Proceedings of the Workshop

Mobile Interaction with the Real World (MIRW 2006)

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Human Computer Interaction with Mobile Devices and Services
(MobileHCI 2006)

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Preface

Welcome to the MobileHCI 2006 workshop Mobile Interaction with the Real World (MIRW 2006). We accepted 13 papers that will be presented within the workshop. We would like to thank the authors for their contributions and the organizers of MobileHCI 2006 for hosting MIRW 2006. Furthermore we would like to thank the research project Perci (www.hcilab.org/projects/perci/) funded by the NTT DoCoMo Euro-Labs for the support to publish this workshop record in a printed form.

We look forward to the workshop providing a rich environment for academia and industry to foster active collaboration in the area of mobile interactions with the real world.

Espoo, September 12 2006

Enrico Rukzio, Massimo Paolucci, Tim Finin, Paul Wisner, Terry Payne

Theme of the Workshop

Mobile devices have become a pervasive part of our everyday lives. People have mobile phones, smart phones and PDAs which they take with them almost everywhere. So far these mobile devices have been mostly used for interactions between the user, her mobile device and the services (phone calls, writing short messages and organizer functionalities) she uses.

In the last years we saw increased interest in using the mobile device for interactions with other people (mobile gaming) and places (location based mobile services, mobile guides). But so far there has been no forum which concentrates on mobile interactions with real world objects. Examples for this are for instances the usage of RFID/NFC equipped mobile devices for interactions with smart objects such as advertisement posters or vending machines; the usage of mobile devices as a universal remote control or the usage of mobile devices for direct interactions (e.g. based on image recognition) with objects in a museum. When looking at this research area the following questions occur:

- Which kind of interactions with the real world are possible??
- What should these user interfaces look like?
- How should systems and services for these kinds of mobile interactions be designed?
- How can these real world services or objects be described (WSDL, UPnP, Java interfaces, XML, task descriptions, etc.)?
- Can these interfaces be automatically generated?
- Should these real world services be defined in a standardized way (e.g. with semantic web services)?

Topics

Possible topics for the workshop include (but are not limited to):

- Mobile interaction with real world objects and smart objects
- Automatic user interface generation
- Semantic web within mobile applications and interactions
- Using mobile devices as user interfaces for terminals and vending machines
- Guidelines for mobile interactions with the real world
- Interactions between mobile devices and the real world
- Multimodal interaction taking mobile devices into account
- Usage of sensors of mobile devices (camera, microphone, GPS, etc.) for pervasive applications
- Interaction metaphors for pervasive applications and services
- Augmented, virtual and mixed reality on mobile phones and PDAs (tracking, markers, visualisation)
- Portable media players (e.g. iPod Video) and personal servers as mobile interaction devices
- Interactive context-aware services on mobile devices
- User experience, user studies
- Applications and scenarios

Goals

The main goal of the workshop is to develop an understanding of how mobile devices (particularly mobile phones, smartphones and PDAs) can be used as interaction devices. We will provide a forum to share information, results, and ideas on current research in this area. Furthermore we aim to develop new ideas on how mobile phones can be exploited for new forms of interaction with the environment. We will bring together researchers and practitioners who are concerned with design, development, and implementation of new applications and services using personal mobile devices as user interfaces.

Webpage

All information about the workshop, the papers and the proceedings are available at the website of the workshop **http://www.hcilab.org/events/mirw2006/**.

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Telling a Story on a Tag: The Importance of Markers' Visual Design for Real World Applications

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ABSTRACT

Tag recognition can be a convenient and quick information access method for mobile applications. Tags act like URLs allowing users to leave and retrieve digital information associated to physical objects or locations. Visual tag can be recognized using standard digital cameras, now common on commercial mobile phones. This paper demonstrates an application of d-touch, a visual tag recognition system running on Symbian OS phones that leaves considerable freedom in the graphic design of the tags. The design process for visual tags to be used in a urban Ubicomp project is presented, highlighting the importance of the graphic design of tags for real-world applications.

Categories and Subject Descriptors

H.5 [**Information Systems**]: Information Interfaces and Presentation. J.5 [**Computer Applications**]: Fine Arts.

General Terms

Algorithms, Design, Experimentation, Human Factors.

Keywords

d-touch, Electronic Lens, Topological Recognition, Fiducial Recognition, Marker Visual Design.

1. INTRODUCTION

Mobile applications can provide ubiquitous information access through the increasing connectivity and multimedia capabilities of mobile phones and PDAs. While output capabilities of these devices are constantly improved (improved audio quality, high resolution and high contrast displays and even display peripherals embedded in eyeglasses and mini video projectors), input often acts as a bottleneck. Both the limited size of keyboards and the conditions of use ("on the move"), make text entry often problematic, especially for text not based on dictionary words such as URLs.

When it is possible to associate information, or more generally interaction, with a specific physical object or location, automatic *tag recognition* can be used as an efficient and fast input method. The idea is to have a set of tags – each with a unique identifier – that users can *scan* or *read* through their mobile devices; each tag identifier can then act like a generic URL, allowing users to retrieve or leave digital information related to the tagged object or location. For example, tags can be associated to artworks exhibited in a museum, items for sale in a shop, monuments or points of interest in a city [5]. Different technologies can be used for tagging, the most common are Radio-Frequency ID (RFID) and visual recognition based on computer vision.

RFID tags can be recognised by dedicated readers that emit a radio signal, generally in the MHz range, and "listen" to responses to this signal by nearby tags [4]. Readers can have range from few centimetres to metres. Because of the properties of radio propagation, RFID tags do not need to be at line-of-sight with the reader, so they can be hidden under a surface and made invisible to the eye. This property can be advantageous in some circumstances, such as for scanning all items getting in and out of a storage warehouse, or when the presence of a tag can be taken for granted (for example if *all* items in a shop are tagged). However, in more generic situations the presence of RFID tags still needs to be made evident to users through visual signs [6]. RFID readers are embedded on some phone prototypes, but are not yet common on commercial devices, probably due to the specificity of their use.

Visual tags, also referred to as *markers*, are graphic symbols that can be read by a standard digital camera, like the ones embedded in camera-phones, and decoded through a computer vision algorithm that can either run locally on the phone or on a remote server. Because the system uses the visible spectrum, to decode a visual tag the camera has to be pointed directly at the symbol and this has to be visible to the human eye. Several systems for decoding visual tags on commercial mobile phones are available, both commercially and as output of academic research [7, 9, 10].

In all of the existing systems, information is encoded in the geometry of the markers (i.e. their shape), as a consequence the markers visual design is determined solely by the system specific encoding algorithm, without taking into account any aesthetic criteria.

2. D-TOUCH: TOPOLOGY-BASED VISUAL TAG RECOGNITION

d-touch is a visual tag recognition system that encodes information in the topological structure of its markers, rather than

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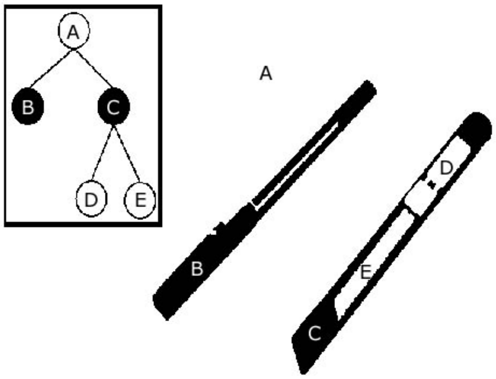

Figure 1. An example region adjacency tree. Regions in the scene (on the right) correspond to nodes of the tree (on the left).

their shape (i.e. their geometry) [1,2]. As a consequence, the visual design of the markers is less constrained than many other visual marker systems, and it can be governed by aesthetic principles: form and function, rather than just function.

The topology of d-touch markers is considered in terms of their adjacency structure. The markers are composed of black and white regions (*connected components*) and the adjacency structure of these regions (i.e. the way the regions are *nested*) can be used as an identifier. The adjacency information is stored in a region adjacency tree, as illustrated for a generic scene in Figure 1 and for one marker in Figure 2. Each node of the tree corresponds to a connected region, two nodes are connected by an arc if and only if the two corresponding regions are neighbouring. Each tree can be represented as a string of integers [1], conveniently usable as a marker ID. Figure 3 shows two markers that are topologically equivalent to that of Figure 2, demonstrating how the system leaves freedom in the visual design of the markers. Figure 4 illustrates another marker "hidden" in text, together with its topological structure.

The markers can be decoded purely through their topology, but it is optionally possible to also take into account their geometry. This option can produce a larger number of different identifiers. For example even though the two markers of Figure 3 are topologically equivalent, they can be read as 1234 (left) and 1243 (right), where the numbers correspond to the number of black regions inside each white square (reading left to right, top to bottom). Using geometry it is possible to define 24 different markers of this type. It must be underlined that this is just an example and that larger number of different identifiers can be available with d-touch.

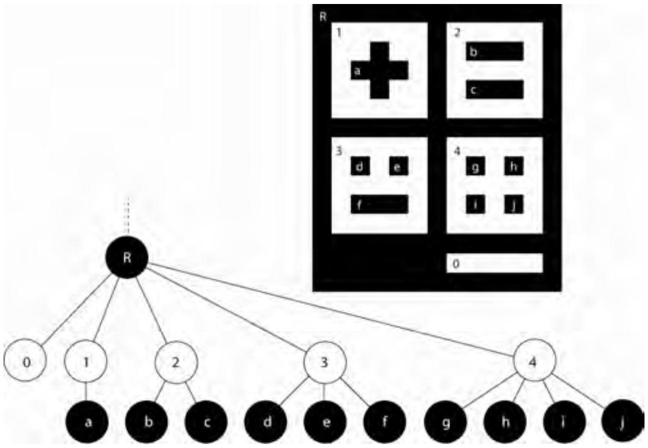

Figure 2. A d-touch marker with the corresponding region adjacency tree.

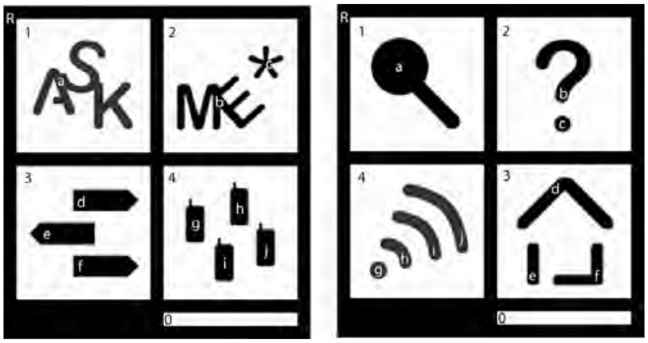

Figure 3. Two markers with the same topology as the one in figure 2.

The system was originally developed in C++ for desktop applications under Linux and MS Windows. It was later ported to the Symbian OS mobile platform. d-touch was designed for real-time graphics and audio interactive applications, it uses little or no floating point operations (depending on whether or not the marker geometry is taken into account). This characteristic makes it ideal for embedded devices without FPU, such as most commercial mobile phones. d-touch is available under GNU Public Licence on http://sourceforge.net/projects/libdtouch/.

3. CONTEXT: THE ELECTRONIC LENS PROJECT

d-touch was used in the Electronic Lens, a social networking application developed at the MIT Media Lab [3]. The application enables users to create location based discussion and communities. Citizens can share information and opinions – which are related to a specific place in their city – and participate

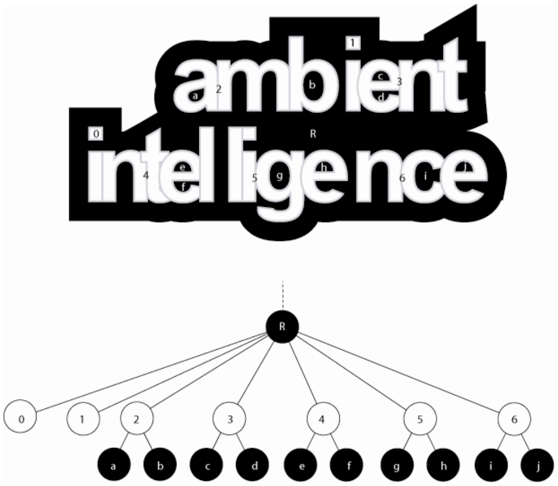

Figure 4. A marker "hidden" in type, and the corresponding region adjacency tree.

in discussions of public interest in a democratic way.

Private or more restricted discussions are also possible by setting up personalized groups. When leaving a message, a user can decide who will be able to access it. The Electronic Lens incorporates several components: the d-touch tag recognition system, the RadioActive voice chat system [11], the xLink context manager system [8] and other ones currently under development.

The Electronic Lens provides a tangible experience of the physical environment and local communities. It creates the opportunity to gain a new perception of the city, and encourages participation in civic decision making process. The application can function as a guide, as a local story-teller and as a way to network people with the same interests. Personal opinions as well as corporate information can be part of a tag and its related content. Within the project, visual tags function as a landmark, around which the interaction takes place.

The project in its initial phase was tested in April 2006 in Manresa, Spain with the support of the Generalitat de Catalunya (the Catalan regional government) and the Ajuntament de Manresa (city council). In a workshop setting, a group of 16 local high school students tagged building in their city and used the mobile device application during one week to explore new ways of communication.

4. DESIGN PROCESS

The Electronic Lens project was promoted and supported by the Generalitat de Catalunya, the Catalan regional government which somehow took the role of a client in terms of expectations and ideas of the project. The interest of the institution was to examine how mobile and location based technology can improve the mutual relationship between citizens and government. Because of the official endorsement, the tags needed to be perceived as formal, authorized items that add value to the objects they are placed on – rather than polluting the environment as ordinary stickers could do. Part of the project involved placing tags on the façades of private buildings, this caused special concern, as the owners should feel honored by having their walls tagged. Similar to a seal, the tag should stand for a place of interest and special distinction and attract pedestrians and users in a visually appealing way. With the institution logotype of the Generalitat on the final design, the tag got even an official signature.

Figure 5. A tag for the Electronic Lens project. It includes 3 d-touch markers and other graphic elements.

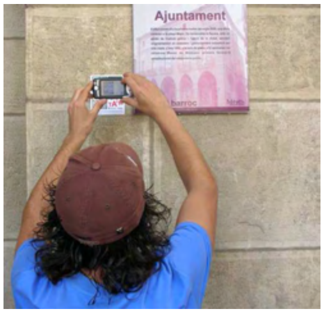

Figure 6. A tag in use during the trial in Manresa.

When designing the physical tag for the Electronic Lens project, the aim was to tell a story by transforming the markers into sets of icons. Supplemental text, illustration and logotypes that had no technical functionality were also used to complete the design from an informational and aesthetic point of view. The design includes icons for expressing one's opinion, for leaving one's view of things through pictures, for a networked city with information accessible through mobile devices, and for the pleasure that comes up with exploring what potentially lies quiet behind this physical marker.

