it is a growing popular movement for people of all ages and every game stretches the boundaries of the subjects explored. One recent example is 'En resa som ingen annan' (A journey like none else), an educational game directed to high school students that stages the experience of a fugitive fleeing from a foreign country and seeking asylum in Sweden. This particular game was staged in October 2003 at the historical museum in Stockholm, in collaboration between a professional theatre ensemble and SVEROK, an umbrella organization for live role players (and other types of gamers) in Sweden.

CHALLENGES AND OPPORTUNITIES TO COMBINE UBIQUITOUS COMPUTING AND LARPs

Content from Many Sources

The LARP community has a strong tradition in creating their own games. The organizers of a LARP often spend a year or more constructing the conditions (the game world, the intrigue, the roles etc.) for the game. The participants work equally as much on designing their characters, props, and costumes. (LARPers often play the same character throughout a sequence of games.) During the game session, everybody contributes to the content by means of their improvised performances. As opposed to a computerized game, there are no limits to what the participants can do in the game. It is for example not unusual for players to invent subplots while gaming, that were not part of the original design.

The problem of the game master role

In traditional table-top role playing games, the game flow is controlled by a game master that monitors all events and decides on the story line. In LARPs, this role is weaker: the game organizers have both too little insight into the events that are happening, in particular if the game occurs over a large area, and too few means to influence players. A number of techniques have been developed to deal with this problem. In particular, game masters will control the flow of information in the game through spreading rumors at appropriate times.

Supporting Free Play

Regan and Inkpen [9] classify LARPs as *free play* activities which have been argued allow participants to develop physical, mental and social skills [13]. Free play has been defined by five characteristic factors (Voluntary, Spontaneous, Require Make-Believe, Engaging, Enjoyable) which can be seen as functional requirements that any technology must support [9]. Further, supporting social interaction and physical activity has been suggested as additional requirements [10]. Supporting these elements through use of ubiquitous computing can not only offer possibilities to enhance the experience but also allow functionality that otherwise would be difficult or resource consuming to provide (e.g. summaries of previous events or synchronizing geographically separated players).

THE ROLE OF TECHNOLOGY IN LIVE ACTION ROLE PLAYING

Enhanced Reality

The 'in-game' experience in a LARP is primarily obtained from setting the game in a suitable environment, but also from the clothes worn and the equipment used. Although LARP organizers take great effort to create as realistic environments as possible, there are limitations as to what can be done in this way. Here, ubiquitous technology can play a role to create an enhanced or even 'enchanted' [5] reality experience. When we explore this option, it is important to examine the possible roles (and here we mean roles in the same way as actors take roles) technology can play in a live action role playing game.

The first and most obvious role that technology can take is to *represent itself*. A mobile phone can 'play' a mobile phone, a TV a TV, and so on. This is particularly useful when role playing is used for training purposes, such as in a crisis team, but can of course be used in any appropriate game setting. Behind the scenes, the content distributed over the phone and TV is simulated or part of the LARP performance, possibly adapted to the current game flow to create an interesting or realistic situation.

Information technology can also be *redressed as some other technology*. Games that play in an alien setting such as a different time period, a fantasy world, or a futuristic scenario, benefit from a reality-enhanced setting in that the alien technology can be simulated. Simulating magic is an example of this (in line with Arthur C. Clarke's [4] saying: "any sufficiently advanced technology is indistinguishable from magic") and well-known magical artifacts like crystal balls, magical mirrors or wizard books might from that perspective be defined as technology. An interesting variant is when technology is used to simulate old technology that is difficult or expensive to recreate in today's world. As pointed out by Binsted [2], the fact that the purpose and usage models of magic artifacts are well-known from folk tales and fantasy stories, make them a powerful design metaphor for ubiquitous technology also outside fictional domains.

Another use of technology is to *extend and enhance our bodies*. Examples from the fantasy world could be that elves have better hearing than humans, and orcs can see in the dark. This can be reached using embedded technology hidden in costumes, masks etc. Technology can also enable us to play entirely non-human beings; animals or aliens. (As we saw from the 18th century example, it has always been popular to play mechanical monsters.) One example of this type of technology is the Elf-ear (see figure 3), a final year student project at Blekinge Institute of Technology. The project focused on realizing the elves supernatural hearing ability. The main aspect considered during the design of the Elf-ear was that LARP sessions are extremely sensitive to disturbances from the "outer" world, 'real world intrusion', and the main problem was to adapt today's technology to a form that would not break the 'in-game' experience.

Figure 3. Wearing elf ears.

Finally, technology support can be *entirely invisible*, and take no overt role in the actual game. The major use of invisible technology would be to aid the game master role, by tracking events in the game using sensors attached to participants or objects, or embedded in the environment. This information can then be used by a game master or an automatic game manager to control the flow of events and information in the game. But invisible technology can also be useful to extend the player experience. Participants may for example wear headsets that produce a sound landscape, or 'whisper thoughts' into the ears of the participants to inform them and help them to realize the role they are playing.

User Created Content

Content creation for ordinary computer and console games is one of the major costs in game production. This is a seen as a worthwhile investment not only because it is one of the main selling points of games but because developers can control how players experience the content, guaranteeing that at least the majority of the content is experienced during the playing of a whole game. For pervasive games this is not necessarily the case, especially if the game is one that is location dependent. Location specific content is necessary, so creating the content for a pervasive game that is going to be released on a worldwide basis is not feasible; creating content that is general enough to fit any specific location may be possible but risks being bland as it does not adapt to the local situation.

Thus, enhanced reality games require new methods to handle the creation and insertion of player content. With game content we do not primarily mean created media, like sound or images, but narrative components and game play elements.

In the LARP setting, we also have the issue of player-generated technology. The addition of computational capabilities to everyday objects gives these objects the possibility to have internal states that modify their behavior and be able to change the way they change their behavior. For users to reap the full benefit from ubiquitous computing, they must be able to control the objects' behavior themselves; in essence being able to program or configure them in a direct, explicit way. Using traditional programming methods is unfeasible due to the large number of devices and would also require that all users had programming skills. Even if one disregards these two objectives, the lack of computer screen and keyboard on artifacts that hide their computational affordances would require that configuration of devices take place at a traditional computer either before an activity or by interrupting the activity. To solve this problem, techniques for end-user programming that are self-contained within the objects need to be developed.

Support for Story Adaptation

Story formation and control in Live Action Role Playing has large similarities to that in interactive narratives [8]. The LARP 'game master' role is very similar to the role of an automatic story control engine in an interactive narrative. But there are also large differences. One lies in the level of control that the game master can exert over the players and the environment: in an interactive narrative, the game master is in full control over artificial players and events in the environment, to the level of controlling the thoughts of players. In the LARP setting, the situation is reversed: To support free play, the game master must constantly adapt the story line to player's improvisations and spurious events in the environment (such as when it starts to rain), and is limited to weak means of influencing people in their actions, most notably through information spread. Furthermore, as opposed from typical games, there are few limits on what participants can do. In this sense, LARPs are also different from massive multiplayer online games, where there is a certain room for user improvisation in the dialogue and social interplay between players but where the game designers still are able to control exactly which events can happen and what they should lead to. Finally, a LARP game master is restricted to unreliable and incomplete information sources. The game master must be equipped with some sort of 'control room' interface, but here we cannot rely on the control room as a place; administration must be performed on location, and administrators must be able to enter social environments where ubiquitous computing systems support various activities without interrupting the 'in-game' activity.

Post-Event Documentation

Even when a game is designed to be played several times, the game can take many different directions and each game event is a new experience. Furthermore, not all players experience the same thing, even though participating in the same event. This is partly due to players being distributed in space. But it is also common to design a LARP story as one overall story and a set of substories, where each player only has a role in one or a few of the substories. Finally, we must consider that free play activities should enable people to enter and leave at will: some participants may come in late in the game, or leave for a part of the time.

These properties make it extremely interesting to the participants to obtain proper documentation of the events. One important usage of ubiquitous technology in game events is thus as a means of documenting the game, possibly in ways that help the gamers to edit the collected documentation into personal stories about the event.

TWO EXAMPLE GAMES

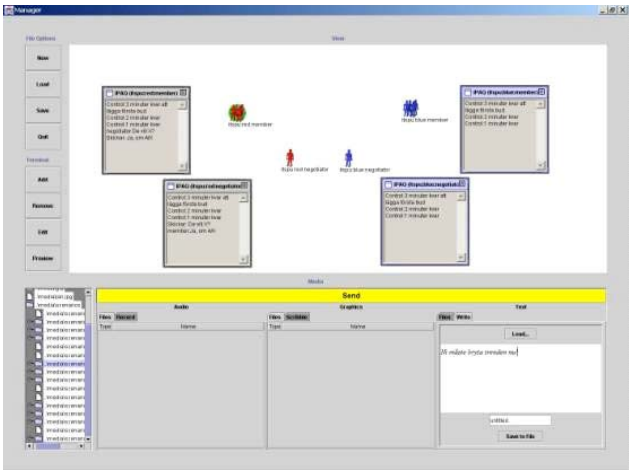

Figure 3. The game leader interface in ItsPU.

ItsPu

In ITsPU[1] (IT support for workforce education) a short-term project performed in collaboration with VINNOVA (Swedish Agency for Innovation Systems) a professional management and team-building course was played out with the aid of pervasive technology. Together with two small companies a demonstrator was developed to explore the usage of mobile technology in this area.

The game chosen was a negotiation game between two teams with a fairly strict rule set and was acted out between players in the same room. The technology used in this project consisted of hand-held computers and a laptop for the leader connected by wireless communication. The software developed enabled players to communicate within each team without revealing information to the other team. The software also let leaders influence the course of the games.

The results of the game tests were quite promising. For the two participating companies the new technology resulted in an increased quality of their services in three ways. The most important effect was that the leader/game manager role was enhanced, since the use of technology in player to player communication provided the game leader with better and more discrete control of the cause of actions. Furthermore, the participants gained an richer 'in-game' experience from playing the game with technology support. Finally, the use of portable technology made it possible to use space directly in a game that otherwise is bound to a table-top game setup.

Alien Revival

This game concept was developed as part of a Ph.D. course in Interactive Narratives at Stockholm University. The task

[1] http://www.sics.se/ice/projects/itspu/

was to create a concept based on the movie Alien, which the group choose to do through enhanced reality.

The game was designed to be played in a claustrophobic environment, such as an underground culvert system or a cellar. The participants would be equipped with a PDA used as a tracking device that would show the position of the alien, and later in the game, function as a weapon. They would also wear a headset both as a communication device, and to represent the alien by a sound landscape. Sounds from the alien would be heard when the alien was close (slippery, running footsteps) or attacking (a far more menacing and sudden sound). One interesting design choice made was that the visual and audio devices would simulate faulty equipment: sounds would be distorted and tracks on the tracking device would sometimes disappear.

The perhaps mot interesting design feature was the idea of a link between the alien and a cat. The cat was played by a live cat, walking around in the corridors, equipped with a position tracking device. The position of the cat was known to the alien, which was played by a very simple virtual agent, with a very primitive self-preservation behavior: hunger, some fear for weapons (at least when it was still young and small), and a like for cats. This meant that when a player saw the cat, the risk that the alien was also close would be greater.

The Alien Revival example shows how fairly simple device technology can be used to create a very strong 'in-game' experience. The example of the cat shows that it is also useful to enable the game to adapt to events that are not controlled by the game engine, in this case the movements of the cat.

CONCLUSIONS

We have discussed how live role playing forms a particularly interesting and challenging context for ubiquitous technology, and provided two rather different scenarios of how ubiquitous technology can be used to support role playing games.

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Supporting Interaction with Office Door Displays

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ABSTRACT
Despite the interest surrounding 'ubiquitous computing', the number of deployed and evaluated ubicomp systems is still relatively small and consequently our understanding of some of the issues surrounding interaction with such systems is still somewhat limited. In this paper, we share our experiences of supporting interaction with office door displays deployed within the computing department of Lancaster University. The collection of ten displays (known as Hermes) are fully operational (twenty four seven) and are used every day within the department and could (at least along two main corridors in the department) be classed as ubiquitous. The first Hermes displays were deployed nearly two years ago and since that time various modifications have been made to support the diverse interaction needs of the Hermes owner community.

Keywords
Ubiquitous Computing, Situated and Remote Interaction

INTRODUCTION
Despite the interest surrounding 'ubiquitous computing' with Weiser's vision of computers "interwoven into the fabric of everyday life" [11] the number of deployed and evaluated ubicomp systems is still relatively small and consequently our understanding of some of the issues surrounding interaction with such systems is still somewhat limited.

In this paper, we share some of our experiences (over nearly two years) of supporting interaction between ubiquitous (at least along two main corridors in the Lancaster University Computing department) office door displays and the 'owners' of these displays. The name given to the collection of office door displays is Hermes [1,2,3] (named after the messenger to the gods in Greek mythology).