The design is visually coherent and the technical functionality could be completely *hidden* into it. All the technical constraints were fulfilled without any visible detriment as a result of an iterative optimization process. The final design included 3 sets, each of 4 icons, each set embedded in a d-touch marker. From the technical point of view, each "Electronic Lens tag" includes 3 d-touch markers of the type shown in Figures 2 and 3 – because each marker can assume 24 different values it is possible to define more than 12000 different tags (to simplify the processing only *sets* of markers are considered, not *permutations*), enough for the project that required only 500. The logotype of the government and the red pregunta'm ("ask me" in Catalan) did not have a technical function but are essential part to communicate the project and its official aspect (Figure 5).

Different types of tags were iteratively designed – evolving from a pure, abstract data code (Figure 2) to a carefully crafted design, with an "invisible" data code that leaves space for communication graphics.

The functional aspects of the tag constrain the design to the use of high contrast, positive and negative planes and modularity, as well as use of matte materials because of camera recognition issues with reflective surfaces. Still, d-touch is a flexible visual tag recognition system that allows a wide range of personalization by encoding information in the topological structure of the markers.

The choice of the material for the tags was also object of research. The aim was to create a high-quality flexible label, that could be placed on curved surfaces (e.g. lamp-posts), water resistant, removable but definitely easy to stick on rough textured surfaces as sandstone or on shiny surfaces as plastic. The tags were printed with an ink-jet plotter on a water-resistant heavy-weight vinyl, with an ink-jet plotter. They were attached to buildings with an easily removable adhesive, applied by the user the moment he or she places the tag. The characteristics of the adhesive allowed to fix the tag on practically any type of surface.

5. FURTHER DEVELOPMENT AND FUTURE APPLICATIONS

As discussed in the previous section, the design process described in this paper was a collaborative effort and required technical understanding of the recognition algorithm.

Further development will aim at enabling the design of d-touch markers with minimal understanding of the underling technology, for example through the realization of a drawing software (or even better a plug-in for an existing application) that can interactively guide the design of functional markers.

Personalization and appropriation play a strong role in the mobile devices market: users customize their phones with screen backgrounds, phone shells and ring-tones, generating high revenue volumes. Based on this, it can be interesting to allow end-users to design or modify tags, for example through a web-application. The personalized tags can then be printed by users themselves with standard consumer-grade printers and be affixed to objects or buildings, in order to annotate them with digital information. This process also resonates with the phenomenon of *graffiti tagging*: spray-painting their initials or pseudonym on wall individuals or groups mark and appropriate the urban territory.

Because d-touch can be deployed on a large number of commercial phones without custom hardware, there is potential for large scale tagging trials. It would be possible to equip a a medium size community with camera phones and study how individuals take advantage of the ability of leaving messages in specific locations or attached to specific objects. The results could then be easily generalized to other tagging technologies. Potential is also foreseen for printed paper: adding a visual tag to a printed magazine or poster involves absolutely no additional cost and it can allow publishers to more easily link on-line resources (multimedia material, discussion forums, updates) to the printed content. The possibility to adapt the graphic aspect of the markers is very important in a market where aesthetic plays a major role.

6. CONCLUSION

This paper presented the design of a set of visual tags that can be read through a computer vision system but at the same time tell a story through their visual iconic aspect. The design was possible thanks to the use of d-touch a recognition system that leaves considerable freedom for the geometry of its tags.

Liberating the design of visual tags from being data codes, and making it a visual medium that allows to tell a story or give a glimpse of what is hidden behind the tag is a very powerful way to improve the user's experience. The personalization of visual tags offers an additional channel to communicate the identity of multimedia projects.

7. ACKNOWLEDGEMENTS

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d-touch was initially developed while Enrico Costanza was at the University of York, England, under the academic supervision of John Robinson, and at Media Lab Europe, Ireland, under the direction of Rebecca Allen.

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Mobile Pointing & Input System for Eyeglass Display

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ABSTRACT

The needs of watching a movie with a mobile device such as a head-mounted display (HMD), an eyeglass display (EGD) are increasing nowadays. One of the hardest part of it is an interaction method where users point at objects and input commands in the display of the mobile devices. In this paper, we present a new method using fiduciary marker-based tracking technology of augmented reality. Our method uses an active marker displayed on the small liquid crystal display (LCD) of a mobile phone, and a camera on the EGD to point the marker out of the view. Comparing to the legacy methods such as a keypad, a touch-screen, and a gyro, our method is proved to be more robust and reliable in real mobile environments.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Input devices and strategies.*

I.3.6 [**Computer Graphics**]: Methodology and Techniques – *Interaction techniques*.

General Terms

Human Factors, Design, Experimentation, Verification.

Keywords

Augmented Reality, Mobile Pointing, Active Marker.

1. INTRODUCTION

Mobile phones are, nowadays, equipped with many peripherals such as a global positioning system (GPS) receiver, a gesture recognition module, a TV tuner, etc. The limited size of the display on the mobile phones, however, confines the types of services. One of possible solutions is using HMD or EGD for enlarging the display size. The commercialized HMDs are relatively heavy to wear for long hours, and cause some strains of eyes or dizziness, but an EGD has been developed to alleviate such problems and in the market as a mobile phone accessory [1].

However, there is a shortcoming of the EGD as an accessory of the mobile phone even though it provides a virtual large display in mobile environments. The EGD makes it hard to use the existing mobile input methods, such as a keypad, a touch-screen, menus, etc., because the EGD obstructs a user's view to see a small mobile display or key buttons while wearing the display device. Furthermore, it becomes necessary to select a virtual button overlaid on the large display and to input an internet address onto a web browser when the user enjoys a movie (i.e. DMB[1]) or surfs the internet (i.e. WiBro[2]).

In this paper, we introduce a mobile pointing and input system using an active marker to move a pointer, to select a virtual object, or to input alphanumeric information for the internet browser, while enjoying a virtual large screen of the EGD in real mobile environments. Active maker is a marker displayed on the LCD of mobile phone so that its brightness and shape can be adapted to improve the detection rate. Moreover, we measured the performance of our proposed system by the Fitts' law [10], which is popular to evaluate the performance of pointing system in the field of human computer interaction/interface. Then we compared our results with the commercialized pointing device which was developed for a desktop computer but also could be applied to the conventional mobile phones.

Figure 1. The concept of mobile pointing & input system.

2. RELATED WORKS

Many researches focus on developing pointing devices and input systems in mobile environments especially in the field of virtual reality and wearable computer [2, 3]. FingerMouse equipped with a small stereo camera set and an image processing module enabled users to point at the position of virtual screen using bare hands [2]. Glove-based method having small fiducial markers on the thumbs or the back of gloves provided pointing and input method for wearable or desktop computers [3]. Seiko Epson developed a pointing device to locate the 3D position of a fingertip [4]. The system is composed of a magnetic ring and a HMD. The magnetic ring has two magnetic field sensors on lateral sides to triangulate the position of the ring. But it is not practical in real environments

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[1] DMB (Digital Multimedia Broadcasting) is a digital transmission system for sending data, radio and TV to mobile devices such as mobile phones. It can operate via satellite (S-DMB) or terrestrial (T-DMB) transmission.

[2] WiBro (Wireless Broadband) is a wireless broadband internet technology being developed by the Korean telecoms industry.

because the user has to wear an extra device, the finger ring, in addition with the HMD.

AR Sketching proposed a pointing method and its system architecture which could be used as a 3D mouse of a HMD [5]. The 3D pointing device contains two cameras mounted on HMD and three different colored light-emitting diodes (LEDs) attached over the conventional optical mouse. By using a simple color tracking algorithm, the position of the pointing device can be detected, and then the user can make a sketch in the air.

MagicMouse proposed the wearable pointing system using fiducial marker-based tracking technology of augmented reality [6]. A camera on the monitor of desktop computer tracks a black and white cardboard square marker on the back of MagicMouse glove by using the ARToolKit library [8]. Our system inspired by the pointing method of MagicMouse to apply it in real mobile environments.

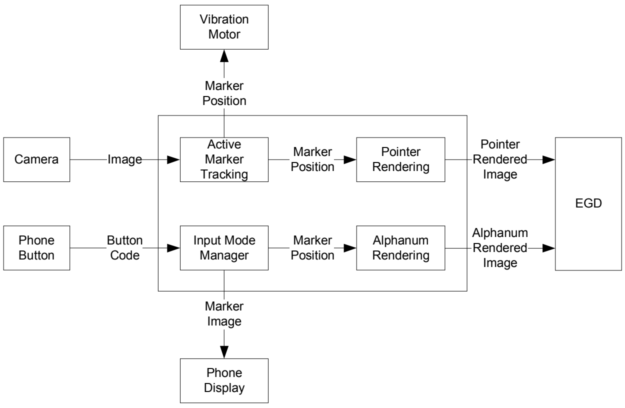

Figure 2. Overall system architecture.

3. MOBILE POINTING & INPUT SYSTEM

We propose and implement a new pointing and input system enabling the conventional mobile phone both as a mouse and as a keyboard in mobile environments while the user enjoys movies or surfs the internet on the large virtual screen (20 ~ 100 inches) of an EGD. Figure 1 indicates the overall concept of our system. A user wears an EGD to view both a real world and superimposed virtual objects generated by mobile phone. As a prototype example, we run a web browser to surf the internet, and then we select the button of the browser and click it by moving the phone as a pointer and pressing a button of it just as we use a mouse of the desktop computer.

We implemented our system upon the unreleased mobile platform manufactured by Samsung Electronics, which was developed originally as an evaluation system to test various software modules. The active marker tracking module was derived from [8, 9], and modified for our hardware platform and marker properties. Figure 2 shows overall architecture of our system.

The physical display size of mobile phone is 2 inches to show an active marker. The real size of the marker is only 1.6 inches because of the easy detection of rectangular border of it. As a result, the pixel size of the active marker captured by the camera (240×320) is in the range of 25×20 ~ 60×50 when the maximum distance between camera and marker is less than 1.5 meters because of the length of human arm. Even though we used the small LCD of the mobile phone to show an active marker, the brightness and the shape of the marker could be changed easily by the user or automatically by the mobile phone. This makes it possible to detect the marker even in dark or dim environments.

3.1 Active Marker

A user can switch the status of the mobile phone between the pointing mode and the function mode. When the mobile phone changes into the pointing mode by the input mode manager (located at lower left corner in figure 2), it enables the active marker tracking module (located at upper left corner in figure 2) which begins capturing images through the EGD’s camera, and locates the active marker displayed on the small LCD of the mobile phone. The active marker means a controllable visual fiducial marker which could be changed its brightness and shape. Figure 3 (a) shows the active marker displayed on the mobile phone.

If any marker could not be detected over the predetermined time interval (3 ~ 5 seconds in our experiments), the proposed system would change the brightness of active marker gradually. The frequency of changing brightness is about 2 ~ 4 Hz according to whether any marker is detected or not because the tracking performance of our system is less than 8 ~ 10 fps. General mobile phone provides only 3 ~ 5 levels of brightness (i.e. dark, dim, bright and so on), but our system needs more levels to raise the detection rate even in outdoor environments so that we developed a customized backlight unit (BLU) and a control unit which has 8 ~ 16 levels of brightness and additional control signals. To make bright BLU, we installed 6 LEDs in parallel into Samsung Electronics’ BLU. Our BLU has 350 cd (brighter than 250 cd of general BLU) and Advanced Analogic Technologies’ AAT3156 BLU controller. To control the brightness levels, simple serial control (S2C) provided by AAT3156 BLU controller was used as a control signal code through 1-wire serial interface.

In the case that any marker could not detected even after changing the full levels of brightness, the pattern of the active marker would be changed and then the tracking module tries to detect the changed marker patterns. As changing the marker patterns, the brightness control process is applied again until the marker could be found out.

Although the total number of the marker patterns used in our experiments is only 2, the developers can add more patterns which aim to be robust and optimal in various mobile environments. In most of indoor environments such as subways, commuter buses, etc. where our system has been tested, we could detect the active markers except for strong reflection over the display. To reduce the reflection, we made the LCD surface of our system coated by anti-reflection spray as [7] used it on a PDA screen.

3.2 Mobile Pointing

The active marker tracking module was implemented with the help of the source code of ARToolkit Library and ARToolkitPlus [8, 9], and added necessary modules to control the brightness and patterns of active marker. The tracking performance of our system is 8 ~ 10 fps under the XScale/PXA263 (400 MHz) processor for the smart phone and Microsoft Mobile Windows. To examine our system, we used Accupix's MPG-230DM as an EGD with Samsung Electronics' phone camera module (320×240). Both of devices can be connected with our mobile phone through an audio/video connector.

Figure 3 (b) shows the rendered red arrow superimposed over the active marker. In our system, it is not necessary to use the orientation information of the active marker provided by the libraries of [8, 9] when a user selects an input area or presses a button of widgets. Rather it disturbs the pointing task because the rendered pointing arrow jitters, even when a user does not move the phone. Therefore, we use only 3 DOF, $(X_{pos}, Y_{pos}, Z_{pos})$, from the transformation matrix of active marker ignoring the orientation information.

3.3 Alphanumeric Input

To manipulate information in the real mobile environments, it is necessary to input alphabets and numbers beside of pointing tasks. In our proposed system, there is no extra processing module to input alphabets and numbers. The user can change the modes from the pointing mode to the input mode, then the rendered pointing arrow displayed on EGD is changed its shape to a cursor like that of desktop computer and do not show any active marker to be tracked. Instead of the pointing arrow, a button layout is overlaid near the input position to help user to press the suitable button without occlusions. Figure 3 (c) shows the alphanumeric input mode just after the user clicks the address input area of web browser.

In general, alphabets and numbers are printed on the physical buttons of mobile phone in order to input different letters or numbers by the same button. Especially, many mobile phones used in Asia have more letters beside of alphabets and numbers. For example, the mobile phone used in Korea has 4 different character input mode: Korean, English, numbers and symbols. To provide easy input, our system shows only one letter set over the rendered buttons -- only consonants or vowels of Korean in case of Korean input mode and then changes its mode as the user wants to do.

4. EXPERIMENTS AND RESULTS

To evaluate the performance of our proposed mobile pointing & input system, we adopted the Fitts' law [10] which has been often used as a model for pointing tasks in user interface and quantization of the task. Equation (1) describes the Fitts' law where T is the average movement time between two pointing targets, A is the amplitude (or distance) between them and W is the width of a target where user's selection is happened. Coefficients, a and b, are empirically determined values.

$$T = a + b\log_2\left(\frac{A}{W} + 1\right) \tag{1}$$

The logarithmic term of (1) means the index of difficulty (ID) of pointing task which describes the difficulty degree of the task; it is the better pointing system that has smaller T value than the others in the condition of the same ID value.

Fitts' law was invented originally for 1D pointing tasks but Accot et al. [11] and T. Grossman et al. [12] extended and made it applicable to 2D and 3D pointing tasks. Although the proposed pointing system in this paper provides 3D pointing method, the display device, EGD which was used for our experiment, shows only 2D image and moreover the commercialized pointing device which was used to be compared with our proposed system, also provides 2D coordinates of itself, so that we apply equation (2), a 2D Euclidean model [11] of Fitts' law.

$$T = a + b\log_2\left(\sqrt{\left(\frac{A}{W}\right)^2 + \eta\left(\frac{A}{H}\right)^2} + 1\right) \tag{2}$$

(a) Active marker. **(b) Point mode.** **(c) Input mode.**

(d) Experiments to measure the performance of pointing task.

Figure 3. Images shown on EGD.

Given the target has a rectangular shape, W and H are each width and height of it, and η means a weight value determined by experiments. A has the same meaning in equation (1), that is, the distance between two centre positions of targets. After testing our system, we determined $\eta = 0.42$.

The experimental method is almost the same with that of [11], but we reduce the distance between two target buttons displayed on EGD because it has lower resolution (320×240) than the screen of desktop computer does, and add two diagonal moving tasks in addition to horizontal and vertical moving tasks.

All of the tested *(W, H, A)* combinations are summarized in Table 1. According to the combinations, we have to try 88 different pointing tasks per one person. The same person tried the pointing task two times in the same condition.

Table 1. Conditions of experiment.

W = H	W = H = 10	W = H = 30	W = H = 50
W < H	W = 10	H = {15, 20}	
	W = 30	H = {45, 60}	
W > H	H = 10	W = {15, 20}	
	H = 30	W = {45, 60}	
A	A = {100, 200}		

After experimenting for two days, a fitted equation (3) for proposed pointing system and a fitted equation (4) for the counterpart are derived from the results of regression line fitting according to the measured movement time, T_p, T_g.

$$T_p \approx 212.88 + 259.55 \log_2\left(\sqrt{\left(\frac{A}{W}\right)^2 + 0.42\left(\frac{A}{H}\right)^2} + 1\right) \quad (3)$$

$$T_g \approx 82.72 + 371.28 \log_2\left(\sqrt{\left(\frac{A}{W}\right)^2 + 0.42\left(\frac{A}{H}\right)^2} + 1\right) \quad (4)$$

Figure 4 plots the fitted movement time of equation (3) and (4) against *ID* while excluding several outliers of the measured movement time. As shown in Figure 4, we clearly see that the proposed pointing system can be manipulated in faster speed compared with that of the counterpart in the same difficulty level.

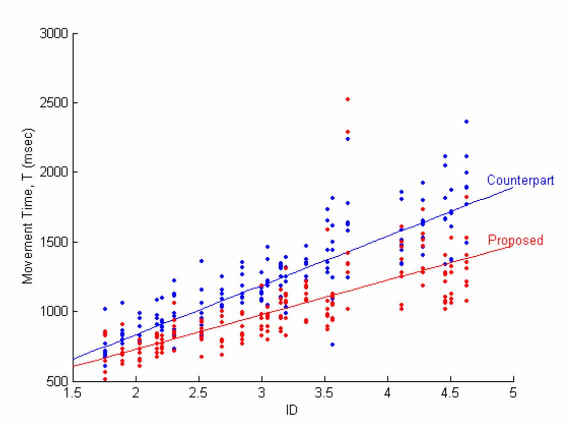

Figure 4. Experimental results.

5. CONCLUSIONS

We proposed and implemented a new concept of pointing & input system using the active marker which was inspired by the previous works of augmented reality, and applied it into a real mobile phone. Compared with the previous works, our proposed system is more practical in real mobile environment and provides a very cheap solution which is applicable to conventional mobile phones. We used the Fitts' law as a quantization model to measure its performance, and evaluated our system with a commercialized product and then showed the improvements of the proposed system.

There were a few persons to express inconvenience using our system because it provided only an absolute pointing mode. After studying many circumstances where a user wants to do with pointing tasks, we could suggest more practical systems in real outdoor mobile environments.

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Constructing assemblies for purposeful interactions

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ABSTRACT

This paper describes the development of a modular system of interactive tiles to support therapists' in performing therapeutic activities together with impaired children in a swimming pool. This work is based upon a deep understanding of therapist work practice and it has been integrated with a creative approach along iterative design cycles. These activities created the foundation on which the *Active Surfaces* concept and prototype has been developed.

Active Surfaces support mobile interactions and dynamic configuration of assemblies of tiles. Each tile represents an interactive unit, able to communicate with other tiles and to exchange data. A tile is always aware of its position in respect to the others and able to provide a meaningful feedback in the interaction with the users. This enables the Active Surfaces to engage in the therapeutic activities.

Categories and Subject Descriptors

C.3 **[Special-purpose and application-based systems]** *Microprocessor/microcomputer applications, Process control systems, Real-time and embedded systems, Signal processing systems.*

General Terms

Performance, Design, Reliability, Experimentation, Human Factors.

Keywords

Ambient computing, Palpable computing, end-user composition, programming by example.

1. INTRODUCTION

The notion of ambient computing has been consolidated focusing on the design of distributed, pervasive and reactive systems able to communicate with us and to continuously adapt to our current needs and expectations [1]. These systems have developed hybrid interfaces capable to interpret and represent both the distribution and the embodiment of technologies. From an interaction design perspective the exploration of smart objects and distributed systems gain interest on social interactions in mobile gaming, collaborative activities and location based mobile services.

In order to examine and investigate these aspects we look at an evolutionary approach on ambient computing with the notion of Palpability. Palpable computing purposely addresses the way in which humans meaningfully can interact with distributed computational systems available in the environment. Palpable computing aims at supporting user control by composing and de-composing assemblies of devices and services. These assemblies are configurable by the user depending on the context, her needs and expectations. Consequently, these systems should support the continuous attribution and negotiation of meaning through interaction.

These challenges and others are addressed in the EU-funded Integrated Project PalCom: Palpable Computing – A new perspective on Ambient Computing (http://www.ist-palcom.org). This project uses the term 'palpable computing' to denote a new kind of ambient computing which is concerned with the above mentioned challenges in complex and dynamic ambient computing environments.

These themes become crucial if applied to critical domains such as health care and rehabilitation. In this paper we will present a design concept supporting rehabilitation practice embodying some of the qualities that creates the foundation of palpable computing. The main inspiration for this application comes from the practice built around rehabilitation activities and from the activities performed in the swimming pool to rehabilitate disabled people.

In their current practice, motor and cognitive rehabilitations are mutually separated. Specific tasks and tools are designed for the motor physiotherapy; whereas other tasks, aids and tools are defined to support the acquisition of cognitive skills. The two activities are usually never integrated.

The swimming pool represents a privileged environment for rehabilitation. At the public swimming pool in Siena a volunteer association provides training and group activities for disabled people. The swimming pool by itself represents a powerful setting, because the water supports the body and takes the weight off the joints. Movements within the water are easier and less painful. Moreover, water is a great 'equalizer' for disabled people who find that their movements are easier and less different from those of non-disabled people while inside the water.

Our aim is to join cognitive and physical rehabilitation objectives by providing the children with meaningful activity games supported by a distributed system of smart surfaces. The application system relies on the specification and reference implementation of a virtual machine for PalCom devices, the PreVM, designed to match the evolving needs within the PalCom project [2].

1. ACTIVE SURFACES

Active surfaces is thought of as mobile smart devices that can serve for mobile gaming and rehabilitation activities. In the following section the concept and the early working prototype are introduced.

The tiles act as building blocks that can be combined with a library of content (e.g. images, sounds and pictures). Furthermore they have reactive behaviors in relation to different input actions and orientation. Each tile provides outputs as visual or tactile feedback to support the accomplishment of the tasks and to guide the patients in the interaction as described in the scenario below.

Today exists' three kind of Active Surface components; an Assembler Tiles and a number of 'normal' tiles. Apart from these there is also a user interface, the MUI [3]. The PreVM is the platform running under these components, being a language-neutral virtual machine designed to support object oriented languages running in low power consumption systems. PreVM is dynamically typed and requires each language to implement its proper type checks (e.g., the "instance of" relation in Java), but on the other hand imposes no restrictions on the type system of the languages that it supports [2]. PreVM programs are deployed in binary components which are instantiated as run-time components, objects that encapsulate a set of classes and their required and provided interfaces.

The 'normal' tiles are the ones used in the different activities and games together with the different users. Then there exists a privileged tile, the Assembler Tile is used by the therapists to program the other tiles. The MUI is used in a pre-activity phase to create general game logics and rules that later can be used in the pool. A therapist downloads the general rules created into the Assembler Tile and brings this to the pool. Now the therapists can assemble different 'normal' tiles using the Assembler tile to support a wide range of activities. The tiles themselves once assembled constitute a network of physical (and software) objects that communicate and exchange data and are able to recognize their relative positions.

These features allow constructing meaningful configurations of different tiles. Each configuration is intended as an assembly of components. The therapists can configure these assemblies of components to define rehabilitation tasks. They can save successful configurations, keep memories of previous configurations and generate new assemblies to support patients' specific needs. The rehabilitation activities enabled by the active surfaces allow a smooth integration of cognitive and physical task.

The Active Surfaces concept accounts for the need of configurability, constructability, modularity, physicality and creativity in rehabilitation practice. 'One' Active Surface consists of a tile, measuring 30*30 cm. Each Active Surface is thought of as a modular unit that can communicate with the others by its six sides. The tiles are able to recognize their relative positions in respect to other tiles. A number of tile components can be assembled to constitute a network of physical (and software) objects that communicate and exchange data. Many qualities of palpable devices are embodied in the Active Surfaces concept. Today a prototype is being used for evaluation purposes based upon a Basic Stamp 2 micro controller and IR communication. These tiles offer limited functionality, but sufficient for initial trials and proof-of-concept. The next generation of tiles embedding the full vision and the palpable framework is currently under development together with University of Aarhus (Denmark) and the Lund University (Sweden).

The main idea is to rethink the environment of the pool, making it a place for rehabilitation and play activities. As described above the pool is designed for swimming: the water serves as the mean of interaction. People usually don't have any (strong) relation with the pool by itself: the edges and the bottom are not conceived for any purpose of interaction. The design process aims at re-considering the surfaces of the pool and to change the activities that usually take place there [4],[5].

From an interaction design perspective the goal is to design new activities for the rehabilitation by designing enabling environments and tools. The Active Surfaces is the concept that embodies these issues. The surface of the pool becomes active re-designing the bottom, the edges and even the water surface. In this vision the floating tiles constitute one of the main supports for the interaction and the therapeutic activity.

Figure 1. Initial working prototype under construction and final result

2. PALPABLE QUALITIES

Active Surfaces represents an exemplar application for the framework of the palpable computing. It consists of embedded devices and distributed services. Palpability emerges as a property-in-use of the tiles' assembly. Dynamics of physical-logical construction/ deconstruction, mobile interaction and services communication sum up the palpable qualities of the application.

Being conceived as an assembly, active surfaces could provide a valuable example of physical construction / deconstruction of components. In that way the physical construction of assemblies [2] provides end-users with control of the system behaviour and adaptation to the context. The Active Surfaces constitute assemblies on different levels: on the logical level the therapist can define what the rules are and what the purpose is. On the functional level the user can mark out the relations and the sequences. Eventually, on the physical levels user can define which patterns and connections can take place.

To support end-user composition, the Active Surfaces is also complemented by a Migrating UI (MUI) browser mechanism[1]

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[1] The MUI End-User Composition Tool is used for programming the behavior of the tiles. MUI, developed within PalCom project

for programming the rules and the behaviours to be instantiated in the tiles. The therapist then creates patterns by physically building tiles' sequences [6]. The tiles address also scalability, offering the opportunity to produce scalable solutions still relying on low level resources management. Palpable computing systems, and indeed any ambient computing system, involve an heterogeneous mix of distributed, embedded devices with different capabilities. The palpable computing system, and Active Surfaces as such, must provide scalability and stability across different devices so that errors in one part the system do not propagate to other parts of the system. These features are supported by an appropriate degree of decoupling between different parts of the implementation.

At the same time the understandability of the system can still be guaranteed. This also concerns the balance between system automation and therapist' (i.e. user) control: the tiles have to preserve the understandability and support the users to maintain control over the technology.

Flexible ad-hoc networks support the connections among single devices where each tile preserves its own identity thus dynamically seeking for available tiles in the vicinity. The tiles continuously inspect what communication processes are taking place at the moment looking for specific connection on all its sides.

The concept also enables the exploration of the relation between change/stability in configuring the tiles. In fact the assembly' behaviors are instantiated in physical configurations that can be saved, reused (also in part) and instantiated in different physical patterns. She can show the right pattern (sequence) to the system and record(save) the configuration by using an assembler tile. Being a flexible system it has to guarantee a proper level of persistence as well. The dynamics between configurations' change and stability may address the future practice of rehabilitation and the way in which the Active Surfaces could support it.

3. SCENARIO

Along the different phases of the work analysis we used scenarios to evaluate, together with our stakeholders, how the defined concepts could suit their needs and to envision possible usage of the final tools. Scenarios themselves were used as design objects and they evolved along the design process being created, refined and also sometimes dismissed [7].

The Active surfaces concept was refined through an iterative scenario-based design process. Most of all, the concept has been assessed and validated in order to try out the envisioned solutions. These sessions with users have informed the next phase of the design process: the prototyping. During these sessions we decided to focus on floating tiles to make a proof of concept through the early prototype. The prototype we developed has been used for early exploratory tests with the targeted end-users, both therapists and patients, during ongoing rehabilitation sessions in the swimming pool.

As mentioned above, the Active Surfaces is today based upon a number of tile-components. There are two kinds of tiles: the Assembler Tile (AT) and the normal play tiles (about 15 to start with). A part from these different tiles there is a graphical user interface called the MUI that is used to create general input/output schemas for different games.

In the scenario below the Tiles' states are described through the use of a "happiness" state. These terms are used with specific meanings in the scenario and in the code development. We consider different states of happiness (conditions' satisfaction) for the position and orientation of the tiles in the assembly.

- *SideHappiness* means that a tile realizes that it is correctly connected on a particular side. On the side(s) that are Happy the tile provide the users with HappySide feedback. If all its sides are correctly aligned, LocalHappiness is instead achieved.
- *LocalHappiness* means the tile is properly connected to the others and it has on each side the tiles it was looking for. It is in the right position and it is correctly orientated in the assembly
- *AllHappiness* means all the tiles satisfy the *LocalHappiness* and, knowing that all the others are sending that feedback, they realize a global happiness, satisfaction of the activity game.

These different happy-states are also visualized in figure 2.

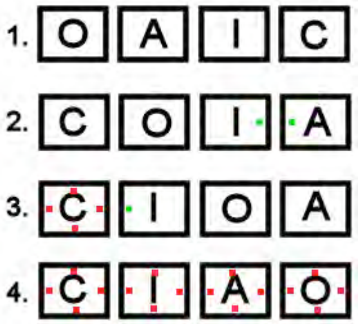

Figure 2. Row 1: No happiness.