Hermes provides simple asynchronous messaging services, enabling an office occupant to share context (should they desire to do so) by leaving graphical and textural messages that can be viewed by anyone passing their office, Hermes also allows visitors to an office to leave messages for the occupant. We provide a variety of mechanisms for users to interact with the Hermes system, both locally and remotely, so users can select the most appropriate methods for their circumstances. All use of Hermes is logged so we can study the patterns of interaction which occur [1]. The development process of Hermes is driven using a user-centred participatory design based approach, and this is where it differs from broadly similar commercial products such as Appliance Studios' RoomWizard™ [10] and ePortal from Tegralis [4].

As the number of deployed Hermes displays has increased, the number of different mechanisms available to owners to interact with their door displays has also increased in order to encompass the diverse interaction needs of the Hermes owner community.

The next section presents a short overview of the Hermes system, followed by a description of the mechanisms available from owners to interact with their Hermes displays. The fourth section presents related work and the final section presents a summary and concluding remarks.

AN OVERVIEW OF THE HERMES SYSTEM
Our work on developing Hermes displays started in October 2001. The hardware and software solution chosen was based around a PocketPC based PDA running the CrEme JVM, and using the departments 802.11b wireless network for communication with a central server (please see [3] for more details of the Hermes architecture).

Figure 1: An early Hermes door display.

The PDAs are securely housed a purpose built aluminium cases (figure 1). The ten units currently deployed are situated along two main corridors within the computing department. A view along one of these corridors is shown in figure 2. One reason for deploying the units in this concentrated way (rather than having just one or two units deployed per corridor in the department) is that it gives the appearance of the Hermes displays a kind of normality and also helps to provide one with a sense for how the displays might be accepted if deployed truly ubiquitously throughout the department.

Figure 2: A concentration of Hermes displays.

Visitors can leave a note for the owner of a Hermes display by simply walking up to the device tapping the 'leave note' button and then scribbling a message on the display using the attached stylus. U.K. disabilities legislation states that public facilities need to be positioned at a height that does not unduly discriminate against people using a wheelchair. For this reason, it was necessary to place the units at a fairly low height (approximately 150 cm) off the floor. However, one of the implications of this is that taller people do have to stoop in order to leave a message. We are hoping to design a new 'movable' casing to help solve this problem.

When a message is left by a visitor, the note does not remain on the screen. Furthermore, any message left by a visitor is automatically removed from display if the visitor accidentally (or indeed deliberately) does not tap on the 'finished' button after scribbling their message. This aspect of the behaviour of the system was requested by the owners of Hermes displays who did not want 'inappropriate' messages appearing for public view outside their office door [3].

The owners of Hermes displays can read messages left for them via a web interface, an e-mail client, or by using any of the deployed Hermes displays (once a short authentication process has been completed).

As regards enabling a Hermes display owner to leave a message on their display, a number of mechanisms are currently available and these are discussed in the following section.

MECHANISMS AVAILABLE TO AN OWNER FOR INTERACTING WITH THEIR HERMES DISPLAY

Using a Web-based Interface

Initially, the only way with which an owner could interact with their office display was through a web interface (figure 3). Through this interface users can set either a default or a temporary message. A default message is displayed as a form of background message and is usually used to display a picture or a piece of text such as "Please leave a message". When a temporary message is set, this message will replace the default message but once dismissed the default message will once again be displayed.

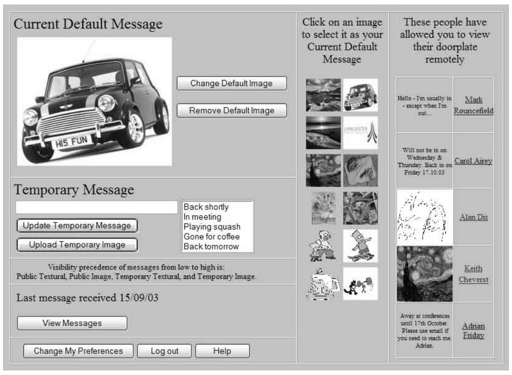

Figure 3: The Hermes web interface.

The web interface is currently being modified to enable the owner of a Hermes display to observe the displays of other Hermes owners that have set appropriate permissions. This facility is intended to support micro-coordination and help save wasted journeys to an unoccupied colleague's office. At one level, this functionality represents a kind of web based in/out board but rather than simply receiving two-state values (i.e. 'in' or 'out') Hermes owners tend to provide a far greater degree of context on their Hermes displays. Recent analysis of 300 sample messages showed that over 80% contained some additional context information, such as the owner's location, activity or expected return time back to the office [1].

One problem associated with the use of the web interface for setting messages is that unless the web page happens to be a foreground window on an owner's desktop then no visual prompting is provided to the owner to remind him or her to set a message. Consequently, a number of Hermes owners found that they would walk out of their office without setting a message, see their Hermes display, realize that they had not set a message and then either return to their office to leave a message via the web interface, or, more often than not, make themselves a pledge to remember next time! Our first solution to this problem was to enable owners to set messages using the Hermes display itself.

Using the Hermes Display

An owner may use the touch sensitive screen of the Hermes display itself to leave a highly expressive message by firstly completing a short (username/PIN) authentication procedure. An example of this is shown in figure 4.

Figure 4: One Hermes owner's expression of being 'busy'.

Although this particular method of leaving a message was very popular for one particular Hermes owner, it was apparent that many owners were finding the authentication task too time consuming (even for units supporting iButton based authentication). Consequently (and following discussions with owners) we introduced a more time efficient (though less secure) mechanism for enabling an owner to set a temporary message using their Hermes display. In more detail, owners can set messages (from a predefined list) with only two taps on their Hermes display. The first tap brings up the interface shown in figure 5, the owner can then tap on the appropriate button in order to select the message of their choice. It is possible for a user to change their list of predefined messages via a web form accessible from the web interface shown in figure 3.

A temporary message can be removed quickly and simply by tapping the screen of the Hermes display. For this reason, if an owner wishes to ensure that a message is not accidentally (or deliberately) removed, they are advised to set the message as a 'default' message.

Figure 5: UI for setting a temporary message.

Using a Tangible Interface

Interestingly, some owners commented that even the Hermes display itself did not provide an appropriate/sufficient visual prompt for setting a message. Indeed, one owner in particular commented that although he was a strong advocate of the Hermes concept he found that he frequently forgot to set a message when exiting his office because he tended not to notice his Hermes display when leaving his office.

This enterprising owner resolved to solve the problem through the development of an additional hardware component, which would provide a more tangible interface through which the owner could set his current status and, perhaps more importantly, could be placed in a highly visual position within his office.

The additional hardware component (shown in figure 6) takes the form of an additional set of physical buttons (each with associated LEDs to provide feedback to the user when a button is pressed) each of which allows a specific, user tailorable, state to be selected. This device is constructed using a PIC 16F628 microcontroller and RS232 serial driver. Key presses are conveyed to the user's desktop PC via a serial line, where they are read by a custom built Windows .NET service. Key presses are subsequently interpreted and automatically used to configure the Hermes system via its web interface.

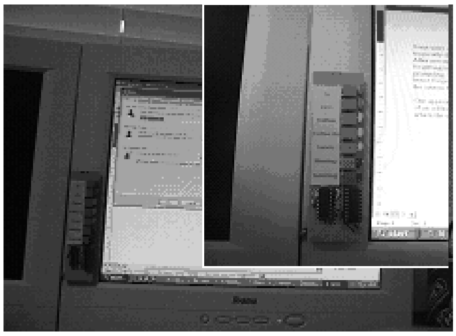

Figure 6: The placement of a prototype tangible interface

Several different physical positions are possible for the keypad device but the Hermes owner in question found that his favourite was alongside his monitor (so that he sees the keypad when getting up from his desk) as illustrated in figure 6. Although the owner mentioned that locating the device on the *inside* of his door frame also had the desired visual prompt effect.

Since deploying the tangible interface the owner in question has found that he sets messages much more regularly than he did previously.

Initial discussions about the suitability of the tangible interface with other Hermes owners have been positive and we plan to produce and deploy additional and more refined versions of the tangible interfaces shortly.

Using a Mobile Phone

One of the early motivations for starting work on Hermes was to explore issues of remote interaction with situated displays. Clearly, the owner of a display can interact 'remotely' by using the web interface but we also wanted to explore whether a 'mobile' user would also find it useful to be able to set messages on their Hermes display. Consequently, we designed the system to enable the owner of a Hermes display to set a message on his or her Hermes display by sending an SMS (or most recently an MMS) via his or her mobile phone.

The facility is in fact not used by many Hermes owners but those that do you use the facility do so quite frequently and have commented that they find the facility extremely useful for leaving an appropriate and timely message when it is clear that they are going to be late for an appointment at their office. More details of this particular aspect of the system and its use can be found in [2].

Figure 7: Using a phone for creating freehand messages.

Another use of the mobile phone that we are currently exploring is enabling the owners of Hermes displays who also posses an appropriate mobile phone (e.g. the Sony Ericsson P800) to use that phone to compose freehand messages and then transfer or 'beam' the image representing the message to their Hermes display over Bluetooth. The possible advantages of this facility include: a potential automated proximity detection/authentication process using Bluetooth devices in 'Discoverable' mode, a more familiar/sophisticated interface (e.g. that shown in figure 7) for leaving messages and overcomes the problem (at least for the owner) of having to stoop in order to scribble a message on the Hermes display.

Using a Standard E-mail Client

Another way in which an owner can set a message is through an e-mail client. This particular option was requested by one owner in particular.

The next planned deployment of a Hermes display is outside the office of another one of our department's secretaries. This secretary works a limited (but not regular) set of hours per week and lets others know of her future availability by sending a simple e-mail to all staff in the department, e.g. "Away Thursday, back Fri am. Jane". Using the e-mail facility we hope that Jane will be able to set messages on her Hermes display with little additional effort by simply cc'ing her e-mail to the Hermes e-mail address.

Using an MSN Messenger client

A further request from a recent Hermes owner has been to enable him to send messages to his Hermes display using a client for MSN Messenger. We are currently developing such a client which will also enable an owner's Messenger status to be automatically presented on his or her Hermes display where this is appropriate and appropriate permissions have been granted.

RELATED WORK

The potential significance of Situated displays for supporting cooperation between colleagues was highlighted recently by a special workshop on Public, Community and Situated Displays [9] held as part of the 2002 ACM conference on Computer Supported Cooperative Work. In addition to highlighting the potential, this workshop also highlighted the scarcity of actual deployed/evaluated systems. Furthermore, the situated displays that have been deployed tend to be based on large plasma type displays that are placed in public areas, e.g. reception areas.

A number of systems exploring the use of situated displays have been developed previously. However, the research agenda of much of this previous work appears to focus on the "one off" production of a proof of concept demonstrators in order to gauge technical feasibility and initial user feedback rather than for performing longitudinal study of usage.

For example, McCarthy developed the 'OutCast' service to provide "a personal yet shared display on the outside of an individual's office" [5]. In contrast to the relatively small screens utilised by Hermes, the OutCast system utilizes a 20 inch flat-panel monitor augmented by a touch-screen, which is embedded in a cubicle (office) wall and connected to a computer situated inside the owner's office. The OutCast system can be configured by its owner to display a range of content. Unfortunately, at the time of writing the OutCast system only has one unit deployed. Feedback gathered suggests that visitors appreciate the ability to view the owner's calendar information and his or her location. However, it is unclear how owners would feel about making such information available on their OutCast display.

Research on the development of 'dynamic' door displays has also been conducted at Georgia Tech [7]. Technologically the Hermes system is very similar to the prototype door displays developed at Georgia. In common with the OutCast system, the Georgia displays are automatically updated to reflect the owner's current location and also his or her calendar information.

The dynamic door displays were also designed to enable owners to control the content displayed to a visitor based on the actual identity of the visitor. In common with the developers at Georgia, we were also interested in exploring the extent to which owner's may wish to control the information presented to a visitor based on the visitor's identity, especially where this information represents some form of personal context such as location. Unfortunately, the work at Georgia on deploying the dynamic door displays came to an end before any significant deployment or reasonable evaluation of the system was able to take place.

A project at Carnegie Mellon University is investigating how office doors can be augmented with computer generated displays to support the functions of 'aesthetic display' and 'interruption gateway' [8]. This latter 'mediator' function arose from the researchers' observation that people often use their door to signal their availability or interuptability. The CMU system actually projects an image onto a window in the office door from a projector located in the office, this image is visible from the outside of the door. The information projected onto the office door is of three main types: virtual notes, digital art (such as web pages, personalized graphics etc.) and awareness information. The system uses a simple traffic-light metaphor to enable users located in the office to stipulate their interuptability.

At the time of writing, the system at CMU has only been deployed on a single office door (the office of a group of PhD students, including some of the researchers working on the system). However, as part of their future work the researchers describe their intention to deploy more systems in order to carry out more comprehensive field trials and a more iterative development cycle.