Row 2: HappySide for 'I' and 'A' between the 'I' and 'A' sides (Green feedback on HappySides).

Row 3: 'C' is LocalHappy (Red feedback) and 'I' has one HappySide (Green feedback).

Row 4: All tiles are LocalHappy, this gives a complete happiness within the system.

4.1 Active Surfaces in use

The configuration of the activity is performed outside the pool, maybe even at the home of the therapist/trainer or in a remote office. This can also be done in the vicinity of the pool, but there is no specific need for that from a system perspective. The therapist brings the assembler tile (AT), attach it to the Service Browser (SB) and configure the future activity by setting configurable game parameters (e.g. Type of Game: Position game, Output Mode: Blinking Light).

The AT can have either a cable connection (i.e. RJ-45 Ethernet) or a wireless one between the system (e.g. a laptop or a hand-held device like a PocketPC) hosting the SB and the AT.

(www.palcom.dk) at the University of Lund, lets the therapist browse existing tiles and their configurations. She can discover the tiles currently in use, and design a new exercise in a MUI browser (running on a PDA or a laptop).

The therapist can now bring the AT to the poolside and align the tiles she would like to include in the game in the 'winning' position or pattern. Now the AT is connected to the structure of tiles and this initiates a number of activities. The therapist triggers the motion sensor on the AT with a 'one touch'-input. This sends a broadcast message to the connected tiles to remember their own and their neighbour's positions.

After executing this command all the tiles have memorized their own and their neighbour's position and orientation. They also notify the therapist that the configuration and assembly of the game is successful completed through the requested output (since the tiles now are in the AllHappy state).

Figure 3. Exploring the use of the Active Surface prototype

The therapist is now ready to start the activity with the patient and throws the tiles into the pool. The child tries different wrong alternatives by moving the tiles around the pool.

At first the child puts two tiles aligned correctly, but still not with the complete solution presented. This gives a local feedback that the two tiles are correctly placed while the final feedback is still not given. This LocallyHappy, or even only HappySide provides the user with a (for example) light output, isolated to the correctly aligned side(s). The child finally aligns all the tiles in the right position. This gives the final output. The game is solved.

4. DISCUSSION

The concept of Active Surfaces elaborates on a new challenging view of the rehabilitation practice and mobile game design.

The scenarios we developed are based on the idea of end-user composition, mobile interaction and control and it seems promising and interesting for the stakeholders. In particular, users appreciate the idea of being supported by ready-at-hand technology, easy to program and to manage. The Active Surfaces provides them with the possibility to improve the day by day rehabilitation practice.

The concept elaborates on a new challenging view of construction complemented with deconstruction of physical assembly. The therapist is asked to manipulate and physically configure the tiles while the dynamic and self-configuring discovering of components occurs. This guarantees minimum skills in technology and programming for the users.

Active Surfaces provides the therapist with the possibility to adapt the technology pursuing extreme changing and flexibility beyond system stability. In that way we have situations where total control is desirable, but has to be complemented with sense making and meaning attribution of events.

Palpable computing can be seen as extending ambient computing with additional characteristics for user control. Palpable computing systems offer not only invisibility (the capacity of unobtrusively performing computing tasks in the background environment) but also visibility, that is, the capacity of making visible to users what they are doing and what they may do. Moreover, systems should offer both construction (the ability to support end-user composition of devices or services to form new devices and/or services) and also deconstruction, that is, the ability to disassemble a device or service into its constituent parts to enable understanding and manipulating of each part individually [2].

Palpable computing may constitute the framework for the definition of design guidelines for mobile interactive systems. Challenges in the shape of dichotomies as the ones described above, can serve as means through which the designers might interpret and re-define pervasive applications.

5. ACKNOWLEDGMENTS

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A graphic language for touch-based interactions

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Abstract

This project explores the visual link between information and physical things, specifically around the emerging use of mobile phones to interact with digitally augmented objects and spaces.

General Terms

Design, Experimentation, Human Factors.

Keywords

Interaction design, mobile technology, embodied interaction, visual design, interface design, rfid, nfc.

1.Introduction

As mobile phones are increasingly able to read and write to Radio Frequency Identification (RFID) transponders embedded in the physical world, how do we represent an object that has digital function, information or history beyond it's physical form? What are the visual clues for this interaction? Here we are interested in the visual link between digital information and physical things in the early days of ubiquitous computing where consistency and standardisation will be beneficial for early user-adoption.

Digital information, history, functionality and services embedded within everyday objects is one model of ubiquitous computing in which every object is a node within an 'internet of things'. A variant of RFID called Near Field Communication (NFC) allows people to interact with physical spaces and objects by the action of touching a mobile phone to an RFID tag. This is perhaps the first sign of mobile phone being central to the early adoption of the internet of things, where otherwise 'dumb' or 'silent' objects right at the very edges of the network are enabled through the action of touch.

Unlike Semacode or other 2D barcode systems, RFID is most likely a hidden chip embedded under the surface of an object. This is both an advantage and a disadvantage; giving us the opportunity to hide possible interactions without visually degrading the surface, but also reducing the user's ability to know the range of possible interactions with everyday objects. Clearly we shouldn't rely on the kind of 'mystery meat' navigation that has become the scourge of the web-design world, where we have to roll-over or touch everything to find out it's meaning.

This work doesn't attempt to be a definitive system for indicating touch-based interactions. It proposes directions that may be useful towards standardisation and consistency, but is mainly an exploratory process to find out how digital/physical interactions might work. It has been inspired by a lack of research in visibility issues in ubiquitous computing and 'locative media'. It attempts to uncover interesting design and interaction opportunities while the technology is still largely out of the hands of everyday users.

2.Background

Existing iconography for interactions with objects like push buttons on pedestrian crossings, contactless cards, signage and instructional diagrams offer great inspiration for the patterns of a new graphic language.

figure 1. Felica-based consumer electronics from Sony, showing Felica icon that indicates touch interaction.

There is a growing collection of existing iconography in contactless payment systems, with a number of interesting graphic treatments (see figure 2).

'Felica' is Sony's implementation of NFC, and is being integrated into a growing number of mobile phones and mobile consumer electronics. Sony has used a clean and distinctive icon that shows an RFID card being placed with a finger (see figure 1). Although this is a great, instructional icon for this kind of action, it's use is limited to cards, and it doesn't indicate the right kind of action using a mobile phone.

figure 2. Existing iconography for touch-based interactions. These interactions are mainly ticketing, payment or interactions with functions in public space.

There are also instances of touch-based interactions being represented by characters, colours and iconography that are abstracted from the action itself.

Suica is the dominant form of contactless payment in Japan, and the Suica Penguin is perhaps the best known icon, that is used consistently with a strong colour schemes of green and black (see figure 3).

figure 3. Suica penguin advertising RFID-based payment services at a convenience store in Japan.

In terms of visual branding this strong character has contributed to the widespread acceptance of RFID technology in Japan. Although this is a great example of a way of 'humanising technology' through association, the iconography is tied into an existing brand and is unlikely to be adopted as a more generic iconography for digitally augmented objects.

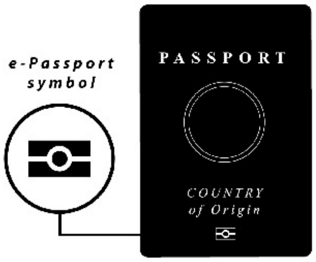

figure 4. Icon for RFID-based passports (left).
figure 5. Icon for AIM Global EPC RFID tags (right).

Two more generic examples are officially mandated icons for RFID iconography. Figure 4 shows an icon mandated by the International Civil Aviation Organisation (ICAO) and is designed to visually represent RFIDs embedded in passports, it is being used on current passports issued in the US.

Figure 5 is proposed by the Association of Automatic Identification and Mobility (AIM Global) and is designed to be affixed on readers and transponders in the supply chain, to help logistics workers to identify RFID enabled labels. Two-character codes are used to identify the frequency, the defining agency for the data, and the data on the tag.

Both of these icons are copyrighted and tightly controlled for use only in restricted cases. In both cases the purpose of the icons is for specialist identification, this is particularly troubling in the case of the RFID passport that gives very little indication of the either the content or the electronic nature of the object.

3.Graphic development

Sketching revealed five initial directions: circles, wireless, card-based, mobile-based and arrows (See figure 6 and 7). The icons range from being generic (abstracted circles or arrows to indicate function) to specific (mobile phones or cards touching tags).

Figure 6. Initial sketches for an RFID interaction icon

Arrows might be suitable for specific functions or actions in combinations with other illustrative material. Icons with mobile phones or cards might be helpful in situations where basic usability for a wide range of users is required. Although the ‘wireless’ icons are often found in many current card readers, they do not successfully indicate the touch-based interactions inherent in the technology, and may be confused with WiFi or Bluetooth. The circular icons work at the highest level, and might be most suitable for generic labelling.

A simple circle was chosen for further investigation (see figure 8). This circle is surrounded by an ‘aura’ described by a dashed line. This communicates the near-field nature of the technology but also describes a physical object that contains something beyond its physical form. The dashed line distinguishes touch-based interactions from generic wireless interactions.

In most current NFC implementations, such as the 3220 from Nokia and many Felica phones, the RFID reader is in the bottom of the phone. This means that the area of ‘activation’ is obscured in many cases by the phone and hand. The circular iconography allows for a space to be marked as ‘active’ by the size of the circle, and we might see it used to mark areas rather than points. Usability may improve when these icons are around the same size as the phone, rather than a discrete point to touch.

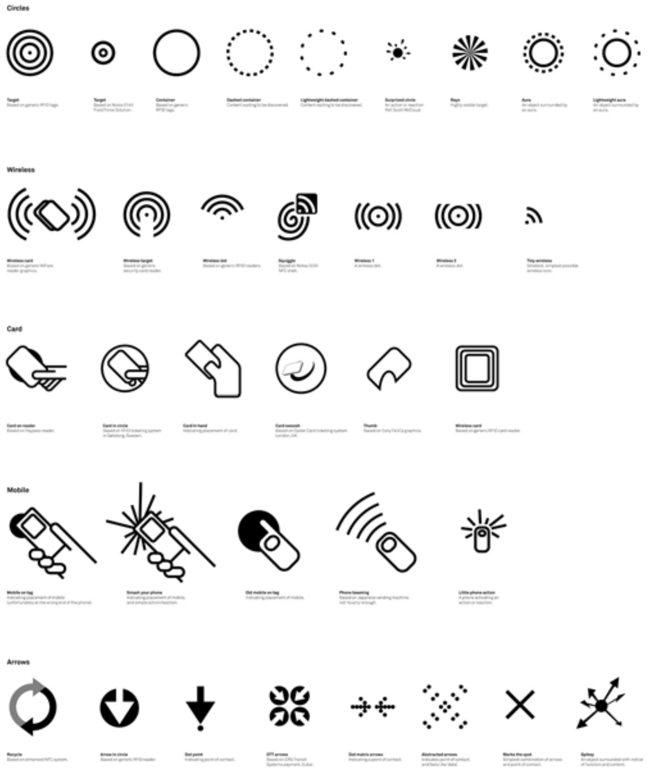

figure 7. Final selection of sketches.

figure 8. Circular icons with dashed lines.

4.Applications

A number of applications of the iconography have been explored and these will form the basis of a new project and paper. Two examples of evidence produced by the project follow.

figure 9. The address book fridge.

Figure 9 is an exploration of the potential personal use of RFID fridge magnets, that would turn pictures and other content on the family fridge into objects that trigger phone calls or other kinds of communication.

figure 10. Wearable tags by Ulla Maaria Mutanen.

Figure 10 is an investigation of the graphic language applied to wearable crafted products, where the icon is sewed into handcrafted clothes, indicating that they contain a history of their use. This was created by Ulla-Maaria Mutanen who is particularly interested with the idea of tracking craft products and introducing new interactions and economics within consumer products.

5.Future directions

This is work in progress, and there are clear directions to look at specific applications, suitable uses and extensions. Ideally it should develop into a richer language as the applications for this type of interaction become more specific and related to the types of objects or information being used. For example it would be interesting to find a treatment that could be applied to situations as diverse as a gaming sticker offering power-ups to a bus stop offering timetable downloads.

There are also interesting questions about location and context. How large or visible should they be? Are there places that should not be 'active'? And how will this fit with the natural, centres of gravity of the mobile phone in public and private space.

The icons are available to download under a creative commons licence; users are free to use and modify them. We are very interested to see how they can be applied and extended.

elasticspace.com/2005/11/graphic-language-for-touch

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[2] eNFC, Inside Contactless.

[3] Paypass, Mastercard.

[4] ExpressPay, American Express.

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[10] ERG Transit Systems payment, Dubai.

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User Perceptions on Mobile Interaction with Visual and RFID Tags

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ABSTRACT

In this paper, we present a study of user perceptions on mobile interaction with visual and RFID tags. Although mobile interaction with tags has been proposed in several earlier studies, user perceptions and usability comparisons of different tag technologies have not been intensively investigated. Our field study charts currently existing user perceptions and reveals potential usability risks that are due to the limited or erroneous understanding of the interaction technique.

Categories and Subject Descriptors

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design, Human Factors.

Keywords

Mobile interaction, user studies, RFID, visual tags, physical interaction.

1. INTRODUCTION

Interacting with the physical world via a mobile handheld device is a relatively new paradigm, which has quickly emerged during recent years. Several factors have contributed to this development trend. Technological advances in mobile devices such as component miniaturization and diminished energy consumption have enabled development of gadgets that have more features and computing power. Integrating cameras, motion sensors, and radio frequency identification (RFID) or barcode readers have made new interaction concepts possible. Mobile devices have become extremely common, as mobile phone adoption rate approaches 100% of the population in numerous countries. Moreover, a mobile phone is typically carried with the owner [2], and thus offers a personal computing platform that is practically constantly accessible by the individual user. Due to these factors, mobile phones hold much potential as a platform for accessing ubiquitous computing services and interacting with smart environments.

Tags utilizing different technologies have been introduced for interacting with physical objects in a variety of applications and uses. For instance, augmented reality applications have been demonstrated [9], gesture recognition based on visual tags has been performed [1], and tags have been used for annotating the physical environment [4]. The use scenarios also include accessing information through interacting with a tag or using the tag for initiating some other information channel, *e.g.* Bluetooth or internet connection [3, 6, 7]. In [5], users were taught the use of a mobile exhibition diary application, where diary entry locations were identified with visual tags placed around the exhibition area.

Typically, interaction with a tag employs physical gesture where the user (or more precisely, user's device) points at or touches a tag, which can be for instance an RFID tag recognized with a device integrated reader or a visual tag read with a camera [6, 7, 8]. Most of the research focus so far has been concentrating on creating new concepts, or utilizing tags as part of a larger system, as opposed to specifically studying the interaction paradigm itself. Typical for the existing studies is that they are often used as a proof of concept with only a small sample of users, often in a non-authentic environment, with guided instruction prior to performing interaction tasks. There exists very little data on how users would interact with tags without any specific instruction, their expectations of the technology, and their perceptions regarding interacting with these objects in public places. The goals of our study, conducted in an 'everyday life environment' (an outdoor pedestrian shopping mall) was to assess the current knowledge or expectations people had with the tag technology, the intuitiveness of usage, social acceptability, and to predict any potential barriers to use. We uses two types of tags, RFID and visual 2D barcodes, and compare the results gained with each.

2. DESIGN OF THE STUDY

The study consisted of interviews, which were carried out in the city center of Oulu, Finland, in June 2006. The interviews were held on a pedestrian mall next to a busy shopping area at the city center. Participants were chosen from those present on the street, to achieve a balance of male and female, with ages ranging from teenager to middle aged (50+). Although the interview was designed to last for five-seven minutes, most interviews ended up taking more like ten minutes, and several lasted for more than twenty. This discrepancy was due to the unexpectedly enthusiastic response of participants to this technology. The interview language was Finnish, or if not spoken by the interviewee, English.

During the interview, each participant was shown two posters, one employing an RFID tag and one a visual tag, see Figure 1. Participants were first asked about their familiarity with a particular tag technology, and then given a brief easy-to-understand explanation of how the tag works (though they were *not* told how to interact with it). The participant was asked what kind of information they would expect to receive from the tag, and then given a properly-equipped mobile phone and asked to demonstrate how they would interact with the tag, Figure 2. Answers to the interview questions, as well as observations on usage were recorded by the researchers. After the user had tried to use the tag and was shown the proper usage scenario, he or she was asked to reflect on the intuitiveness and ease-of-use of the experience. For each participant, this process was repeated with both types of tags. To avoid bias the order was altered so that half of the participants started with RFID, half with visual tags.

Figure 1. The poster used in the study. Above the complete poster with the visual tag, and below the lower part of the RFID poster (tag is behind the paper).

Figure 2. A study participants reading RFID tag with a phone

The study included 26 participants (11 female, 15 male). All study participants happened to own a mobile phone. The background information of the participants is presented in Tables 1 and 2.

Table1: Age distribution of the participants

Age	No. of participants
<20	8
20-29	8
30-40	7
>40	3

Table 2: Mobile phone usage of the study participants

	Yes	No
Carried currently a phone with:	25	0
Owned a camera phone:	12	13

3. RESULTS

3.1 General perceptions

In the study it was found that the used tag technologies were generally unknown to the participants, see Figure 3. A large majority of the interviewed were not familiar with the concept of either the RFID or visual tag, although for some, RFID tags were known from security tags on clothing or compact discs. Despite of visual recognition of the tag, they were not aware of their usage in the current context. In general the participants were receptive and enthusiastic towards the presented information acquisition methods and came up with suggestions for novel applications. The responses indicated a general sense of openness towards new technology, and eagerness to incorporate it into their daily lives.

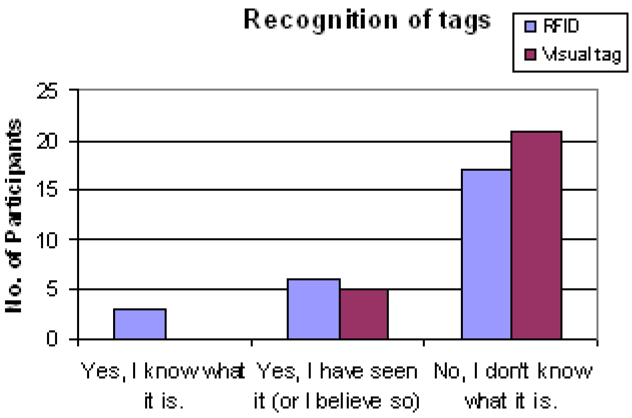

Figure 3. Participants' answers in if they recognized what the tags were or if they had seen them earlier.

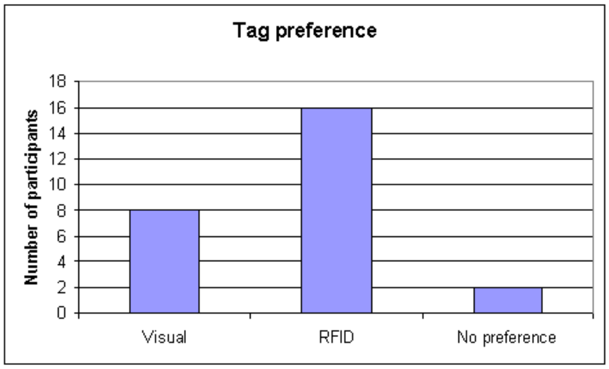

Figure 4. Participants' preferences for the tags.

3.2 Establishing a mental model

3.2.1 Physically interacting with the tag

As physical tags were mostly unknown to the participants, they had no prior experience on which to base their interactions with this technology, other than the brief description of the technology which we supplied. It was apparent from the interviews that the participants had developed a diverse range of mental models governing what kind of information the tags could store, and how that information could be transferred to their mobile phone.

Visual tag For the visual tag, once it was established that it was just ink printed on the surface of the paper, most users deduced that you need to use the camera to access the information. Some users suggested that they actually needed to take a picture of the visual tag, while others just pointed the camera at the tag and waited for it to register automatically.

RFID tag Given its decreased visibility (*i.e.* hidden behind the paper), and more advanced technology, it makes sense that the appropriate interaction technique with the RFID tags proved slightly more elusive for participants. When asked how they would interact with the RFID tag, responses included utilizing text messaging, Bluetooth, manually opening up a URL in a mobile browser, reading it via an infrared port, calling a stored number to hear pre-recorded information, and taking a picture.

3.2.2 Tag content vs. context

One issue that people were unclear on is the distinction between the content of the tag and how the phone will actually utilize that content. When asked what information the tag may contain, many users correctly guessed it would contain band-related information, and some suggested specifically that the tag may contain an mp3 file. One user even asked how much data the RFID tag can hold. One element of the descriptions that was missing was that the participants did not specify what the phone would actually do with that information. Implicit in many participants' responses was that the phone would just store the information for later use. No one actually stated explicitly that the tag could open a specific webpage in the browser on your phone.

3.3 Comparison of user preferences

Sixteen out of the twenty-four study participants preferred the interaction paradigm of the RFID tag, while the remaining eight preferred the visual tag (Figure 4).

RFID tag The RFID swipe was viewed as being quicker, taking less effort, and generally feeling more natural than taking the picture of a visual tag. Those that favored RFID also liked that it did not require opening any additional application. However, some people had reservations about the 'active' broadcast nature of the RFID, and worried that they could be picking up RFID information without intending to.

Visual tag Those that preferred the visual tag stated that the physical action of taking a photo is more comfortable and socially acceptable than waving your phone on the wall.

Aesthetic considerations There were also differing opinions with respect to the aesthetics of the two different types of tags. Some people disliked the way the visual tag looked, saying that it was too "official" or technological looking, while others praised it for its sleek look, and said that they thought it made the poster look cooler. Based solely on the appearance of the visual tag, one female participant decided that she would not be able to use the visual tag because she was "not a mathematical person".

Interestingly, several participants actually expressed concern about adoption issues, thinking from the perspective of those who would be using the tags as information producers. They preferred the visual tags because they were cheaper to use and caused less waste.

4. DISCUSSION

When a user is faced with any unfamiliar situation, it is expected that he or she will attempt to make sense of the world by developing a mental model based on any prior relevant experience. As most users had not seen either of these physical tags before, we gently introduced the basics of each technology to study participants through understandable analogies. Participants' subsequent demonstrations of how they would interact with the tags represent varying levels of comprehension of the technologies, an important point to take into account when educating users on the availability of services enabled by these technologies, the capabilities of their mobile phone, and considering methods of deploying tags into the environment.

Range and visibility Another characteristic that affected participants' interactions with the RFID and visual tags is their range and visibility. The range of the RFID tags is less than 10 centimeters (approx. 4 inches). Due to this short range of function the user needs to be informed precisely of the location of the tag, although the tag itself does not need to be visible. In the study, the RFID was attached to behind the poster and its location was indicated with visual icon. The visual icon utilized (two concentric circles) was not a commonly known indicator for RFID and did not therefore provide any previously known cues for interaction. As the usage of RFIDs or other invisible near-field communication (NFC) becomes more common, it will be important to develop standardized visual cues, enabling users to easily recognize the presence of an NFC, and execute the known interaction method.

Push vs. pull Judging from participants' responses when we asked how they would interact with either of the tags, it was apparent that some of them did not understand the distinction of a *push* technology (*e.g.*, RFID, which transmits information to your phone) versus a *pull* technology (*e.g.*, visual tags, which require you to seek the information stored in them). Interestingly, although participants had used cameraphones before and were used to the idea of snapping a photo, many had expected the visual tag to be recognized by pointing at it with the camera, without initiating an explicit capture action. This implies that the users expected the system to be 'sense' the presence of a tag. This kind of behavior of visual tags can be traced back to a mental model of bar codes, as seen in shops counter with laser readers.

One important design goal that can be derived from these findings is that you cannot expect a user to understand the technology behind different physical tags. As the goals of these two types of tags are the same, it will be important to make the content transfer mechanism transparent to users.

Content disposition Both of the tags were expected to contain direct textual information related to the band presented in the poster. The device and application were considered as a "lens" to view their information content being otherwise in incomprehensible form. The users were surprised when the recognized identifier triggered a browser which then retrieved information from the internet. They did not expect the identifier to acts as reference nor trigger for other applications.

Information persistence In addition, the information display was expected to be dependent on the proximity with the tag. The tag was held in the scope of the device, either within the viewfinder of the camera or in the proximity of the RFID module even after the actual tag recognition occurred. This observation also supports the concept of the device as a lens to view local information.

5. CONCLUSIONS

User perceptions on interacting with tags have not been extensively studied. If user studies on the interaction paradigm have been performed, they have typically been used for confirming the interaction paradigm selected for a certain application. These studies have commonly employed only a small amount of people, and have typically been performed in laboratory environment, university campus, or with IT students or professionals. In our study, we concentrated on the perceptions people had about visual and RFID tags, with the intent to elucidate the issues related to mobile interaction with them. We conducted and performed a field study where 26 selected participants were interviewed in a city center of Oulu, Finland. The interview sessions also included interacting with a mobile phone and RFID and visual tags.

In the study we found that the large majority of the participants were not familiar with the concept of either the RFID or visual tag and did not have clear knowledge of their application prior to the interview. The tags were assumed to contain direct information in encrypted form and users were surprised on unexpected access to networked data resources.

The study results reveal that there are potential usability risks with the mobile interaction with RFID and visual tags. Currently, the mental model that people have on the technologies is still very vague, and although different concepts of using tags for mobile interaction have been considered in research communities for years and are currently gaining popularity in an enterprise context, the idea has not yet been adopted by large audiences because of the lack of existing commercial consumer applications.

The study showed that there are no existing practices and mental models for the usage of visual and non-visual tags in the studied domain. For comparison we are planning to conduct similar study in other regional location and culture to be able to compare the stage of development and the cultural variables affecting to the usage of the tags. In addition, the development of appropriate visual cues for invisible tags will require more studies.

6. ACKNOWLEDGMENTS

The authors thank Dian band members for the permission to use their material in the study.

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Hovering: Visualising RFID Hyperlinks in a Mobile Phone

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ABSTRACT

Physical browsing is a mobile terminal and tag based interaction paradigm for pervasive computing environments. The tags offer to the users physical hyperlinks that can be read with a mobile terminal and that lead to some pervasive services or information. Hovering is an interaction technique, which allows the user to quickly check the contents of a tag by 'hovering' the mobile terminal over the tag. In this paper, I describe a prototype system that implements the hovering concept with a mobile phone and RFID tags. The purpose of the system is to study physical hyperlink visualisations, both in the physical environment, and in the graphical user interface of the mobile terminal.

Categories and Subject Descriptors

H5.2 [**Information interfaces and presentation**]: User interfaces – *input devices and strategies.*

General Terms

Human Factors.

Keywords

RFID, physical browsing, mobile phone, hyperlink, visualisation

1. INTRODUCTION

In physical browsing, the user can access information or services about an object by physically selecting the object itself, for example by touching or pointing to the object. The enabling technology for this is tags that contain the information – for example a Universal Resource Locator (URL) – related to the object to which it is attached. A tagged physical environment can be seen as analogous to a WWW page. It contains *physical hyperlinks* to different services and the user can 'click' these links with a mobile terminal in the same way desktop WWW links can be selected with a mouse.

As links in desktop web, the physical hyperlinks should be visualised to let the user know that 1) there is a link, 2) where it is located, 3) how it can be selected and 4) what will happen after the link is selected. The visualisation can happen in many levels: in the physical object itself the tag may have some icons representing its action and selection method, or the link can be visualised in various ways in the graphical user interface of the mobile terminal.

In this paper, I describe a physical browsing system built on a Nokia 3220 mobile phone. This application enables users to use physical shortcuts to activate digital services in their mobile phone. The purpose of the system is to be a tool for studying user interaction with physical hyperlinks. This system allows similar interaction with links as Nokia's built-in "Service Discovery" application but with extended link visualisation capabilities.

Physical hyperlink visualisation is still a relatively unstudied issue. We have presented some challenges [4] related to the visualisation of the tags. Riekki *et al*. [3] have also studied visualisations of RFID (Radio-frequency Identifier) tags. Generally, physical browsing systems in literature (for example [1], [2] and [5]) do not report in detail their pre-selection visualisations, if they exist. Weinreich & Lamersdorf [6] have implemented a link visualisation system for desktop WWW. Their system takes into account several attributes of a link, for example title, author, language and server response and display them as tooltips when the pointer is hovering over the link.

2. USER INTERACTION

The basic sequence of touch-based mobile interaction with physical hyperlinks is that the user brings the mobile terminal close to the link, after which the terminal reads the contents of the link and displays it to the user. In hovering, the user can 'hover' the mobile terminal over a link similarly to how hovering works in desktop web. In desktop web browser, when the pointer is hovering over a link, additional information about the link is typically displayed. The browser usually displays the address the link leads to in the status bar and if the link has a title, it is displayed as a tooltip next to the link. In this mobile phone based hovering, the link information is displayed in the mobile phone screen before the link is actually selected and activated. This way the user can quickly check the contents of several links before actually selecting any of them (Figure 1).

Figure 1. The user is checking what links the business card contains.

Hovering differs from confirmation dialogs ("Do you want to go to http://www.foo.com?") by not being a question to be answered. It does not present a modal dialog that has to be answered, instead it quickly displays some information about the link and the user can hover over several links to check each of their contents.

There are two main display modes in the hovering application: single and list (see Figure 2). In the single mode, only one link at a time is displayed but more information is available. In the list mode several links are displayed as a list. In either mode, pressing the Select button will activate the link, for example show the information or make the phone call to the number read from the tag. In the list mode, more information about the link, similarly to the single mode, is displayed when the user chooses to view the link list item in its entirety.