Although not based on situated displays it is worth mentioning work on the Audio Aura [6] system. With this system, a sound is played outside a colleague's office and the volume of the sound varies according to the duration that the colleague has been away from his/her office. As such, the system deliberately reduces the accuracy of information representing a person's movements while still supporting coordination between colleagues.

SUMMARY AND CONCLUDING REMARKS

One of the key factors that will determine the extent to which any system such as Hermes is adopted by its users is the extent to which the system is designed (or indeed redesigned) in order to encompasses the diverse range of needs of its users. As a designer, one needs to be wary of trying to impose or prescribe particular ways of interacting with the system that may be at odds with some of its users. For example, the tangible interface was developed (in this case by the user concerned, true participatory design!) because none of the approaches available to him matched his particular needs.

A fundamental requirement of the Hermes project is regular use over the longer term. In order for this to happen Hermes must present its users with clear advantages over alternative traditional systems such as the Post-it™ note. Like Post-it™ notes, the situated nature of Hermes is essential. It is both public - anyone coming to the door can see it, and private - you actually have to be at the door. However, Hermes has additional advantages in that the users of Hermes are able to interact with the system from their current situation, wherever that may be. This is important both because of the diversity of users' styles of use and also because it allows the displays to be updated when and where the users have the need. Without this the displays would not be as timely and hence less useful.

Although the Hermes system has been in place for nearly two years, we still consider the system to be in its infancy. In terms of supporting interaction, this paper has described the various ways in which the Hermes system has evolved in order to meet the different and varied needs of its growing user base. As further units are deployed, no doubt additional support for interaction will be required and hopefully further increase our understanding of the interaction issues associated with this class of situated display.

ACKNOWLEDGMENTS

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Towards Natural, Intuitive and Non-intrusive HCI Devices for Roundtable Meetings

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ABSTRACT

Round table meeting are frequently used between professionals to design new approaches, review developments, or make decisions. These meeting are highly collaborative and usually the objects or documents to be discussed are on the table. More and more these objects and documents are not physically present but only virtually available, e.g. displayed on a computer screen. Using conventional input devices such as mouse and keyboard the interaction with these virtual objects and documents is often constrained to one operator while the other meeting participants can observe and suggest but not interact with them, which hinders creativity and collaborative working. This is a major constraint particularly to architects who are used to manipulate physical models during round table review meeting.

In this paper, we describe an overview of an augmented round table system for architecture and urban planning that enables several meeting participants to actively interact with virtual objects visualised through head mounted displays on the round table. In particular, this paper describes 1) the means of interaction that were developed for the augmented round table, namely wireless wands and tangible interfaces, command hand gestures and finger tip tracking, and 2) the user interaction. Preliminary feedback from end user tests is positive.

Keywords

tangible user interfaces, gestures, finger pointing, wand, augmented reality, collaborative virtual environments

INTRODUCTION

Roundtable meetings are regularly used in professional life e.g. for creative brainstorming, decision-making, or planning. Engineers may use them to design products, interdisciplinary groups to create new product ideas, and medical doctors to plan a complex surgery. Common to all these meetings is that the participants are sitting together, seeing each other, and communicating verbally and through hand gestures and facial expressions. Furthermore, documents and objects are often on the table to support the discussion.

A profession that frequently uses roundtable meetings is architecture, particularly for design review meetings where a project is reviewed by senior architects and their assistants. These meetings are extremely collaborative and inventive to find new ideas or solve problems. They are often starting with simple sketches (hand drawings), improving over several stages of 2D plans and 3D models, getting more and more complex, finally leading to very complex CAD models and highly sophisticated (real) 3D models. It is a highly iterative process, which is often very time-consuming. Architects consider the possibility of interactively changing and touching the sketches, plans, and models as an important part of inspiration during design review meetings.

The use of CAD tools allows for more rapid changes and iterations, however, at the expense of collaborative interactivity. One operator is interacting with the CAD program while the others are observing and suggesting verbally and through gestures or sketches.

This paper presents an overview of an augmented round table for architecture and urban planning providing multi-user interaction with the system through tangible interfaces and gestures. The next section gives a short introduction to the context these interfaces are used in which is followed by a descriptions of the input mechanisms and the actual user interaction. Finally, a short discussion is given.

CONTEXT – AUGMENTED ROUND TABLE PROJECT

The ARTHUR project (Augmented Round Table for Architecture and Urban Planning) [9] is an interdisciplinary research project between technology developers and end users (architects), partly funded by the European Union. Its intention is to bridge the gap between real and virtual worlds by enhancing the users' current working environment with virtual 3D objects. The developments of the ARTHUR system focus on providing an intuitive environment, which supports natural interaction with virtual objects while sustaining existing communication and interaction mechanisms. Real world objects are used as tangible interfaces [2, 5] together with hand gestures to augment the social situation in a meeting and make 3D environments attractive even to non-experts. The ARTHUR project develops new types of user-friendly see-through displays, non-intrusive object tracking mechanisms and intuitive user interface mechanisms within a location independent multi-user real-time augmented reality environment. The ARTHUR system addresses a wide area of possible collaborative applications with focus on architecture and urban planning.

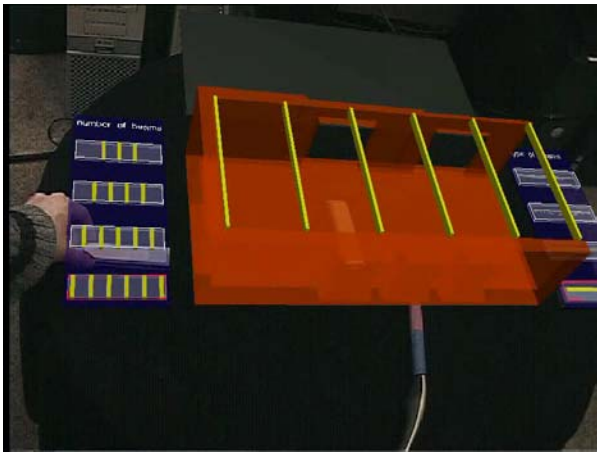

Figure 1. Real world items as tangible interfaces. The figure shows a virtual object and a virtual menu, both controllable by real world objects.

The goal of the project is to develop an intuitive augmented reality environment supporting common round table meetings. Existing approaches such as BUILT-IT [7] use separate projections screens, or such as MagicMeeting [8] limit direct user communication due to video augmentation. In our approach virtual 3D objects are projected into the common working environment of the users by semi-transparent wearable stereoscopic head mounted displays (HMDs). Thus, virtual 3D objects enhance round table meetings. In contrast to other approaches such as MARE [4] we focus on natural interactions using unobtrusive AR based input mechanisms. Therefore we develop new intuitive interaction mechanisms. One approach is the use of real world items to realize tangible and intuitive interfaces for the manipulation of 3D objects (see Figure 1). This presumes a flexible and sophisticated object tracking mechanism. The ARTHUR system therefore applies a tracking mechanisms based on computer vision. While similar interface approaches have been presented earlier [1], our approach aims to support meetings involving several people, creating a real collaborative AR environment [1]. While other collaborative approaches such as EMMIE system [3] rather focused on providing platform independent access to various data using AR, ARTHUR tries to enhance the use of complex (3D) data in a more natural way.

The multi-user AR environment developed allows multiple users to share a virtual space projected into their common working environment (see Figure 2). While in general the participants see and interact with the same virtual objects, personal menus and individual additional information can be provided to each user. Changes to shared virtual objects are immediately visible to all other users, creating the sensation of actually interacting with a single, rather concrete than virtual object.

Figure 2. Viewing and manipulating shared virtual objects in a common round table meeting.

The system allows to easily integrating its visualization and interaction capabilities with existing professional or special purpose software. Integrations of the system with a solar gain simulation program and commercial CAD software has been realised.

As part of the ARTHUR system a new type of a high-resolution see-through head mounted display has been developed (see the first prototype in Figure 4 and the second prototype in FigureFigure 3). Beside viewing quality (resolution, brightness, etc.), ergonomic design issues guaranteeing a comfortable use were realized. Another very important feature, essential for efficient collaboration, is the ability to see other participants' eyes during a session – usually not possible with other types of displays.

Computer vision techniques using head mounted and fixed cameras are used to track the movements of real world items (placeholder objects - PHO, wand) and to recognize hand gestures. Due to the computer vision based approach users can interact without any disturbing cables or sensors connected to their interface elements. The input mechanisms and the physical interface devices will be described in more detail in the next section.

Figure 3. Head mounted display. Second prototype.

Computer vision techniques using head mounted and fixed cameras are used to track the movements of real world items (placeholder objects - PHO, wand) and to recognize hand gestures. Due to the computer vision based approach users can interact without any disturbing cables or sensors connected to their interface elements. The input mechanisms and the physical interface devices will be described in more detail in the next section.

ARTHUR INPUT MECHANISMS

Two main types of input mechanisms are used for the realization of intuitive user interaction; 1) devices such as tangible interfaces and wands, and 2) hand gestures and fingertip tracking.

Input Devices

The user interface devices are dedicated objects that are tracked by the computer vision system using colour and shape information. There are two types of devices: placeholder objects and wand-like pointers.

Placeholder objects

Placeholder objects are tracked in the table plane, in two translational and one rotational degrees-of-freedom (3DOF). They are of a convenient size to be grabbed and moved by the users (see Figure 1). More than ten placeholders may be used concurrently.

The users may take a placeholder object, associate it with a any virtual object and move this virtual object by moving the placeholder object, thereby creating a direct manipulation interface (see menu item selector in Figure 1).

Wands

The wands (see Figure 2) are tracked in 5 DOF – all except roll – by the head mounted cameras, Figure 4. This has the advantage that the wand is always tracked when it is in the users field of view. The wands have three buttons for functionalities such as pick or select.

Users may select and manipulate the shape of virtual objects with a pointer or uses it to navigate in virtual menus, see Figure 2.

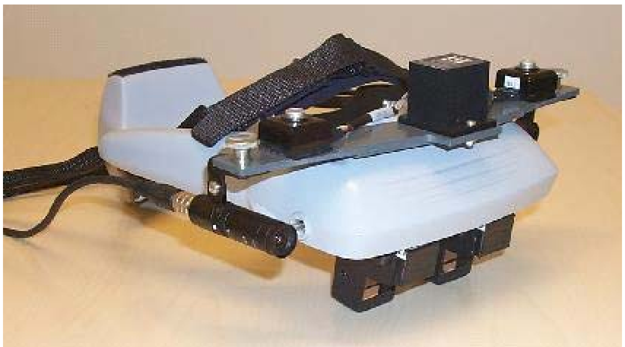

Figure 4. Head mounted display with cameras and head tracking system. First prototype.

Gestures

Two types of gestures can be used, static command gestures and 3D fingertip tracking. Both are tracked by the head mounted cameras.

Static command gestures

A set of five static command gestures is implemented. The number of fingers shown to a head mounted camera corresponds to a gesture, Figure 5. The gestures are identifies by first segmenting the hand as the largest coherent skin-colour blob. Next the centre of the hand is found as the centre of mass. A number of concentric-circles with radius in the centre of the hand are searches for skin-coloured regions. A voting scheme now decides the number of fingers given the current constellation of skin-coloured regions.

The command gestures may be used to get a pop-up menu or for functions such as copy-cut-paste.

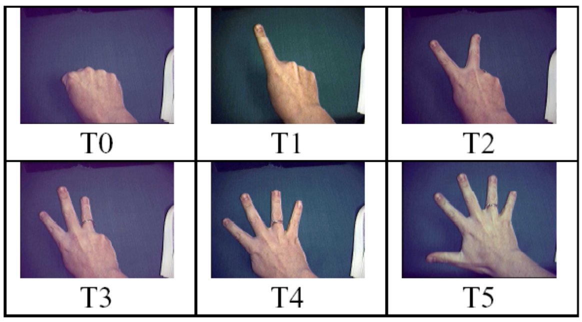

Figure 5. Static command gestures

3D fingertip

The 3D position of the user's index fingertip is tracked in both of the head mounted cameras using the algorithm described above. When only one finger is detected it is concluded that it is the index finger and its tip is located by searching along the finger. Triangulation is now conducted in order to find the 3D position of the finger tip.

This pointing gesture can be accompanied by a "click" gesture which is performed by moving the thumb away from the index finger and back again. This movement is detected by analyzing the changes in the size of the bounding box of the hand.

The fingertip tracking may be used to draw a line in space (Figure 6) or to navigate in pop-up menus, select items and execute actions.

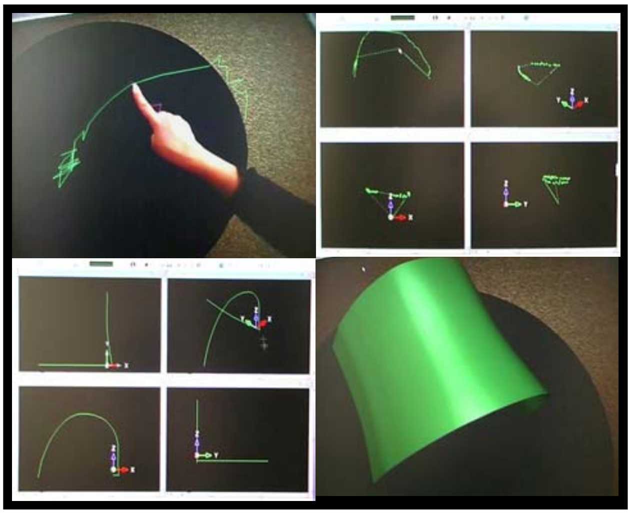

Figure 6. 3D finger tip tracking used for shape creation within a CAD tool

ARTHUR USER INTERACTION

The user interactions based on PHOs are position and orientation manipulations of virtual objects. For this purpose PHOs are associated with virtual objects or groups of virtual objects forming a tangible interface to the virtual world. We call this an interaction unit (IAU), see Figure 7. In order to create such associations, the PHOs first need an appropriate (default) representation within the virtual world. This is an invisible virtual object, of the same size as the original PHO. By detecting e.g. collision between this ghost object and other virtual objects, associations can be triggered. The internal PHO representation in the virtual world may also be used for proper representation of occlusions (i.e. the PHO occluding virtual scene objects). In this case it is called a phantom.

Figure 7. Interaction unit

There are two general interaction mechanisms provided by PHOs. Either the properties of the physical PHO are directly mapped to a virtual object (i.e. the position and orientation of the virtual object will follow that of the PHO) or a functional relationship between such properties is defined (e.g. moving a PHO will scale a virtual object). Thus the manipulation of virtual objects is rather restricted by physical properties than properties of the virtual objects themselves [6]. An example of the first mechanisms is the table top menu shown in Figure 1. The appropriate menu entry is selected and high-lighted upon collision between the PHOs ghost object and the geometry of the virtual menu entry.

Interacting with the 5DOF wand differs in that way that not only collisions between the PHOs ghost and virtual objects may be used, but also a picking ray along the pointing direction of the input device. In conjunction with the mouse-like buttons this provides easy interaction also with objects outside the arm range of the user. This is especially used for selecting objects including menu entries, see Figure 8.

While providing only 3DOF, the finger tip tracking can be used very similar to the wand device in most cases. However, no ghosts and phantoms are available for users' hands. Thus initiating an interaction is more intuitive than using the wand device, but on the other hand may be more cumbersome, Figure 6.

Gestures (except the finger tip tracking) are currently used as commands only, e.g. for starting and stopping a certain action or for changing states of objects.

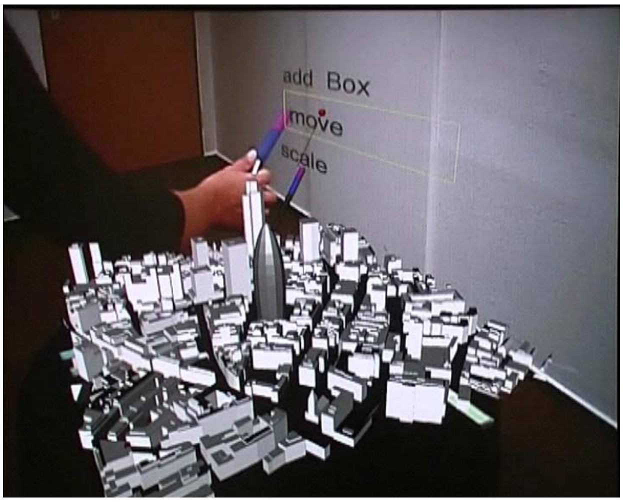

Figure 8. User selecting in a virtual pop-up menu with the 5DOF wand

DISCUSSION and SUMMARY

This paper presented the Augmented Round Table a collaborative environment for architecture and urban planning and in particular the input mechanisms and the user interaction. The interface relies on unobtrusive input mechanisms and natural and intuitive user interactions.

The system is currently tested by the end users and first user feedback is positive. More results are expected within the next months.

In future work we will enhance this interface by additional multi-modal facilities and evaluate the approach by further user studies.

ACKNOWLEDGMENTS

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Towards a Transparent Proactive User Interface for a Shopping Assistant

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ABSTRACT

In this paper we describe an adaptive shopping assistant system that utilises plan recognition. Radio Frequency Identification (RFID) sensory is used to transparently observe a shopper's actions, from which the plan recogniser tries to infer the goals of the user. Using this information, a proactive mobile assistant mounted on an instrumented shopping cart offers adapted support tailored to the shopper's concrete needs.

Keywords

Shopping Assistant, Plan Recognition, Implicit Interaction, RFID

Motivation

Support for online shoppers such as review databases, comparison shopping, or collaborative filtering are now well established. Some effort has been made in the last years to transfer these concepts to the offline shopping domain. While previous work focused on the functional aspects of such systems, less care has been currently taken on the seamless integration of these assistance services into the physical shopping process.

That this integration is important for the usability and therefore acceptance of electronic support tools is demonstrated by the information kiosks installed in many shops providing product catalogues and product searches. As it can be broadly observed, these systems are rarely used by customers. Reasons for this may be that their usage is unintuitive and (at least seem to be) too difficult, or because standing static in front of a display inhibits the fun of strolling around in a shop.

In general, compared to user interfaces using explicit interaction elements like buttons or menus, ubiquitous proactive user interfaces using implicit interaction promise to reduce the inhibition threshold and overhead of using such a tool. This especially holds in the physical shopping domain where stress and time pressure potentially force a customer to fully concentrate on the original task or where the customer is not willing or able to learn the operation of a complex shopping support system.

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To investigate the use of proactive user interfaces driven by implicit interaction in a real world shopping scenario, we developed the *Smart Shopping Assistant Infrastructure* that we will present in the first half of this paper. This infrastructure is fully implemented and running in our lab. In the second half of this paper we will describe a first prototype of a proactive and transparent shopping support application built upon the presented infrastructure. This application has also been implemented and is running, but evaluation yet has to be done.

Related Work

Some effort has been made in the past to transfer support available for online shoppers to the real world shopping domain.

The *Pocket BargainFinder* [2] is a mobile device that enables the user to query an online comparison shopping service while being in a physical store. Having found an item of interest, the user scans in its barcode and receives a list of online retailers and their individual prices for the specified item. Another application assisting customers during their offline shopping tour is *DealFinder* [3], which provides collaborative filtering functionality in the physical shopping domain. Using a GPS equipped PDA users can asynchronously share information about product prices and availability. This information can be queried by other users through a location aware interface.

Although both presented applications provide a clear benefit to the user, their usage does not integrate very well with the ordinary shopping process. Despite the fact that these tools require the user to actively handle and operate an external device (explicit interaction), these applications essentially provide "meta help" concerning the overall shopping need instead of supporting the concrete process of buying. Therefore, they are used as external expert applications rather than as integrated tools to support the every day shopping tour.

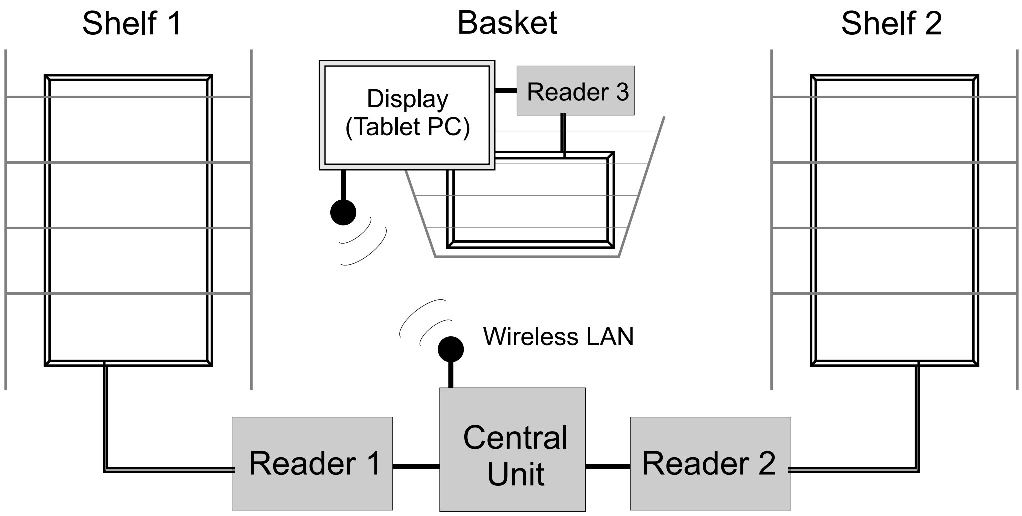

Figure 1: Components of the Smart Shopping Assistant Infrastructure.

In contrast to this, the *Personal Shopping Assistant* (PSA) developed by the *Future Store Initiative* [4] aims at providing in-store support during an ordinary shopping tour. In the *Future Store* project, major players from the IT and consumer goods industry have united to develop new ways of supply chain management and customer support. In April 2003 the first future store was opened for private customers. The PSA presented in this store is implemented as a mobile unit mounted on a shopping cart's handle and equipped with a touch screen and barcode scanner.

Like all the other applications presented above the PSA uses explicit interaction to fulfil simple tasks like keeping the shopping list or delivering on demand product information or product location. Even if the PSA seems to be a good candidate for an every day ubiquitous shopping tool, the need for explicit interaction requires the user to learn its operation and draws away much of the users attention when shopping.

The Smart Shopping Assistant Infrastructure

In contrast to explicit interaction – where the user controls an application through buttons, menus, dialogs, or some kind of written or spoken command language – an application utilising implicit interaction is driven by the user's actions in the environment and their current context.

In the real world shopping domain, relevant user actions for example include moving around in the store, looking at items of interest or advertising displays, or physical interaction with products. Relevant context for example includes the user model, the location model, and the products available in the store or involved in user actions.

Although all actions mentioned above are useful to know, in our first implementation of the smart shopping assistant infrastructure (SSAI) we focus on the transparent and unobtrusive observation of interaction between users and products and the context involved, especially the according user and product models. Additional sensors like tracking systems are nice to have and therefore may be incorporated in future versions of the SSAI, but are not seen to provide important additional insights on the user interface aspect at the current state of the project. Nevertheless it should be pointed out that such additional sensory is required to practically apply the SSAI to a complex real world shopping scenario.

Our SSAI consists of a central server, an instrumented shopping cart and two instrumented shelves. Shelves and shopping cart are equipped with RFID sensory to recognise the products placed inside them. Therefore all products sold in the store are tagged with RFID transponders. Help is provided through a tablet PC mounted on the shopping cart. While figure 1 shows the overall setup of the SSAI, figure 2 gives a closer view on the instrumented shopping cart, especially on the RFID reader with it's antenna fixed to the bottom side of the basket (c) and the tablet PC mounted to the handle (b), hosting the shopping assistant, controlling the RFID reader, and connecting the cart with the central server via wireless networking.

With this setup, user actions like taking a product and putting it down can be recognised by repeatedly polling the transponder's IDs in the antenna field of each shelf and cart. These observations are fed into the shopping assistant applications running on the central server. The application reacts to these observations and the context provided by the user and the products present and generates appropriate user support. Finally the support is pushed as dynamic HTML pages to the shopping cart and displayed to the user.

Figure 2: Instrumented Shopping Cart (a) with Tablet PC on the handle (b) and RFID antenna on the bottom side of the basket (c).

A Sample Shopping Assitant Application

To explore the benefits and limitations of implicit interaction in the shopping domain we implemented a sample shopping assistant application based on the SSAI. In this section we describe the help provided by the sample shopping assistant from the user's perspective, before we will have a closer look at the insides of the application and the employed techniques later on.

After the user, let's call him Bob, picked up one of the instrumented shopping carts and registered himself with the cart through his customer card, the users starts his shopping tour supported by the Smart Shopping Assistant as exemplified in figure 3.

In the first example the user takes a package of tea out of the shelf, holding it in his hands for a while. Because the user model (being part of the context provided by the user) states that the user's experience with this kind of product is very sparse, the shopping assistant infers that the user may have a need for in-depth product information and therefore displays appropriate product information on the shopping cart display (a).

Next the user takes a bag of noodles. From the user model, the system discovers that Bob is a pasta expert. At this time, he has not yet decided to buy this product[1], so the shopping assistant infers that the user may be searching for a similar product that better suits his needs and displays a list of similar products available (b).

Having found the proposed product, the user now holds both products in his hands simultaneously. The shopping assistant infers that product comparison information may be needed regarding the two products. It displays a comparison chart to the user merging product information of both products (c).