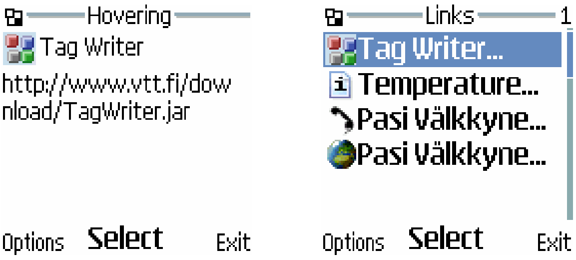

Figure 2. On the left is shown the single link display mode. Only one link is displayed but with more information than in the list mode on the right.

Each link has a title, contents and an icon. The title is a human-readable short description of the link. The contents contain the actual content of the link, for example a web address. The icon gives a graphical cue about the type of the content so that the user does not necessarily have to try to figure it out from the content resource.

As seen in Figure 3, each content type has its own visual icon. The purpose of the icon is to give a quick way to see what the type of the link content is. Additionally, it is intended to help differentiate in the list mode between links that have the same title but different content type. For example, a phone number and a web address might both have as the title the name of the person whose phone number and web address they are, but with different icons they can be quickly told from each other.

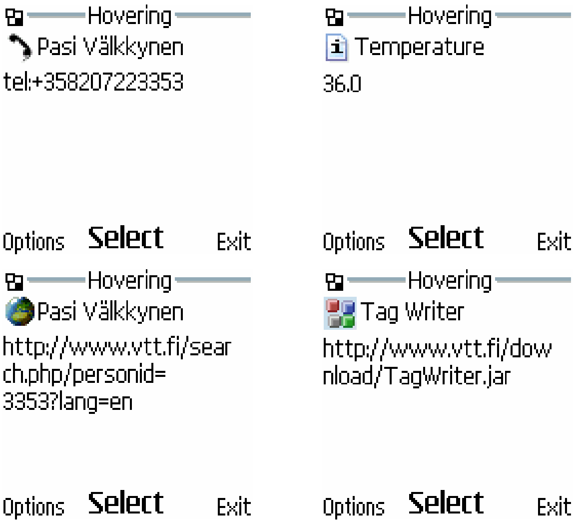

Figure 3. Different content types. On the upper row there are visualisations for phone call and local information, and on the lower row remote information and installable application.

All information links were initially visualised as 'i' but with the current mobile network speeds, there is a huge difference with interacting only with local connectivity or with remote services (for example a WWW page). If a link leads to an external communication, it is visualised with a globe symbol in the hovering application and only local services are visualised as 'i'. One reason for the globe symbol is that Nokia 3220 uses the globe icon for web access. This should make it easy to recognise to a user who is used to the phone.

3. SYSTEM

The hovering system is built on Nokia 3220 mobile phone[1] with Nokia's Xpress-on NFC shell. The software platform of the phone is S40[2] that can run Java MIDlets.

NFC[3] records are used to store the data in the tags in different fields. Each tag has a Title field, and a URI field. The Title field is used to display the title of the link in human-readable form and the URI is used to store the content. The content can be a link to a web resource, a telephone number, a link to a JAR file for downloading and installing applications, or a sensor reading.

The sensor reading does not come from a real sensor, instead it is a random number from a suitable range. The purpose of the sensor "mock-up" is to demonstrate to users how mobile phone based interaction with RFID sensors might look and feel.

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[1] www.europe.nokia.com/nokia/0,8764,58033,00.html

[2] www.forum.nokia.com/main/0,6566,010_200,00.html

[3] www.nfc-forum.org

The icon is determined from the content of the URI field in the tag. The content type could be checked by querying the web server (in case of WWW resources) but that would take a considerable amount of time with current cellular connection. And after all, the purpose of the system is to be a tool for visualisation studies instead of a physical browsing system that implements all possible security features. I have chosen the same approach as in desktop WWW browsers: the user is given the link title and if he or she can understand how URLs work, the address can also be investigated.

4. CONCLUSION

Optimally the links are visualised also in the physical objects, so that the user can know how to select the link and what action it contains. Hovering can help 1) visualise the action if only selection technology is visualised in the tag (for example NFC symbol), and 2) give additional information about the link such as the actual URL.

The future work on this concept will include building some tagged environments and evaluating the concept with users. Some questions in the evaluation will be the general usefulness of hovering, which display mode (single or list) is more useful and what information the user needs to see about the link. The intention is to study how hovering works with physical visualisations on the tags and how best combine these two visualisation techniques. The current prototype will also be extended to allow interaction with more types of contents, for example SMS messages and tags that can set some context information for the phone.

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The Mobile Phone as a Universal Interaction Device – Are There Limits?

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ABSTRACT

This paper reviews the often cited use of personal mobile devices, such as mobile phones and PDAs, for interacting with appliances, such as TVs, light switches, or vending machines. It argues that mobile devices should not be considered tools for general appliance control, but rather a means to assist users in exceptional situations that they do not encounter on a daily basis. To illustrate this paradigm, a prototype implementation for mobile phones is presented and the setup of a user study to verify its value is discussed.

1. INTRODUCTION

Personal mobile devices, such as mobile phones and PDAs, represent an important building block in many of the systems discussed in the ubicomp community. Their widespread use and their characteristics as a general purpose computing platform make them appear as ideal devices for the implementation of many applications. Scenarios involving personal mobile devices range from attaching digital annotations to physical objects, controlling large public displays, and interacting with appliances of all sorts.

While it is obvious that personal mobile devices can provide the technical functionality needed to implement such novel applications, we believe that from a user-centric perspective, their use cannot be justified in some of the commonly cited ubicomp scenarios. In particular, we challenge the notion of using personal mobile devices for universal appliance interaction, i.e., controlling technical equipment, such as vending machines, thermostats, or answering machines, through mobile phones. In this paper, we discuss preliminary arguments supporting our claim and try to answer the question under which circumstances it is appropriate to use a mobile phone for appliance interaction and under which it is not. We also present a demonstrator illustrating our paradigm and discuss the setup of a user study that we will conduct in order to verify our thesis.

2. UNIVERSAL INTERACTION DEVICES

Handheld devices, in the form of traditional, mostly infrared-based remote controls, have long been used as interaction devices for home equipment. However, there are a number of problems associated with this approach. First, given the many remotely controllable appliances typically found in a household, it is not practical to have a separate remote control for each of them. Second, users often need to carry out tasks that involve more than a single appliance. A typical example is switching on the DVD player, which makes little sense without powering up the TV at the same time. Third, remote controls are usually overloaded with functionality that users hardly ever need. An ideal interaction device should be flexible to adapt to its users' preferences and habits.

A number of research projects and also some commercial products (e.g., Philips Pronto[1]) have grown out of these needs. The simple approach taken by commercial products provides users with a conventional desktop application that allows them to design their own remote control by placing button widgets on a canvas mimicking a traditional remote control. The resulting user interface is then downloaded to a PDA-like, pen-based handheld, which uses traditional infrared transmission to communicate with the target device.

The approaches generally proposed in many research projects rely on the appliances providing a software interface that is rendered on the PDA's display for the user to interact with. The handheld is therefore *self-programming.* Using its wireless communication module (e.g., Bluetooth), the handheld transmits the user's commands to the appliance itself, or a proxy that in turn controls the appliance. Systems of this sort are presented by Hodes et al. in [1] and by Ponnekanti et al. with the ICrafter [12]. However, they are still based on laptops as interaction devices. The XWeb [9] infrastructure is similar, but the authors mention an implementation for pen-based devices without going into details. Common to these systems is the notion of abstract user interfaces to allow for device heterogeneity. By combining the abstract user interface description and a design template, the handheld generates a platform-specific user interface that is presented to the user. The concrete user interface is thus decoupled from the appliance.

Nichols et al. developed the idea further in the Pebbles project, where the authors use a PDA as a *personal universal controller* [8]. A similar, PDA-based system termed the *universal remote console* was proposed by Zimmermann et al [15]. Contributions from both projects led to the standardization of the universal remote console framework within the INCITS V2 technical committee [5]. The standard[2] aims to ensure interoperability between devices from different manufacturers.

Other projects like Yates et al. [14] have examined how interaction with household appliances can be extended to support natural language. They therefore propose a system

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[1] www.pronto.philips.com

[2] www.incits.org/tc_home/v2.htm

that is based on speech recognition. Another issue in this field is the selection of the active device. In environments with many remotely-controllable appliances, it would be desirable if the system automatically detected the most likely target the user wants to interact with. Kaowthumrong et al. [3] use a Markov model to predict a likely appliance and present the corresponding user interface. This work is extended by Isbell et al. [2]. They try not to predict a single appliance, but to determine the task a user wants to accomplish. Using k-means clustering and Markov prediction, their system is able to adapt the presented user interface accordingly. The personalized user interface resulting from this approach is evaluated in a separate user study [10]. The authors compare it with interfaces that users have created manually in order to make them suit their needs best. Users could freely combine buttons from any device and also create special macro buttons that would trigger a sequence of actions, such as switching on both TV and DVD player at the same time. The study revealed that both approaches have weaknesses. While the interfaces manually designed by users often missed important buttons because people have incorrect models of their own behaviour, the machine learning approach requires a lengthy observation period to discover accurate models.

3. SCENARIOS AND USABILITY

Virtually all of the papers cited in the previous section name a more or less similar set of appliances that are considered controllable by personal mobile devices. Among the often mentioned appliances are video recorders, DVD players, TVs, video projectors, stereos, answering machines, light switches, home security systems, ATMs, elevators, copy machines, cars, vending machines, heating control systems, microwaves, ovens, and washing machines.

There is surprisingly little work addressing the question of which appliances are actually suitable for this new paradigm of interaction, and under which circumstances they are so. Koskela et al. [4] have studied the use of mobile phones, PCs, and media terminals in a household over six months. However, the handheld device could only be used to control lights and curtains in their setting. Rode et al. [13] conducted an ethnographic study to find out which household appliances users choose to program. Their research gives, however, no indication for which appliances a personal mobile device may be an appropriate interaction tool. Moreover, they do not consider spontaneous interaction with an appliance, but focus on the programming of actions for the future, and the creation of macros to facilitate repeated tasks.

User studies investigating the performance of personal mobile devices for the spontaneous interaction with appliances were carried out by Nichols et al. [6, 7] as part of the evaluation of their personal universal controller [8]. They studied the use of a PocketPC to control a stereo and a telephone/digital answering machine. In particular, they compared the performance of 12 subjects when accessing the appliance either using the PDA interfaces, or the interface on the actual appliance. They used three metrics in their evaluation: time to accomplish a task, the number of errors made, and how much external help users asked for. For both the stereo and the phone, a list of tasks was created that had to be completed by each of the subjects. About two thirds of the tasks on both lists were chosen to be easy, i.e., requiring no more than one or two buttons pressed on the actual appliance. The more complex tasks involved five or more button presses. The time to accomplish a task was defined as the total time users needed to work through the complete task list. The authors found that, compared to the user interface on the PocketPC, interaction based on the physical appliance's interface took twice as long, entailed twice as many errors, and required five times more external help.

4. WHAT ARE THE REAL BENEFITS?

While these results seem very encouraging on the whole, we believe that more research is needed in this area. We recognize that there are three main areas where personal mobile devices prove a valuable tool for user interaction in smart environments. First, it is straightforward to use them to access information services, such as voicemail systems, or online media libraries, which might eventually replace VCRs, DVD players, and stereos. Second, they are the device of choice for users to discover the invisible information services available in a smart room or attached to a smart object. Third, it is clear that handhelds are well suited to control appliances where interaction at a distance is desirable, such as heating control systems. However, it is less obvious whether personal mobile devices should be used to interact with physical appliances that require the user's presence to operate, such as ATMs, elevators, or microwave ovens.

In line with this, we find it somewhat counterintuitive that the use of a personal mobile device for playing back voice messages recorded by a physical answering machine is more efficient than interacting with the actual appliance. It is our contention that, for many of the appliances mentioned in typical ubicomp papers and the ones listed above, it is not advisable to use handhelds as interaction devices in order to replace existing physical user interfaces. In most everyday situations, direct manipulation of the appliance is easier, faster, and more convenient than handheld-mediated interaction.

In *special situations*, however, this approach can be of great value. By special situations we mean processes that are performed irregularly and rarely. In these cases, users often face one of the following problems: First, they lack the practice needed to remember the individual steps that have to be performed in order to achieve a specific goal. Second, functions that are not accessed on a regular basis are often not present on an appliance's main user interface, both to simplify the interface for common tasks, as well as to save costs. Interaction is often difficult, as keys change their meaning in special contexts, or special functions are accessible only by a hard-to-remember combination of keys. As the following examples illustrate, we face this problem with several devices in our daily lifes:

- Many ovens can be programmed to start cooking a meal at a user given time. However, as this function is rarely accessed, it is hard for users to remember the programming procedure.
- Recent washing machines tend to offer several programs for a given temperature. It is often difficult for users to remember the exact semantics of buttons labeled "40°", "40°S", and "40°E", for example.
- Many appliances, such as laser printers or VCRs, show an error code on a small display when a problem (e.g., a faulty network interface) occurs. Without consulting

the appliance's long-since lost manual, this error code (e.g., "F602") is incomprehensible and of little value for a user.

In contexts that users encounter infrequently, just like the ones outlined above, a personal mobile device can facilitate the user's interaction with the appliance in two ways. The handheld can either *provide information* or *provide a user interface.*

Information Provision When an exceptional situation occurs, the appliance can support the user by providing detailed information on his or her personal mobile device. For example, by opening the relevant section in the appliance's manual on the user's mobile device, a laser printer could instruct him or her to check the network cabling instead of just showing an error code on its integrated display.

User Interface Provision Functions that are rarely needed and are thus not easily accessible through the actual appliance's user interface are offloaded onto the user's personal mobile device, *without* completely replacing the traditional user interace. In this way, a GUI based on familiar widgets can be built to, for example, program an oven's timer, while keeping the haptic user interface for the everyday tasks of switching the oven on and off.

5. PROTOTYPE IMPLEMENTATION

We are currently preparing a user study to test our thesis that it is in exceptional situations where personal mobile devices are most valuable for interacting with appliances. Using the example of a coffee maker (Impressa S70 by Jura), we will have participants perform various tasks using either the appliance's user interface as designed by the manufacturer, or our own interface rendered on a handheld device. We plan to evaluate three distinct use cases. First, we will test the impact of offloading the everyday task of brewing a cup of coffee onto the handheld. Second, we will examine how the user interface influences users' performance in adjusting the water hardness — a task which is performed only infrequently. Finally, we will compare how difficult users find it to replace the coffee maker's filter when they are given either the appliance's printed manual or a software assistant explaining every step needed.

In preparation for our user study, we have already built a Java MIDlet implementing these three use cases. The user interface for adjusting the water hardness is shown in Figure 1, while Figure 2 illustrates the interface assisting the user in changing the water filter. The user is guided, step by step, through the task. In every step, the system highlights the part of the coffee maker the user must operate next. As soon as the user pushes the right arrow on the phone's keypad, the assistant advances to the next step.

The MIDlet runs on a Nokia 3220 mobile phone. We chose this particular model because it is a very simple phone that offers just the basic features found in most mobiles today. Unlike the devices used in evaluations done by others, the Nokia 3220 does not offer pen-based input capabilities, but has a simple keypad instead. In addition to that, its color display is considerably smaller (128 x 128 pixel). The phone has an integrated Near Field Communication (NFC) module, which allows it to read RFID tags. We use the phone's NFC module and an RFID tag on the coffee maker to implement the *touch me paradigm* [11], which we feel is ideal for users when interacting with appliances in their proximity. Another advantage of NFC is that it is possible for a device like a coffee maker to transmit status information directly to the mobile phone. However, we do not make use of this feature yet, but employ NFC merely for the phone to identify the appliance. Based on the received identifier, the phone downloads and execute a Java MIDlet containing the appliance's user interface.

Figure 1: Adjustment of water hardness.

Figure 2: Change of water filter.

Preliminary experiences indicate that the system offers significant benefits to users. As changing the water filter consists of about ten steps and involves the manipulation of physical parts, such as valves and latches, it cannot be easily automated by manufacturers and inevitably requires user participation. For this purpose, the assistant seems to be a very intuitive, yet cost-effective way to facilitate this fairly complex process.

6. CONCLUSION AND OUTLOOK

Personal mobile devices have become an important cornerstone of many ubiquitous computing systems. Apart from fulfilling other functions, they allow users to interact with their environment. While they are undoubtedly an important tool to access both information services and appliances from remote locations, their value as a means to locally interact with physical appliances is less clear. We argue that appliance interaction through personal mobile devices is most effective when it is utilized to assist users in carrying out tasks that are infrequent. Consequently, personal mobile devices should not be seen as a complete replacement for existing haptic user interfaces.

We believe that this hybrid approach of a traditional, haptic user interface, combined with an extended user interface on a mobile device, offers many benefits. Users can continue to directly interact with appliances, which is desirable in most everyday situations. However, in special situations where users would have to remember complex and clumsy sequences of pushing buttons or manipulating the appliance, it is much more intuitive to use a mobile device with its powerful and versatile user interface for interaction. For user interface designers, this is an interesting approach, as it allows them to make use of the full range of possibilities offered by modern GUI toolkits, without the physical and monetary constraints of adding such complex functions as a separate physical control.

Finally, the paradigm presented in this paper is economically attractive for manufacturers. Improving the traditional user interface of an appliance can be very costly. It involves adding means of providing feedback to the user (e.g., LC displays), which, on the one hand, entails additional hardware expenses and might not even be possible due to space constraints. On the other hand, it requires the development of software for an embedded system, which is comparatively expensive. Contrary to these drawbacks, offloading rarely used tasks instead of redesigning traditional appliance user interfaces is a relatively simple endeavor. It is sufficient to develop an application running on widely used and well-supported platforms, such as J2ME or Symbian. Moreover, a software interface can be easily personalized and adapted to the user. A casual user could, for example, be offered a simplified version of the user interface that is presented to a regular user.

We believe that this paradigm is very powerful and will thus continue to evaluate it's utility in a comprehensive user study.

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Alternative RFID based Architectures for Mobile HCI with Physical Objects

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ABSTRACT

High Frequency (HF) passive Radio Frequency IDentification (RFID) is currently a widely adopted technology for mobile HCI with physical objects. Prototypes, pilot projects and industrial systems have been developed in a number of areas mostly following an approach in which RFID tags are either attached to mobile real world entities or carried by mobile users, whilst RFID readers are static and fully integrated into back-end information systems. With RFID readers increasingly embedded on mobile devices, another approach where readers are mobile and tags are static can be followed, depending on conditions and context of use. In this paper we propose an initial simple classification of alternative RFID based architectures following these two interaction approaches and we discuss a generalisation of relevant factors affecting the choice of an RFID based architecture fitting well with a specific domain. Finally, we assess the impact of these alternative RFID architectures on a set of recently proposed usability heuristics for mobile computing.

1. INTRODUCTION

High Frequency (HF) passive Radio Frequency IDentification (RFID) [5] is currently the worldwide most popular and largely adopted radio frequency technology used to interact with real world physical objects. Among the factors contributing to HF passive RFID[1] success, there are a progressive emergence of widely employed standard protocols (e.g ISO and EPCglobal), a complete deregulation in the use of the HF spectrum and the availability of systems (tags and readers) at increasingly lower prices. RFID based prototypes, pilot projects and industrial systems have been conceived, developed and also deployed to the market mainly in areas such as supply-chain tracking of inventory, access control, luggage tracking, electronic payment systems, homeland security, livestock history, library tracking of books and reshelving assistance (see also [9], [10]). Most of the above solutions follow a *Static Reader - SR* approach in which tags are supposed to be either attached to mobile real world entities they identify or carried by users, whilst readers are meant to be static and fully integrated into back-end information systems. New solutions following a *Mobile Reader - MR* approach, where readers are mobile (e.g. on Nokia 3220) and tags are static (cf. [7]), are also currently being devised. In this work we investigate the most suitable contexts (and related issues) in which to use SR and MR approaches and their specific interaction patterns. In particular, we consider scenarios in which mobile users exploit RFID based systems to receive customised information (triggered by tags) either directly on their own mobile devices or by means of some presentation mechanism provided by back-end systems (e.g. LCDs in a shopping centre, printed out maps at a point-of-interest, spoken messages at an access control area). We present some initial steps to help designers and developers focus more clearly on relevant issues, while devising RFID based systems to interact with real world physical objects. The paper is organised as follows: in Section 2 we propose an initial, simplified classification of alternative RFID based system architectures with respect to an SR or MR approach. In Section 3, we show by examples (including one we are currently working on) how real systems can be mapped to these architectures and in Section 4, on the basis of these examples, we provide a generalisation of factors influencing the choice of RFID system architectures. In Section 5 and 6, we respectively discuss how these architectures may impact on a set of heuristics recently introduced to evaluate mobile systems and we conclude with directions for future work.

2. A CLASSIFICATION OF RFID BASED ARCHITECTURES

At a very abstract level, in both the aforementioned SR and MR approaches the information managed by RFID based systems flows through the following functional blocks: initial reading of tags, information customisation on the basis of read input and final presentation of results. For the sake of simplicity, we will restrict our attention to the reading of RFID tags, namely writing of tags is not considered. The reading of tags also includes here possible communication feature with remote systems and the customisation includes both profiling and data management features. Depending on the deployment of the above mentioned functional blocks, it is possible to imagine the following alternative RFID based architectures (see Figure 1):

- *Back End based Architecture (BEA).* This is an SR based architecture in which all functional blocks belong to the back-end system.
- *Full Mobile Device based Architecture (FMDA).* This

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[1] hereafter referred to only as RFID

is an MR based architecture in which all functional blocks belong to the mobile device. In other words, all the information presented to the user is read from a tag and possibly combined with additional information previously read and already available on the device.

- *Partial Mobile Device based Architecture (PMDA).* This is an MR based architecture in which the mobile device is used to read a tag and send the information to the back-end which customises the received information and sends it back to the mobile device for final presentation.

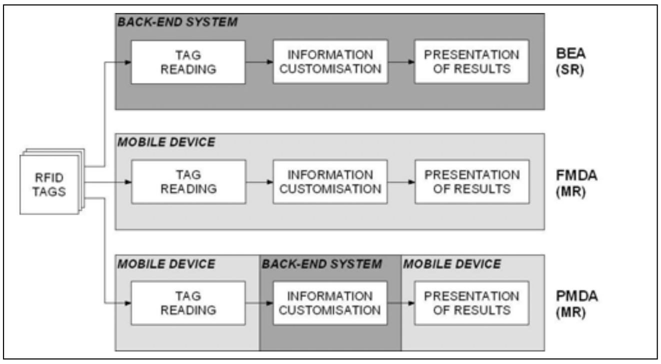

Figure 1: Alternative architectures

3. MAPPING SYSTEMS TO ALTERNATIVE RFID BASED ARCHITECTURES

In this section, we show how real world RFID based systems can be related to our classification and mapped to the SR and MR approaches. In particular, we begin by presenting specific examples which are fitting well only with one of the proposed architectures. Then, we introduce a work-in-progress prototype that we are currently developing following both the SR and MR approaches.

Typical BEA example
Consider the example of a library that uses RFID technologies to support the tracking of books borrowed by readers (as in [2] for instance) and to suggest possible related items when choices are made. In this scenario a few things can be observed: people who borrow books are usually regular visitors to a library and may want to let the library know about their preferences and interests; books are entities which need necessarily to be moved; information about books and their location on the shelves as well as on readers who borrow books are usually already available on back-end systems under the library's control; mechanisms to provide a matching of books and readers' interests can be easily implemented on back-end systems and can be already available; people are mostly interested in receiving suggestions and further information about books when they are in the library; the borrowing operation is usually performed at an established library's checkpoint (e.g. the till) and its overall completion time is expected to be low (e.g. to avoid queues).
It seems natural to augment such a scenario by using RFID tags on books and users in a "barcode-like" fashion. The quick reading of tags (there is no further information in addition to an id) can be easily integrated into the back-end which already provides both the information customisation and the presentation of results.

Typical FMDA example
RFID technologies can be employed to provide extra information about wine assisting users when they have to choose a bottle. In this scenario, users may want to be advised about wines matching their drinking preferences and taste before buying or ordering a bottle. In this case, the interaction experience is typically not restricted to a single place, but users may need assistance in different sites (e.g. supermarkets, restaurants, cafes, pubs) which usually have no previous records about them and cannot perform any matching operation and customisation. Moreover, users may be interested in changing their preferences at runtime before making their choice. Extra information about wines can be assumed to be available locally (e.g. through specific encodings). Finally, customised information on found matches are expected to be sent privately to users and possibly presented on different channels according to their preferences and specific needs (e.g. sight or hearing problems).
The most straightforward way to augment such a scenario is by RFID tagging labels on bottles with all the additional encoded information (as also discussed in [6]) and by keeping all functional blocks on users' mobile devices. Depending on adopted encoding techniques, information on tags can be used directly on mobile devices and no further communication with remote systems is needed. Configuration of profiles and presentation channels can be managed on mobile devices via a specific application.

Typical PMDA example
Imagine a directory service used to retrieve information on real world's objects (cf. [3] and its examples). While on the move, users can be informed of specific details regarding objects and possibly related services (as also in [11], [4]). Information can be filtered and provided on a number of channels depending on mobile users' preferences and context. This is an inherent mobile scenario where users keep going from one object to another and possibly search for information in different spots (there is not a unique checkpoint). Extra information provided on objects and possible associated services can be large. Context is frequently changing and so are conditions of use (e.g. stopping by an object or just passing by it). Users' preferences need to be easily configurable depending on these conditions (e.g. the maximum number of details about objects, the favourite presentation channels). Users do not want to impact too much on mobile devices' resources (e.g. batteries, processing power).
In this scenario, it seems useful to provide users with a mobile device capable of reading RFID tags associated with real world objects. These tags contain indirect information about objects (e.g. an index, a link, a url) which is used on the mobile device to connect to a back-end and trigger a content customisation according to specific profiles. Based on the requested information and on these preferences, the back-end can prepare the retrieved information accordingly and send it back to the mobile device for the appropriate presentation.

An example supporting alternative architectures
There is a possible need for the food industry, public health educators and policy makers to imagine new ways to in-

fluence and perhaps drive improved people's decision making and behaviours related to food consumption (cf. [8]). We are developing an RFID based automatic personal assistant to food choice during out-of-home eating. With such a tool menus in food assets (e.g. restaurants, cafes, pubs) can be customised according to personal nutritional profiles (allergies, intolerances, diets, calories intake) and also budget information. In the current scenario, users go to a food and drinking asset to stay there. They are accustomed to making a decision about their meal after reading available courses on paper made menus or boards (i.e. physical objects). Decision time is usually not a relevant issue (i.e. people can take their time). Moreover, food and drinking establishments can already have in place back-end systems handling information on menus and courses. On the other hand, customers may want to keep their nutritional profiles and budget information private and may need to change this information to receive different customisations presented on a number of alternative channels.

Given the nature of this scenario, it is possible to imagine a typical BEA in which information on menus and courses in back-end systems are enhanced with further details about ingredients and calories. This can have in general a low impact on back-end business processes. Users carry an RFID tag containing their encoded profiles and scan this tag on a reader which needs to be integrated into the back-end and conveniently located in the asset. The back-end performs the profile reading and customises the responses accordingly presenting suitable results and suggestions on a nearby screen with a printing option to preserve a traditional interaction pattern with a physical menu. At the same time, in an alternative FMDA, menus are augmented with RFID tags containing encoded extra information on courses' ingredients and calories. Users can scan the menus with their mobile device which reads the tags and customises the response on the basis of personal profiles configured and managed only by an ad hoc personal application. If on one side both the generation of tags and the provisioning of the mobile application can have a significant impact on back-end business processes, on the other side this last alternative makes the assistance a more private experience and lets users have higher control on their profile configuration.

4. RELEVANT FACTORS IN THE CHOICE OF AN RFID BASED ARCHITECTURE

Based on the given examples, it seems possible to provide a generalisation of items affecting and guiding the choice of possible alternative architectures for RFID based solutions:

- I1-User runtime configuration of applications
- I2-System context of use
- I3-Size and type of information (direct vs. indirect) exchanged between tags and readers
- I4-Information management and customisation
- I5-Information presentation
- I6-Information privacy, security and system trust

Intuitively, an increasing importance of I1 should favour an MR approach (where users can have runtime applications at their disposal) and is therefore an obstacle to a BEA adoption. As about I2, contexts which are tightly integrated into a back-end can clearly justify an SR approach as can inherently nomadic contexts in which users go to different sites and are resolved to make a stop there. In these sites checkpoints are expected to be located in precise and static spots where users can even accept to queue to interact. On the other hand, mobile contexts with a very high frequency of movements and with no easy integration into the back-end prompt to MR approaches and are therefore a driver to FMDA or PMDA. In I3, an increasing size of tags and the availability on them of direct information (immediately usable on the mobile device) can be a driver to FMDA. In fact, more concurrent and independent mobile readers can access in parallel the information on a tag, whereas in BEA only one static reader is used and in PMDA a further latency in final response time can be expected due to communication with the back-end and to the back-end completing the information customisation. Indirect information (e.g. links, urls) are instead a driver to either BEA or PMDA where remote processing is involved to use the information coming from tags. An increasing importance of I4 and I5 are both an obstacle to FMDA, as they can be highly demanding in terms of processing power, whereas when item I6 becomes an issue an MR approach should be favoured either via FMDA or PMDA, where users are more directly in control of critical information and system behaviour.