In the meantime the user has already chosen a handful of groceries. Utilising a recipe book the shopping assistant infers that the user may want to a pasta dish. The assistant decides to display a list of products that may also be useful to cook a pasta meal (d). Because the user model states that the user is vegetarian, the assistant thereby omitted dishes containing meat.

Inside the Shopping Assistant Application

To decide what kind of support to offer depending on the observed implicit interactions, the presented shopping assistant application utilises plan recognition.

Plan recognition is the process of inferring a user's plans and goals by observing his actions. Most plan recognition systems use a *hierarchical plan library* to link subactions to abstract or compound higher order actions. Plans are represented by top-level actions and user goals are ascribed to these plans. The generic plan recognition process observes

[1] Because we have not yet seen him putting it in his shopping basket

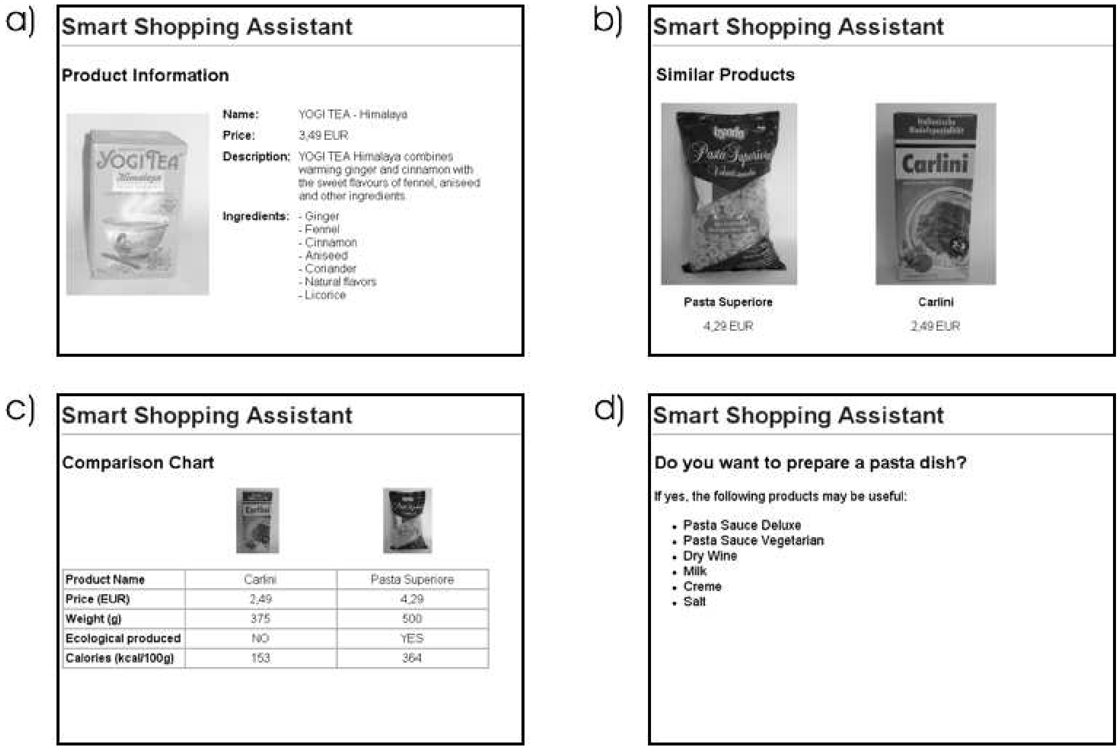

Figure 3: Help provided by the Smart Shopping Assistant for product information (a), product recommendation (b), product comparison (c), and recipe hints (d).

the user and explains these observations by higher order actions found in the plan library. If there exists more than one explanation for a series of observations, the plan recognition process should deliver some hints on how to interpret these results. A common way to get some rating of competing explanations is to apply a probabilistic model in order to compute the likelihood of discovered explanations.

The sample application uses the probabilistic plan recognition system OPRES [5], which is fed with the observed user actions. Therefore, sensor data delivered by the RFID sensors is translated into the symbolic ground level actions *get-prod* and *put-prod* together with the regarding context of involved user and products. Upon the observations, the OPRES plan recognition engine infers hypothetic user plans explaining the observed behaviour. Input parameters of the plan recogniser are the plan library, a probabilistic model describing the probability distribution over all explanations, and the user and product model containing individual user respectively product knowledge.

The plan library used is built upon the actions *get-prod* and *put-prod* as described above. From these actions higher order actions of buying a product (taking it out of a shelf and putting it in the basket) and gathering information (taking it out of a shelf and putting it back after a while) are inferred. From seeing multiple inform or buy actions in a row, we infer top-level plans like gathering in-depth product information, searching similar products, comparing products, or buying a certain bunch of products (for example in order to prepare a pasta dish). Each action can have conditions assigned limiting their applicability, e.g. restricting *compare* actions to products of the same kind.

Finally a support engine takes the output of the plan recogniser and delivers support according to the inferred goal with the highest likelihood of being pursued by the user. For our shopping assistant application, we already discussed the different forms of support provided by the system in the previous section.

Plan Recognition in the Shopping Domain

The shopping domain has some characteristics that make it especially well suited for the application of plan recognition driven tools. As mentioned above, unobtrusive observation of relevant user actions is feasible by the use of according sensors like (head) tracking systems or RFID antennas. Besides the availability of relevant sensor data, another advantage is the common understanding of possible user goals and their limited number of realisations.

Because traditional plan recognition systems have to enumerate all possible ways in which to achieve a goal that should be recognised, plan recognition can become quite difficult if there exists no common scheme to reach a certain goal (in which case it is intractable even for humans). In the shopping domain, most goals fall into one of two main categories (at least for honest shoppers): buying or gathering information. Characteristic behaviour for both goals can be easily observed.

Last but not least once having the infrastructure installed and the sensors running, user behaviour can easily and extensively be recognised and recorded. Based on this data, machine learning techniques can be used as described in [1] to discover potential user plans in each individual shop setting. This process can be repeated whenever there are significant changes in the environment and/or the user behaviour.

Conclusion and Outlook

We presented a smart shopping assistant infrastructure upon which proactive support applications relying on implicit interaction can be developed. We described a first sample implementation of such a shopping assistant application utilising plan recognition that proactively and transparently supports users during their shopping tour. Furthermore we argued that plan recognition is applicable and useful in the shopping domain.

While the observation of *get-prod* and *put-prod* actions implemented so far are useful in recognising general shopping plans, these observations are limited to deliver evidence for plans including physical interaction between a user and products. Additional sensory capturing non interactive behaviour could provide evidence for plans without such interactions like product search (aimlessly moving around in the store) or gathering product information by reading a poster (resting in front of some advertising display).

In a practical application of our proposed infrastructure one has to consider the problematic scalability of RFID sensors. For instance by just having observations from the RFID sensors we can not distinguish between multiple users interacting with the same shelf. Having the additional information of the user's position delivered by some tracking system will allow us to infer which user is taking which product off the shelf, assuming that we know the position of every product. In general many more sensors have to be used alongside RFID antennas to make the shopping assistant infrastructure suitable in a complex application domain.

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Real World Objects as Media for Augmenting Human Memory

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ABSTRACT
This paper describes wearable interfaces for augmenting human memory, i.e., providing users with functions for archiving, transporting, exchanging, and retrieving their experiences by employing real world objects as memory storage, in everyday life. A user conceptually encloses his/her experiences gathered through his/her sense organs into real world objects by simply touching the objects. He/she can also disclose and experience for himself/herself the augmented memories stored in an object by the same operation. This paper presents the following two wearable modules/interfaces for augmenting human memory: the "*Ubiquitous Memories"* and the "*I'm Here!*" The *Ubiquitous Memories* provides users with the functions for associating augmented memories with real world objects. The "*I'm Here!*" retrieves the last recorded augmented memory which contains the target object indicated by the user by automatically and continuously detecting objects held by the user. We believe that the above modules can be integrated into a memory albuming system.

Keywords
Augmented Memory, Wearable Computing, Real World Objects, and Memory Albuming and Sharing

INTRODUCTION

Our research goal is to develop methods and their computational components for augmenting human memory in everyday life. Augmented memory technology has been investigated extensively in recent years in the field of wearable computing [8,10,11]. Such technology makes it easy for a user to refer to multimedia data which include his/her viewpoint video for recalling his/her experiences, e.g., for remembering the person who stands in front of him/her [1,2]. In these systems, the user wears both a head-mounted camera for continuously recording his/her viewpoint images and a head-mounted display (HMD) for viewing information given by the system.

LEAVE BLANK THE LAST 2.5 cm (1") OF THE LEFT COLUMN ON THE FIRST PAGE FOR THE COPYRIGHT NOTICE.

We have proposed a framework for augmented memory albuming systems, named *SARA* [3,7], where 1) a user's viewpoint images are always observed, 2) the images along with the data observed by other worn-sensors are analyzed to detect current context, 3) the images are stored with the context as his/her augmented memories, 4) the memories are additionally annotated/indexed by him/her for later retrieval, and 5) he/she can recall his/her experiences by viewing the memory retrieved by consulting the indexes. We consider the memory albuming to be one of killer applications for wearable computing in everyday life [6].

It is important for memory albuming systems to equip functions for managing memories, i.e., archiving transporting, and retrieving augmented memories. The *Ubiquitous Memories* proposed in this paper provides users with such functions by associating augmented memories with real world objects. He/she is allowed to rearrange his/her memories for later retrieval. He/she can also hold and convey the memories with the associated objects.

Although most of existing augmented memory researches considers managing a user's personal memories, we believe that sharing memories among users is one of essential functions. A user would augment his/her problem-solving ability by referring to others' experiences if they are properly associated with the given problem. The *Ubiquitous Memories* helps its users exchange their experiences. A user is allowed to view all the memories associated with the indicated object if the owner of each memory has approved of other users viewing it. The user can reuse human experience by remembering his/her own memories or by viewing other users' augmented memories rearranged in a real world object.

A memory retrieval function provides a user with the ability for retrieving proper augmented memory from a huge memory archive which continuously increases in recording his/her everyday activity. The "*I'm Here!*" proposed in this paper is an object-based memory retrieval module that identifies the object held by the user. The "*I'm Here!*" shows the user the last recorded video which contains the target object indicated by him/her. Viewing the video, he/she can remember where it is. Prototypes of the two proposed modules/interfaces are independently implemented. They realize natural operations for managing augmented memories by employing ubiquitously spread real world objects as memory archives.

UBIQUITOUS MEMORIES

Conceptual Design

We propose a conceptual design for ideally and naturally bridging the space between augmented memory and human memory by regarding each real world object as an augmented memory archive. Conventionally, a person often perceives and understands a new event that occurred in the real world referring to his/her experiences and knowledge, and then stores the memory of the event into his/her brain. He/she then obtains knowledge to cope with the event by analogically associating the event with his/her experiences. Real world objects, which are related to the event in some sense, could be strong triggers for him/her to remember the event. Suppose that a user had a birthday party with her husband. Many objects in the party space can be memorial ones, e.g., the birthday present, the gift box, the musical box on the table, and the pendulum clock in the room. A real world object also could be the medium for archiving memories which are in some sense similar to each other.

To seamlessly integrate between human experience and augmented memory, we consider that providing users with natural actions for storing/retrieving augmented memories is important. A "human hand" plays an important roll for integrating the augmented memory into objects. Human body is used as media for both perceiving the current context (event) as a memory and propagating the memory to an object, i.e., the memory travels in all over his/her body like electricity and the memory runs out of one of his/her hands in our design. We propose a conceptual design to ideally and naturally correspond augmented memory to human memory. Terms of conceptual actions in Figure 1 are defined as follows:

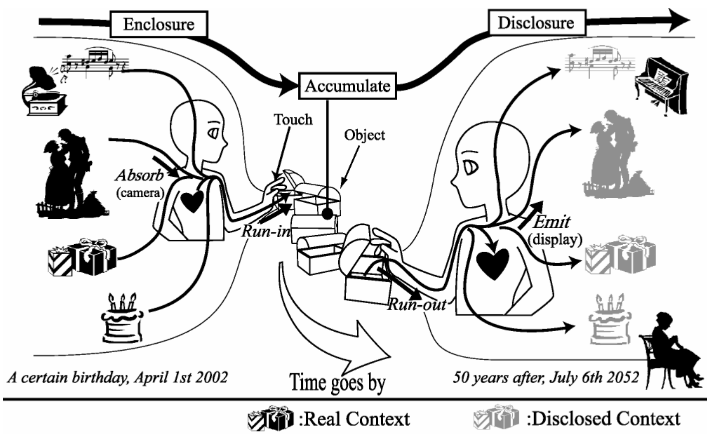


Figure 1: Concept of the Ubiquitous Memories

Enclosure action is shown by two steps of behavior. 1) A person implicitly/explicitly gathers current context through his/her own body. 2) He/she then arranges contexts as ubiquitous augmented memory with a real world object using a touching operation. The latter step is functionally similar to an operation that records video data to a conventional storage media like a video tape. The two steps mentioned above are more exactly defined as the following actions:

Absorb: A person's body acquires contexts from an environment, his/her own body, and his/her mind, as moisture penetrates into his/her skin. Such operation is called "Absorb" and is realized by employing real world sensing devices, e.g., a camera, a microphone, and a thermometer.

Run in: When a person touches a real world object, an augmented memory flows out from his/her hand and runs into the object. A "Run in" functionally associates an augmented memory with an object. In order to actualize this action, the system must recognize a contact between his/her hand and the object, and identify the object.

Accumulation denotes a situation where augmented memories are enclosed in an object. The situation functionally means that the augmented memories are stored in computational storages somewhere on the Internet with links to the object.

Disclosure action is a reproduction method where a person recalls the context enclosed in an object. The "Disclosure" has a similar meaning of replaying media data. This action is composed of the following "Run-out" and "Emit" actions.

Run-out: In contrast to "Run in," augmented memory runs out from an object and travels into a person's body. Computationally, the "Run out" 1) identifies the storage where the augmented memories linked with the object are stored, and 2) retrieves them from the Internet to his/her wearable PC.

Emit: The user restores the context by experiencing some of the retrieved augmented memory in his/her body, and mind. The system should be employed devices, e.g., on a HMD, and a headset, that can play back an augmented memory.

By enclosing an augmented memory in an object, memory-finding behavior directly corresponds to object-searching behavior where the object is associated with the memory in some sense. This correspondence makes a wearer get more intuitive power to find the augmented memory using the principle of human memory encoding [14]. Suppose that a person won first prize in the 100-meter dash at an athletic festival and got a plaque. He/she can easily recall the event when he/she just looks at the plaque because he/she associated the event with the plaque in his/her mind. By providing the wearer with the way to computationally

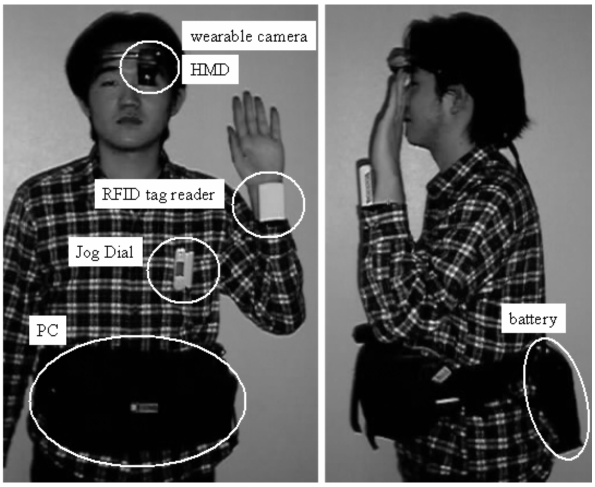


Figure 2: Worn Equipments of the *Ubiquitous Memories*

associate an event with an object, he/she can easily recall the event by finding out the object.

The operation "touching" is employed not only for realizing metaphors that a human hand implies ("Run-in" and "Run-out"), but also for naturally controlling an augmented memory system. *CyberCode* [12,13] proposed a method to detect visual tags in a scene captured by a camera to identify virtually controllable real world objects. Although it is difficult for both the user and computational devices to explicitly select the target object among detected objects in using visual tags, the proposed touching operation makes the selection easier.

Hardware

Figure 2 shows the worn equipments of the prototype of the *Ubiquitous Memories*. The wearer basically wears a HMD to view video memories, and a wearable camera to capture video memory of the wearer's viewpoint. The wearer also wears a Radio Frequency Identification (RFID) tag reader/writer to his/her wrist. The wearer attaches RFID operation tags to control the system to the opposite side of wrist that is set the RFID tag reader/writer. The wearer uses a VAIO jog remote controller for additionally control the system. The wearer carries a PC on his/her waist. The RFID device can immediately read the RFID tag data when the device comes close to the tag. The entire system connects to the World Wide Web via a wireless LAN.

We currently assume that an RFID tag is attached to/implanted in each real world object. We have employed a short-range type RFID system for 1) identifying each real world object, and 2) controlling the stage of the system. The range of the RFID strongly depends on an RFID tag size. Basically, when the wearer touches an object, i.e., the RFID tag reader on his/her wrist comes close to the RFID tag attached to/implanted in the object, the system identifies the object by reading the tag information.

(a) Touching an object (b) Replaying the disclosed memory

Figure 3: HMD view of the operation DISCLOSURE

The information written in an RFID tag contains two types of data. One is to identify a certain object attaching an RFID tag. We have employed a Serial Number (SRN), which is unique to each RFID tag, as an object ID. Another is data 1) to indicate the URL of the server where augmented memories associated with the corresponding object should be stored, and 2) to send a command to the system when the wearer touches one of operation tags.

System Operation Modes

The *Ubiquitous Memories* system has six operation modes: ENCLOSURE, DISCLOSURE, DELETE, MOVE, COPY, and NONE. Note that the system in the NONE mode reacts to wearer's actions only when one of operation tags is touched. Two basic operation tags and three additional operation tags are prepared to change the current mode. The wearer can select one of the following types:

ENCLOSURE: By touching the "enclosure" tag and an object sequentially, the wearer encloses the current augmented memory into the object. In the mode, "Absorb" function and "Run in" function are sequentially operated.

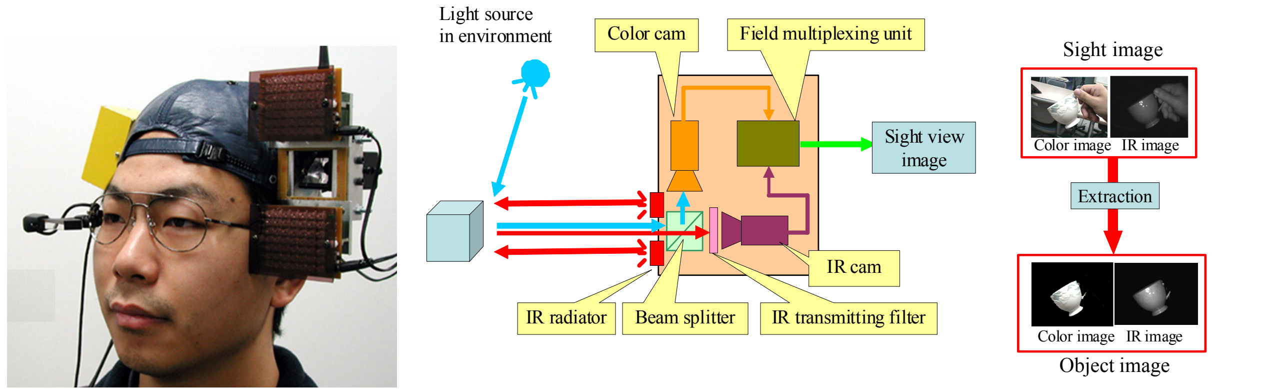
DISCLOSURE: The wearer can disclose an augmented memory from the object he/she touches, i.e., he/she can experience for himself/herself the memory. In the mode, "Run out" function and "Emit" function are sequentially operated. Figure 3 shows screenshots of the system.

The wearer can treat a video memory in the real world like paper documents or data in a PC using the following types of operation tag:

DELETE: The wearer can delete a video memory enclosed in a certain object in "DELETE" mode. This mode is used when he/she accidentally enclosed a wrong video memory, or when he/she thinks that a certain video memory is not needed anymore.

MOVE: This mode is useful when the wearer wants to move a memory from a certain object to another object. For example, the wearer encloses a video memory to a notebook in advance when he/she is in a business trip. He/she rearranges memories to each appropriate object after he/she comes back to his/her office.

COPY: In this mode the wearer can copy a video memory to other objects. An event often has contextual relations with plural real world objects. This mode enables him/her to disperse a video memory to appropriate objects.



(a) Head-mounted devices (b) Block diagram of the ObjectCam (c) Extracting an object image

Figure 4: Overview and configuration of the ObjectCam

Sharing Memories with other wearers

By accessing a real world object, in general, a wearer of the *Ubiquitous Memories* can view all the augmented memories associated with the object if the owner of each memory has approved of others viewing it. A wearer is forced to set the publication level to an augmented memory to limit users who can refer to the memory when he/she encloses it in an object. Additionally the wearer is allowed to set the reference level that indicates the type of candidate memories to be disclosed. We have defined the following attributes:

Publication Level: One of the following three types of publication level is set when the wearer encloses a video memory to an object:
Private: Only the owner of the memory can disclose it.
Group: Members of the specified group can disclose it.
Public: All users are allowed to disclose it.

Reference Level: This level is selected when a wearer discloses a memory from an object. The following three types of reference level can be set:
Personal: He/she can disclose his/her own memories.
Group: He/she can disclose memories of his/her group.
Public: He/she can disclose all the memories if the owner of each memory approved of other users viewing it.

In the disclosure process a wearer can easily find the desired video memory if the number of memory candidates that ware enclosed in the touched object using the jog controller. As the number of enclosed memories increases, however, it becomes more difficult for the wearer to find the memory to be disclosed among the candidates even if he/she limits them by selecting one of the reference levels. By employing the jog dial device, the system provides the wearer with the means to view a snapshot of each memory in the HMD and to select the desired memory by turning around the dial and pushing down the controller.

Discussions

We conducted an experiment to evaluate the effect of employing real world objects as media for augmenting human memory [4]. In this experiment we select three memorization strategies for comparative evaluations and 20 test subjects were included. The system showed the following two considerable results which imply that the system is more useful than conventional externalized memory-aid strategies:

1. People tend to use the system similar to conventional externalized memory-aid strategies such as a memorandum, and a photo album.
2. The result shows "Enclosure" and "Disclosure" operations, which enable wearers to directly record/refer to a video memory into/from an object, have an enough effectiveness to make ubiquitous memories in the real world.

The RFID devices are not essential to implement the concept of the *Ubiquitous Memories*, e.g., an object recognition technology as described in the next section can be applied to identify the object the user is touching. RFID devices are currently suitable for discriminating between real world objects and implementing the *Ubiquitous Memories* because an RFID tag does not require batteries.

I'M HERE!

Hardware and System Design

The "*I'm Here!*" retrieves the augmented memory recorded when the wearer lastly held the object that is indicated by him/her [15]. Viewing the video that was observed by his/her head-mounted camera, he/she can remember where and when he/she placed it. Ultimately we expect that the system will act as if the object itself tells the user "*I'm Here!*" The "*I'm Here!*" continuously identifies the observed object held by the user as one of the registered objects.

We have developed an "ObjectCam," which is a head-mounted combined camera device, to extract an object image from a user's viewpoint image (Figure 4(a)). A video frame consists of a color image field and an infra-red (IR) image field (Figure 4(b)). An IR image displays the reflected IR luminance caused by the IR light source on the device. The system obtains the object image by eliminating background regions from the viewpoint image with the luminance of the IR image, and hand regions by using skin color (Figure 4(c)).

We employ an Integrated Probabilistic Histogram value (IPH) to represent the feature of an image of the object held and manipulated by the user [5]. In object registration, the system records a video of the object. The system divides the images of the object into several image groups which are made from the extracted object images, based on the appearances of the object. The system constructs the feature value from the representative image of each group. We have proved that the proposed method is useful for the user to find objects by experiments [16].

Discussions

The "*I'm Here!*" provides a wearer with the means for retrieving the augmented memories associated with real world objects held by him/her along with the means for identifying each hand-held object. In everyday life, a human sequentially handles plural objects to perform a task. For instance, when he/she wants to have a cup of coffee, he/she prepares his/her cup, boils water in a kettle, and stirs the coffee with a spoon. We are also planning to extend the system to recognize the task the user performs from the sequence of symbols, i.e., accesses to identified objects. Such function would realize that the system suggests to the user what objects should be used [10] and where they are placed.

CONCLUDING REMARKS

This paper introduced methods for managing augmented memories employing real world objects. Each object is considered as a medium for archiving augmented memories and also as a front-end interface for a wearer to access augmented memories. The *Ubiquitous Memories* provides its users with the functions for both transporting and exchanging memories along with the functions for retrieving memories by touching a real world object. This paper also introduced another object-based memory retrieval function "*I'm Here!*" that recognizes the object held by the wearer. We believe that employing real world objects is one of key issues for augmenting human memory. Prototypes of these modules are independently implemented. We are currently integrating them into an augmented memory albuming system.

We are planning to continue implementing and integrating modules for *Memory Retrieval, Exchange, Transportation*, and *Editing*. *Memory Editing* will be particularly important because the augmented memory albuming system should provide the user with a method to make annotations in augmented memories. Bridging the space between real world and symbolized world is also essential to improve the memory albuming functions.

ACKNOWLEDGMENTS

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The Scrutable Personalised Pervasive Computing Environment

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ABSTRACT
This paper describes our work towards personalized views of a personalized pervasive computing environment. This double personalization is supported by an architecture designed to give the user a sense of control over their environment, built upon the ability to gain a good understanding of it.

Keywords
Personalisation, spatial and temporal mappings between real and virtual, dynamic adaptation, presentation planning, public versus private devices.

INTRODUCTION
Invisibility is one of the goals of excellent pervasive computing design. It has at least two aspects. Firstly, the devices should fit so well into the environment and operate so naturally, that the user can effortlessly use them as needed. An associated aspect of the invisible pervasive environment is that it should be unobtrusive. It has also been argued that the pervasive environment should not be distracting [1]. There are many challenges associated with both these aspects of invisibility. We are exploring ways that personalization can both improve the effectiveness of a pervasive computing environment and can ameliorate some of the problems of invisibility.

Consider first the challenges associated with unobtrusiveness. This creates problems because a new user may not be able to work out what services are available. This is not too dissimilar from the problems people currently have with many existing interfaces where it is hard to work out what services a device offers. Even if the user can get past this problem, the next series of challenges follow as the user tries to work out what they need to do to make devices do the actions that the user wants.

For example, consider the case of a simple cupboard, well integrated into a room, with a voice-activated lock. If a new user comes into the room, how are they to determine that there is a cupboard at all? How can they determine what voice commands are needed to open the cupboard? Once you know all about the cupboard and its locking, it may well be provide a very natural and convenient interface, with no hands needed to open it. For the new user, the invisibility of the cupboard and its interface pose real problems. We want to explore issues like this, with the added challenge of personalization. In this example, we might suppose that the cupboard is used to store medicine. In that case, it is desirable that it be invisible to small children. For others, we would like to ensure that a new user can determine the facilities and services available.

This example relates to the user acting upon the room. There are corresponding issues in relation to the opposite communication route. For example, projects like the Georgia Tech Aware Home [2] and the Microsoft Easy Living Project [3] use sensors to track people. It would be very easy for people to fail to realize this. We want to ensure that when people can scrutinize such an environment: when people want to know about sensors, and control whether the sensors are allowed to be active in relation to them, the environment should support this.

In the cases we have described so far, personalization is essentially a complicating factor since it creates additional complexity in the environment. It means, for example, that I could watch my friend Jane interact with the room and then find that it will not operate in the same way for me. There is another role for personalization in dealing with challenges of invisibility: we can exploit personalized information presentation to improve the delivery of information about the environment. This is particularly important in the case of complex functionality within environments. For example, if we want to help a user in their first use of a tool with functionality as complex as a video-recorder, we would like to support them as they work through each of the stages of their first task.

This paper describes the ways that we are working towards addressing the issues we have described.

ARCHITECTURAL OVERVIEW

Of the many ways to deliver information to the user, we are currently exploring use of Personal Devices (PD) such as PDAs or mobile telephones equipped with a camera and a small screen. The overall architecture is shown in Figure 1.

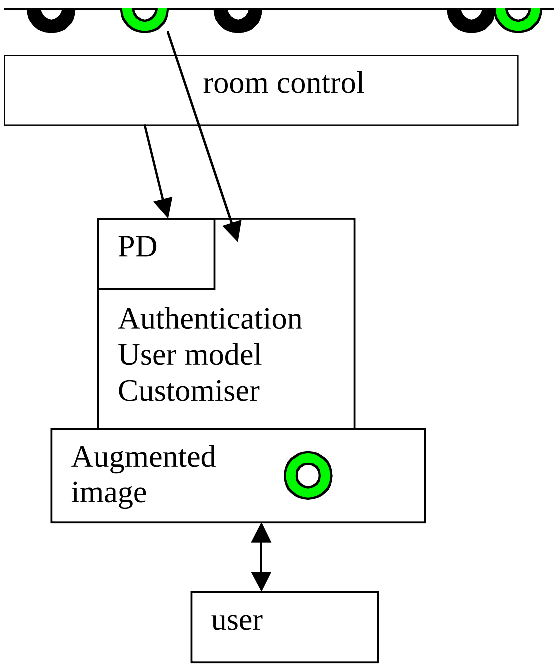

Figure 1. Scrutinisation architecture

The top of the figure represents the environment and the half donuts are pervasive computing elements in the room. The darker ones are not intended for this user but the lighter ones are. Accordingly, the *room control component* of the architecture will provide information only about the aspects that are available to the user.

The *room control component* shown in the figure is logically part of the room. It controls and communicates with all the devices in the room.

The user carries the PD, a personal device which communicates wirelessly with the *room control component*. This device can be used to authenticate the user's identity to the room. Since we currently want to focus on the issues associated with personalization, we take a simple approach to this aspect of the architecture.

The PD has two important personalization roles. First, as indicated in the figure, it holds its owner's user model. This has a range of personal information relevant to supporting use of this room. For example, it would maintain a memory of the users' previous activity in the room: this information would be important for driving those interactions which treat the experienced user differently from a first time visitor to the room. The user model would also maintain details of previous interactions with devices like the ones in the room.

The other critical personalization role of the PD is the *customiser*. This accepts personalisable information about the room from the *room control component* and performs any required personalization on board the PD. We will return to the details of this in the next section.

At this point, we describe the high level goal of this process. The PD enables the user to scrutinize the environment by showing an image of parts of the environment, augmented with personalized annotations. In Figure 1, we indicate this with a line indicating the actual image of the part of the room containing the interface to a pervasive computing element such as the leftmost light half-donut. We show that this is augmented so the user can *see* more than is visible. We now discuss this part of our approach in more detail.

PERSONAL ENVIRONMENT INTERFACE DEVICE

There are many ways that one might provide the information about devices in a pervasive computing environment. We are exploring the approach illustrated in Figure 2 for the case of a medicine cupboard. We envisage that the PD has a camera and the user can point this anywhere in the room. If a child, or other unauthorized person, points their PD at the medicine cupboard, they would see the image shown to the left in Figure 2. By contrast, the adults who live in the house containing the room see the enhanced image shown at the right of Figure 2.

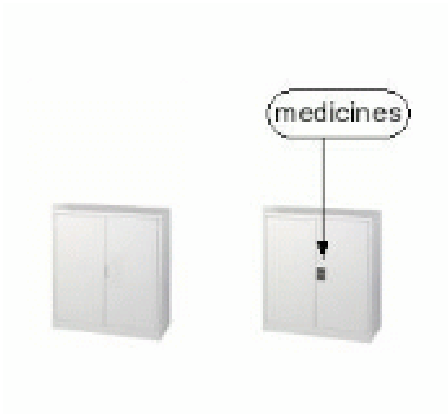

Figure 2. Cupboard without (left) and with (right) augmentation

The implementation of this system makes use of the Augmented Reality toolkit [4]. Objects in the environment have markers attached that can be recognized by the AR toolkit allowing identification of the object. This builds from work on an augmented reality mobile phone [5] which used a camera phone (Sony-Ericsson P800) to capture an image and send it via Bluetooth to a server that finds a marker in the image, augments the image and sends it back to the phone for display.

User model information is maintained using the Personis user modeling system [6]. A particularly important aspect of our approach is that the actual process of personalization is done only on the PD, the user's personal device. This means that the *room control component* must deliver its augmentations with embedded details of how the information delivery can be personalized. It can employ the approaches used to manage adaptive hypertext, with adaptive markup on content. Once the PD receives the augmentation information that this user is authorized to receive, it personalizes the delivery. This means that the user does not need to release parts of their user model into the room. We have made this design choice since users may rightly be concerned about the long term use of personal data once it has been released within a pervasive computing environment. Certainly, the user could engage in a careful interaction with their PD to choose just what information they might be comfortable in releasing. However, this interaction would be at odds with the whole goal of invisibility, non-intrusiveness and seamless interaction.

It is notable that personalized delivery of information has an immensely important role in relation to sophisticated, high functionality devices. In the case where these are well blended into the environment, there is a great need for the scrutability we want to support. However, even when the devices are quite visible, as in the case of printers, current video-recorders and even whitegoods, there is an important role for personalized assistance in determining the relevant functionality of the device and then being aided in accessing that functionality.

RELATED WORK

The "Digiscope" described in [7] presents a very similar system for viewing attributes of objects in the intelligent environment with two major differences. The Digiscope is a large device and not portable or mobile. The Digiscope system displays fixed attributes of objects and does not carry out personalization based on the user or context.

The Augmented Reality toolkit [4] has been used in a variety of applications but most have involved replacing the marker in the image with a computer-rendered 3D image. The Digiscope and our work use the AR toolkit to identify objects and add a text annotation.

A number of systems have used spatially aware displays to interact with virtual environments. Fitzmaurice's Chameleon system[8] uses a mobile display to provide a viewport into a virtual world. The screen used has been both a large screen mounted on the end of movable boom and a palm sized portable display with spatial awareness[9]. The important difference from our work is that these focus on interacting with a virtual model whereas we are presenting additional personalised information about the physical environment.

Of a similar flavour, the Total Recall system[10] uses a PDA to provide a viewport for the contents of a whiteboard so that it can be recalled after the board has been cleaned or overwritten.

Another system described in [11] uses a palmtop-sized video see-through device equiped with a gyro sensor and vision based ID recognition to allow interaction with the environment. A later version [12] takes an approach closer to the AR toolkit. Neither explore the personalisation aspects which are central to our work.

CONCLUSION

This paper has provided just an overview of the approach we are taking towards personalized support for scrutinizing a pervasive computing environment. We have focused on the architecture of the environment and the elements of the PD. There are several other elements we have glossed over. In particular, we have not discussed the range of issues in personalization of the information presentation on the PD. We have also focused on the delivery of augmented images of elements of the room. This will only serve as an effective component of a support for scrutability if there is also an overview map of the room so users know where to point their PD.

We have described two important dimensions of personalization in relation to supporting scrutability of an invisible pervasive computing environment. The first is the possibility of personalization of access, such as several others have considered. The second is more novel, involving personalization of the delivery of information on board the user's PD.

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SearchLight – A Lightweight Search Function for Pervasive Environments

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ABSTRACT

We present a lightweight search function for physical objects in instrumented environments. Objects are tagged with optical markers which are scanned by a steerable camera and projector unit on the ceiling. The same projector can then highlight the objects when given the corresponding marker ID. The process is very robust regarding calibration, and no 3D model of the environment is needed. We discuss the scenario of finding books in a library or office environment and several extensions currently under development.

Introduction

Ubiquitous computing landscapes extend our physical surroundings by a computational layer providing new functionalities. One such functionality can be the capability of objects to make themselves known in order to be noticed or found by humans. This functionality was already proposed in the original Ubiquitous Computing vision [6]. A search function for physical environments would alleviate the need to keep track of all of the things in our environment.

One obvious application is keeping track of books in our office, in a library or a book store. Let's think of a library with ubiquitous display capabilities. Let's assume there will still be a conventional inquiry terminal to find out about books. The inquiry interface on the computer terminal in a library could then just provide an additional ”show me” button for the selected book, which prompts the environment to highlight its position on the shelf.

Let's think of an instrumented office in which there are many books and other things, either neatly sitting on the shelf where they belong, or left somewhere in the room on a pile. A physical search functionality will find and highlight missing objects for us, no matter where we left them. In this paper we describe such a search function for physical objects, and how it was implemented in our instrumented environment.

MU3I 2004, Workshop on Multi-User and Ubiquitous User Interfaces, January 13, 2004 at IUI/CADUI 2004, www.mu3i.org

The SUPIE environment

The Saarland University Pervasive Instrumented Environment (SUPIE) is an instrumented room with various types of displays, sensors, cameras, and other devices. By means of a steerable projector, the room has continuous display capabilities which are limited in resolution and temporal availability (only one area at a time). The various other displays provide islands of higher resolution and interactivity within this display continuum. The projector can project arbitrary light

Figure 1: The steerable projector mounted on the ceiling (top) and one corner of SUPIE with a book shelf (bottom)

Figure 2: Images taken during the scanning process (left) and an example of an AR Toolkit marker (right)

patterns onto all surfaces in the room with line of sight to its position in the center of the ceiling. An attached camera can take high resolution pictures from (almost) the same position and scan them for objects and markers. It also provides a low resolution video stream in real time for the recognition of movements.

Implementation of *SearchLight*

General Thoughts

All that is needed to implement *SearchLight* is the steerable projector with its camera and the capability to recognize optical markers. The only determining factors for finding objects and highlighting them, are the pan and tilt angles of the unit moving the projector. If a marker is found at given pan and tilt angles, these can be stored and used directly for projecting a highlight area around the corresponding object. Thus, not even a 3D model of the room is needed. Absolute registration errors of the camera and projector will cancel each other out since they are mounted in one unit and moved together.

Devices

The steerable projector is mounted on a moving yoke produced by a stage equipment manufacturer, controlled via a DMX interface, and mounted in the center of the ceiling of the room. The unit carries a 3.000 ANSI lumen projector with a lens of long focal length, in order to provide sufficient contrast and brightness in daylight. The camera attached to the projector (see figure 1 right) is a regular Digicam with an image resolution of four Megapixels. The high resolution pictures are triggered and read out over USB with the camera's freely available SDK. Each object that should be found by *SearchLight* is tagged by an AR Toolkit marker (see [1]). Each marker has a large black fringe and an individual small black symbol on a white background. (See figure 2) These markers are recognized by the Java version of AR Toolkit.

Implementation

SearchLight performs two main tasks: It *scans* the room for markers and memorizes the corresponding angles, which are used later to *show* searched objects.

Scan The room is scanned by taking slightly overlapping pictures in all horizontal and vertical directions (see Fig. 2 left). Each picture is analyzed using JAR Toolkit. Marker IDs are stored in a list together with their pan and tilt angle, derived from their position and orientation in the picture and the orientation of the moving yoke when taking the picture.

Show After the room has been scanned, the user can search for marked objects. The object's Marker ID is looked up and the projector unit moves to the position where this marker was detected during the last scan and projects a bright spot around the searched object.

Related Work

The use of a steerable projector to transform environments into continuous displays has first been proposed by Claudio Pinhanez [2] at IBM. In their Siggraph 2001 emerging technologies demo, where colored M&Ms were composed by visitors to form large pixel images, the Everywhere Display Projector was used to highlight trays with different colors on a shelf. The positions of these trays were, however, not acquired automatically. Additional applications are presented in [3], including a ubiquitous product finder and an interactive shelf. The product finder guides people towards products in a store environment, using blank projection surfaces as individual direction signs and interaction spaces. The interactive shelf uses similar surfaces for the display of product-related information. While these prototypes are strongly related to the work presented here, both of them require dedicated projection space in the environment. Raskar et al. present in [4] a method for simultaneous acquisition of room geometry and use of the acquired surfaces as an output medium for mobile projectors. They also use markers for object recognition and annotation, but rely on the user pointing to the right direction. In our demo, the environment actively controls the projector.

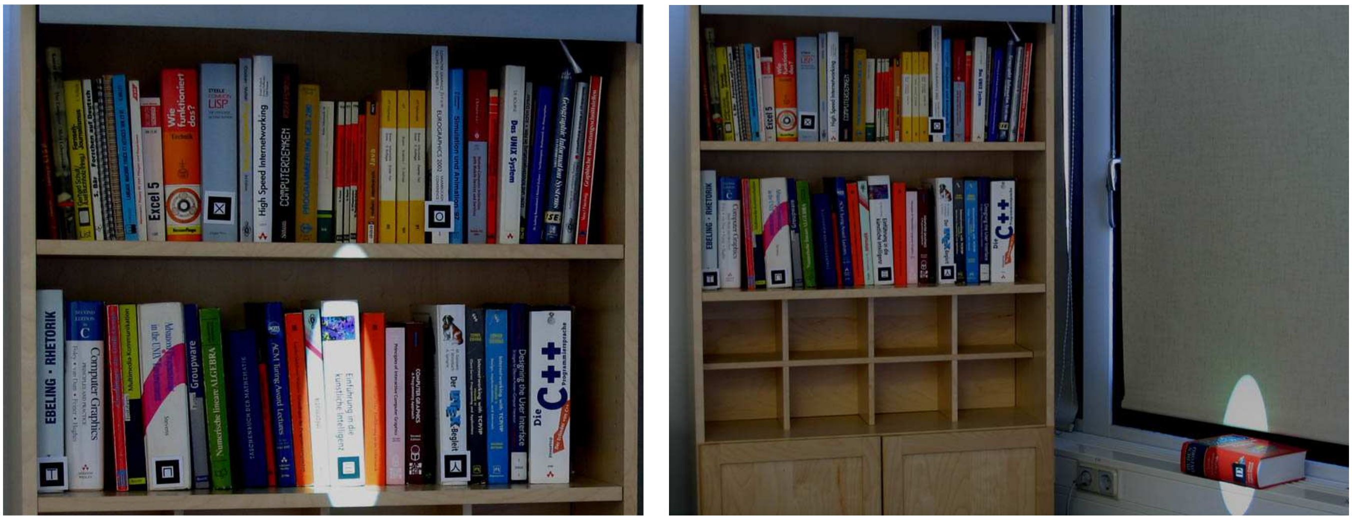

Figure 3: A book was found on the shelf (left) and another one on the window sill (right)

Current Results and Future Work

With our experimental setup in SUPIE (room size 5x6m, shelf on the wall, 4 Megapixel steerable camera with 3x optical zoom in the center of the ceiling) we were able to reliably recognize markers down to a size of 10mm in the whole room. Initial scanning of the room took roughly 1 hour, mostly due to the slow transmission of pictures over the USB 1.1 link to the camera. Currently we are improving *SearchLight* in various respects.

Continuous Model Update

In the current demo, scanning is done only once when *SearchLight* is started. In the future we will use idle times of the projector to systematically re-scan the room for changes. This process will also prioritize regions where changes are more likely by using additional sensors, such as RFID tags or motion detection with other cameras. On the down side, including external sensors will require the use of at least a simple 3D model of the room in order to relate locations of sensor events to pan and tilt angles of the projector. This model might, however, be acquired automatically by methods similar to those described in [5]. Upcoming versions of *SearchLight* may use the camera even when the projector is used for other tasks by just analyzing images as they appear rather than actively steering the camera to certain positions for scanning.

Extension to Other Markers

In theory, existing bar codes on many products could be used for the recognition process. In the case of books, OCR could even eliminate the need for markers altogether, since book spines and covers are designed to clearly identify books. Currently, we are working on integrating RFID tags by watching the region around the RFID antenna. When the antenna registers a change in its field, a new image is taken and the exact position of the new resp. removed object is identified from a difference image. As a side effect the exact silhouette of the object might be obtained for highlighting by the projector.

Fuzzy Search Results

Sometimes the exact position or dimension of a searched object may not be known, for example if the object within an RFID antenna field could not be located unambiguously by the difference image. In this case, the fuzzy search result can be visualized as a spot whose diameter reflects the amount of uncertainty.

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A Lightweight Approach for Experimenting with Tangible Interaction Metaphors

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INTRODUCTION

Interaction techniques for Augmented Reality user interfaces (UIs) differ considerably from well explored 2D UIs, because these include new input and output devices and new interaction metaphors such as tangible interaction.
For experimenting with new devices and metaphors we propose a flexible and lightweight UI framework that supports rapid prototyping of multimodal and collaborative UIs. We use the DWARF [7, 2, 3] framework as foundation. It allows us to build highly dynamic systems enabling the exchange of components at runtime.

OUR APPROACH

Our framework is a UI architecture described by a graph of multiple input and output and control components (User Interface Controller UIC). Furthermore the framework consists of a communication protocol specified in a taxonomy for input tokens [10] and a loose collection of commands [8] that is currently consolidated into a taxonomy.
The input components emit tokens which are received by the UIC. It does a rule based token fusion consisting of *MediaAnalysis* and *CommandSynthesis*. Finally new command tokens are sent to the output components.
We use Petri Nets to model interactions - as is common practice in the area of workflow systems [1].
A Petri Net consists of places, tokens, arcs and transitions. The arcs connect places and transitions. Places and arcs may have capacities. A transition fires when all places at the end of incoming arcs contain (enough) tokens. Transitions execute actions when fired.
Optionally all arcs can have guards on both ends. Guards can define constraints on the type and number of the tokens as well as on the value of the tokens. Transitions only fire when all guards evaluate to true, meaning that all constraints are fulfilled.
In our approach transitions are used to encapsulate atomic interactions. More complex interactions can be modelled by combining several transitions. Our framework allows developers to define rules for *Media Analysis* and *Command Synthesis* and thus modeling interaction in a combination of XML and Java. The rules are encapsulated in the actions performed when transitions fire.

EXAMPLES

In this section we present, in increasing complextity, three examples and their corresponding Petri Nets.

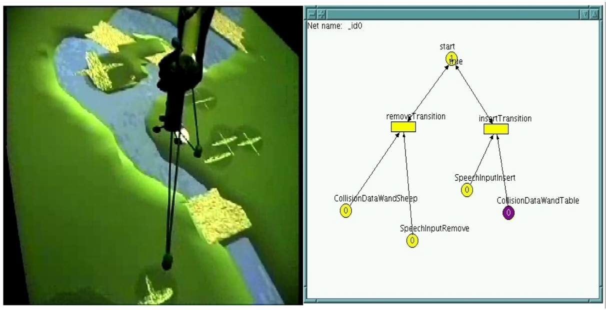

Figure 1: Point-and-Speech interaction in SHEEP. On the left the tangible pointing device, on the right the corresponding Petri Net.

The first example demonstrates how a simple multimodal interaction is modelled in our framework. Figure 1 shows a Petri Net from the SHEEP [9] application, where incoming speech events (”insert Sheep”) and collision events (tangible pointing device hits table) are tokens.
After all places on incoming arcs are filled up, a transition fires. This generates a command object which is sent to the output components. There it leads to the creation of a new sheep.

The second example (see figure 2) demonstrates another simple interaction, but with additional constraints on the flow of events to guarantee consistency. Several sheep can be picked up from the table and dropped back later. Let n be the number of scooped sheep. Then $n > 0$ has to be true, before a sheep can be dropped back onto the table. This *causal constraint* is realized within the guard of the transition which fires the command for dropping a sheep.
Another constraint, realised within the guard for picking up a sheep, is that after a sheep has been dropped, it cannot be picked up again within a certain ammount of time. This *temporal constraint* prevents the user from unwantedly picking

up the dropped sheep with the same interaction. These are very simple examples for constraints. Since the guards logic is implemented in Java more complex constraints are possible.

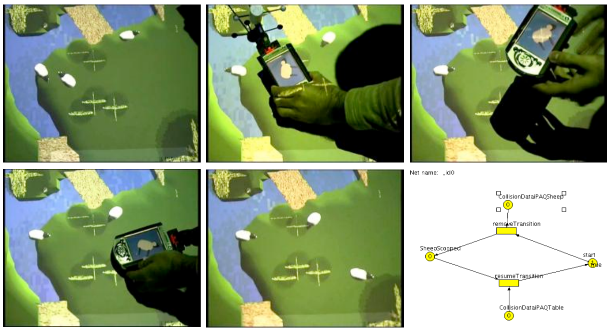

Figure 2: Sequence of images for Scoop-and-Drop interaction with a virtual sheep and an iPAQ. In the lower right corner, the corresponding Petri Net is shown.

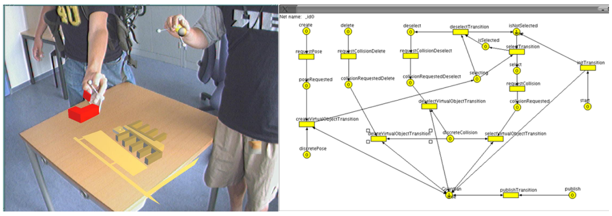

Figure 3: Complex interactions within a tangible modelling application for architects. The corresponding Petri Net is shown on the right.

Within the ARCHIE [5] project, a complex architectural modelling application has been implemented.
The Petri Net for all necessary interactions is shown in figure 3. It enables the user to create, move and change 3D objects (e.g. walls) through multimodal and tangible interactions. Later those objects can be selected and deselected so that their properties can be changed.
In addition to the complex interactions in this application, the concept of private and public spaces [4] has been explored:
Some of the resulting visualizations can only be seen in the Viewers of the user executing them (*private space*) until he decides to publish his applied changes and thus makes them visible in the Viewers of all users (*public space*).
In the first case the command objects are only sent to the user's Viewer, in the second case they are sent to all Viewers. Which of these two mechanisms is used is defined within the transitions that belong to these interactions.

DISCUSSION

The framework has been implemented and used in the SHEEP [9] application and several others [6].
It allows an easy composition of multimodal UIs by abstraction of input and output components. Further it allows us to describe interactions based on the formal model of Petri Nets. Additionally temporal and causal constraints on the interactions can be defined as described in the *Examples* section.
The concept of private and public spaces has been addressed too, utilizing the advantages of the DWARF publisher/subscriber middleware architecture.
Finally the simulator delivers an easy to understand visualization during development and runtime. The simulator visualizes the structure of the Petri Nets themselves and how tokens are passed through and transitions fire during runtime. Screenshots can be seen in the figures 1, 2 and 3
However we encountered some limitations. Petri Nets are by nature rigid. That leads to problems when unexpected things happen and dynamic reactions are necessary. Two mayor problems are caused by this.
Error handling is very limited. And all interactions are predefined, that prevents us from building intelligent and learning systems.
We focus on the flexible adaption of components and the easy, intuitive possibility to model and exchange interaction metaphors. We did encounter that this approach is sufficient to model a broad range of multimodal and collaborative interactions.

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