5. RFID BASED ARCHITECTURES AND MOBILE USABILITY HEURISTICS

In [1] the authors describe a new heuristic-based evaluation methodology for mobile computing and propose a set of usability heuristics that are relevant to mobile human computer interaction. In the following we complement the discussion presented in the previous section by assessing the impact of the identified alternative RFID system architectures on this set of eight heuristics.

H1 - Visibility of system status and losability/ findability of the mobile device. In BEA the system status is invisible to end users as the back-end fully controls the information flow by hosting all functional blocks. If mobile tags (the only mobile devices in such case) get lost, only a relatively small amount of information (depending on tags memory size) is lost and, in any case, the back-end may prevent a malicious use of this information through ad hoc policies (e.g. black list mechanisms). On the other hand, FMDA relies on local personal profiles which might result in a more serious risk for users in case of theft or loss of mobile devices. Finally, with respect to other contextual issues affecting losability and findability of mobile devices hosting RFID readers (increasing energy consumption), battery status is relevant in both FMDA and PMDA and an adequate network coverage is also required in the latter.

H2 - Match between system and the real world. All the architecture options available in our classification employ RFID tags to enrich the user experience by means of either additional or personalised information. In particular, in a BEA the back-end system can be seen as an invisible system having the capability to sense the surrounding environments and automatically present information and services to nearby users. The underlying transparent match of these services with real world RFID tagged objects can require only minimal changes to user behaviour during interaction. As about FMDA and PMDA, an additional burden to user interaction patterns is represented by the need of becoming familiar with the RFID reader available on the mobile device. Scanning of real world objects must be swiftly integrated with traditional presentation mechanisms

H3 - Consistency and mapping. Basically, every option in our architecture classification preserves the traditional interaction pattern users are accustomed to. In BEA, as RFID tags and readers interact transparently in the smart environment, it is possible to smoothly keep a consistency with the interaction context. Users may take advantage of specific enhanced features (e.g. automatic profiling, accounting, tracking) implemented on the back-end systems without even having to provide any explicit input interaction. Traditional behaviours may already trigger mobile human computer interactions consistent with the environment (e.g. a user passing a gate, or scanning a wallet containing an RFID tag to receive customised information). In FMDA and PMDA, due to possible physical limitations of mobile devices' interaction functions and to changing conditions of use, automatic mechanisms should be devised to consistently map the scanning of RFID tagged real objects with corresponding tasks on the device (e.g. automatic opening of a visual browser to retrieve and show an object's specific properties, automatic execution of an embedded TTS to speak out messages related to a service associated with a physical object)

H4 - Good ergonomics and minimalist design. In BEA mobile RFID tags are embedded in real world objects and their progressive miniaturisation should provide a good ergonomics and a minimalist design almost by definition. In FMDA and PDMA issues may arise about the use of an integrated RFID reader into mobile devices, although this is more a hardware related problem and manufacturers already benefit from well established studies and knowledge on ergonomics for mobile devices. Furthermore, since applications for every classified RFID architecture are typically well defined and restricted to specific domains, it is possible to imagine a suitable design of interfaces on different and complementary presentation channels.

H5 - Ease of input, screen readability. In all RFID based system architectures, RFID tags are used by definition to input data which are transmitted transparently to nearby RFID readers. As previously discussed, BEA does not need in general any other additional mobile input device since all the computations are triggered by RFID tag readings. Instead, in FMDA and PMDA there is possibly the need of a further interaction on the mobile device with the input read on tags, although this is not strictly required. On the other hand, screen readability is an issue in both FMDA and PMDA, although the former is more likely to provide easy-to-glance presentation mechanisms due to the possibly small amount of information coming from tags.

H6 - Flexibility, efficiency of use and personalization. In general, BEA seems to be the less flexible solution, because it relies on a static ad hoc infrastructure equipped with RFID readers and possibly a number of fully integrated presentation devices (i.e. LCDs, TTS). Moreover, personalization of system output according to changing contextual needs is tightly bound to the configuration of the back-end applications and possibly the update of information on RFID tags. These can be both inefficient operations. On the other hand, in both FMDA and PMDA, users have a personal and more direct access to information coming from RFID tags and context-dependent suggestions may be provided on mobile devices upon reading of information coming from real world objects. In particular, in FMDA personal profiles and customisation rules can be changed locally at runtime depending on the context.

H7 - Aesthetic, privacy and social conventions. BEA is more tolerant to social conventions and traditional interaction patterns as it is essentially based on a transparent reading of tags which should not affect habits and interaction patterns. Users are hardly requested to change their behaviours if only a simple RFID tag scanning is expected. Instead, privacy issues may arise in BEA and PMDA due to requirements of sending possibly sensitive information to back-end applications for further processing users have no control on. On the other hand, in FMDA user profiles and sensitive information used for customisation of output results are kept private and safe on the mobile device, although this may require novel interaction patterns users have to get used to.

H8 - Realistic error management RFID may fail due to collision problems and/or out-of-range readings. Anti-collision protocols exist and are used to cope with these possible failures and errors which will be managed either on the central back-end systems (in BEA) or locally on each mobile device (in FMDA and PMDA). Furthermore in BEA and PMDA, network disconnections or excessive latencies and delays in the output presentation might produce misbehaviours which need to be dealt with. In both cases, either the back-end system or the mobile device should be able to alert the user and provide alternative ways to safely complete the interaction experience with RFID tagged objects.

6. CONCLUSIONS AND FUTURE WORK

In this paper we have described the initial steps towards the assessment of possible RFID based system architectures which can be used to interact with physical objects. RFID is currently a widely adopted technology employed in mobile HCI with the real world and our first goal is to start describing and discussing relevant issues for designers and developers of RFID based systems and applications. Our main contributions towards achieving this goal have been: an initial classification of RFID based architectures depending on two possible interaction approaches (SR and MR); on the basis of real world examples, a generalisation of relevant factors affecting the choice of an RFID based architecture fitting well with a specific domain; a more in-depth analysis of the impact that RFID based architectures have on a recently proposed and validated set of heuristics for mobile computing.

We intend to further investigate all these aspects in the coming future to possibly verify the feasibility of a more systematic approach or a methodology to follow while devising RFID based solutions to interact with real world physical objects in mobile scenarios.

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Automatic Composition in Service Browsing Environments

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ABSTRACT

This paper present a vision and technologies for a general purpose user interface to smart spaces: a service browser that automatically arranges the available services into configurations that satisfy the user's goal. I describe how to employ established techniques to simplify user interaction with complex environments. Most current approaches limit the user to a choice of predefined tasks. My approach allows the user to express goals that have not be anticipated or previously encoded as tasks. I also highlight areas for new research.

Categories and Subject Descriptors

I.2.8 [**Artificial Intelligence**]: Problem Solving, Control Methods, and Search- Graph and tree search strategies, Heuristic methods, Plan execution, formation, and generation

C.2.4 [**Computer-Communication Networks**]: Distributed Systems– *client/server, distributed applications*

General Terms

Algorithms, Experimentation, Human Factors, Theory

Keywords

Self-organizing systems, mobile computing, artificial intelligence, composition, planning, artificial intelligence, service discovery

1. OVERVIEW

How can we simplify user interaction with complex compositions of nearby devices and their services? I propose a solution that uses artificial intelligence to help users arrange nearby devices into useful compositions and then make use of the composite system. Any number of devices and services can be composed. Unlike previous approaches, devices may be combined for tasks that have not been anticipated.

In mobile computing, the set of nearby devices changes frequently as the devices moves around. I imagine lots of wireless devices that support remote interaction via IP services. Many of these devices will perform specialized functions and will need to be combined with other devices to do useful things. It is desirable to avoid the tedious and recurring chore of configuring devices for different tasks. Configuring devices requires too much understanding of the available services and even experts will not be willing to expend the effort.

I propose combining an automatic device composer with a user interface for browsing the services of nearby devices. The system allows users to select some number of services and use them together. The composer automatically proposes how the selected services can be used together and presents some client user interface. At Nokia Research Center we have already built a service browsing implementation for Nokia S60 phones with a client user interface activation function. I have also built an automatic composer. But, because my composer runs on a laptop computer it has not yet been combined with service browsing.

The research community is exploring many different approaches to accomplishing service composition and service collaboration. Task Computing[1] starts with the selection of a task from a predefined list and the system assists the user in building a composition of services. Service collaboration is also implemented. OWL-S[2] and Semantic Web Services[3] use semantic interface descriptions of a service's purpose (process model) and usage (service profile & grounding). Progress in composition has been impeded by the inherent difficulties in computational semantics: a large portion of research has gone into the topic of interface matching based on semantics. Modules in Metaglue[4] seek out other collaborating modules dynamically as needed. Metaglue and Hyperglue[5] point out the importance of context in designing collaborations. Universal Plug and Play[6] standardizes a few predefined usage models which combine services according to their "theory of operation". There are also many established techniques for the artificial intelligence and planning disciplines.

2. SERVICE BROWSING

In service browsing users can "see" nearby devices as icons on the screen of their mobile device. The icons appear and disappear as devices *come in to* or *go out of* "range". A device is considered to be in "range" when it is both reachable and close enough to be useful.

The service browsing is a user interaction model that is different from most current approaches to using remote services. The common approach is to have the user first select a client application and then that application locates a compatible service. Instead service browsing displays all the current possibilities for the user to choose from.

We have implemented Service Browsing for local "smart space" environments. Next we intend to implement Service Browsing for distributed social overlay networks. The MyNet[7] project

MobileHCI '06, Sept 12-15, Espoo, Finland

implements such a social overlay network system. MyNet lets users shared access to their things with people they know. Users begin building their social networks by “introducing” local devices. Once devices are introduced they are bound together in an overlay network with durable network addressing. The devices will appear to be on the same local network, regardless of their physical locations. By introducing devices, the user can establish a cluster of devices that are connected by the overlay network. In addition, two users can introduce their device clusters. The result is a private overlay network of devices that can be navigated by social links rather than traditional network topology.

When we are done, Service Browsing will support browsing of the local services and the services shared by friends on the social overlay network.

3. AUTOMATIC SERVICE COMPOSITION

Service composition is the process of configuring a set of service providers and service consumers into a useful arrangement. I aim to automate this process through the use of inferencing and planning algorithms.

When service composition is combined with service browsing we create the capability to allow the user to select two or more services (or objects) to be used together. The user expresses his goal without specifying a task or any verb. The user only needs to have a notion that there might be some way that certain things can be used together and then the composer lists the possibilities.

Self-describing interfaces are a key enabler of service composition. It is important to understand what information is available because this is the information that an automatic service composer has to work with. I define three levels of interface descriptions.

The most basic descriptions are *interface names.* Remote applications have only the interface name to describe the interface. A programmer must know the details of an interface when the client is being written. This is the approach used in Java Remote Method Invocation[8] (RMI), Apple Bonjour[9] and interface description language (IDL) based remote invocation tools such as CORBA[10], SunRPC[11] and .NET[12].

The next level of interface description gives the list of methods and arguments. For example, in SOAP, a client can examine a service description document to learn the names and data types of the methods and their arguments. This gives the client enough information to properly invoke a remote method. But it does not convey the meaning of the arguments, what the method will do or how it should be used.

An advanced level of interface description encodes *what* each method will do and *how* it should be used. This approach is used in OWL-S and Semantic Web Services (SWS). The “*what”* is represented by referring to terms arranged in a semantic network. This is called the Semantic Web[13]. It is difficult for someone outside the Semantic Web field to imagine that this is computable. Indeed, computing the compatibility and appropriateness of interfaces matching is a primary challenge in semantic service composition. The “how” is represented as a process or sequence of steps and may also include preconditions and post-conditions for each step.

Because my current focus is on building compositions, I am using the easiest approach to interface descriptions: using interface names to determine the compatibility of interfaces.

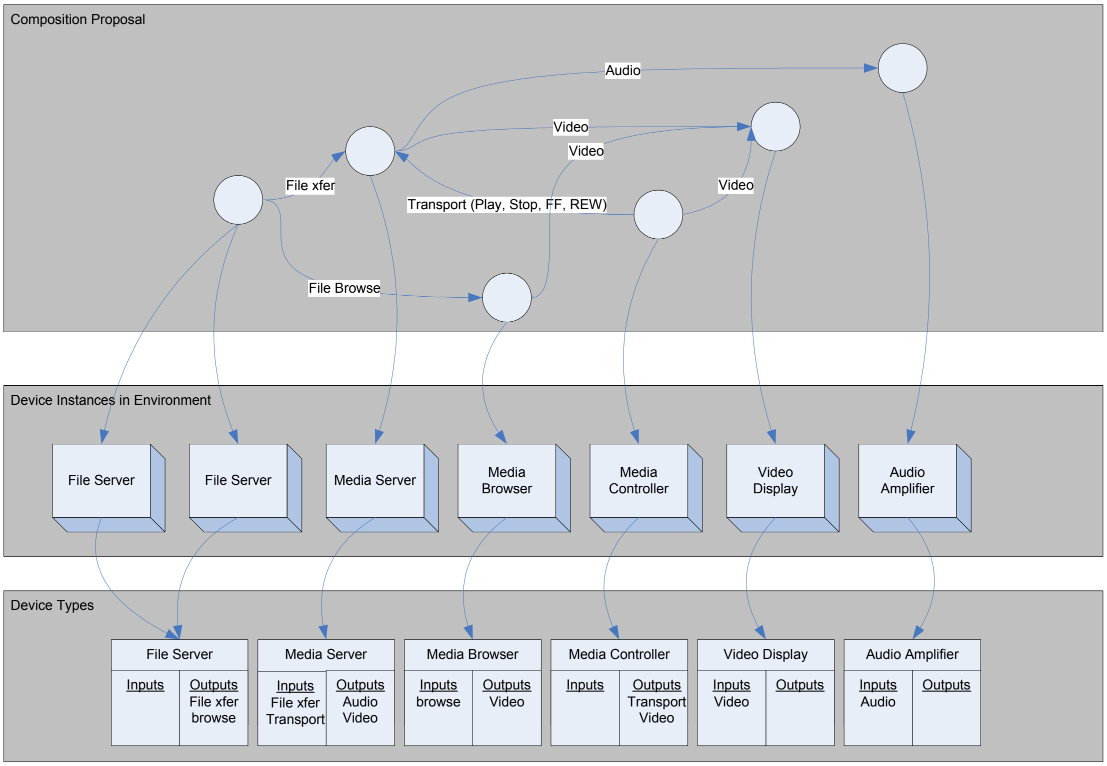

Figure 1. Compositions, Device Instances and Device Types

My service composition framework requires representations of each of the device types (bottom of Figure 1). Device type object includes a list of input and output interface names. Next there are the device instances that are “in range” (middle of Figure 1). These are instances of devices with is “isa” relation to a known device type. The composer generates a composition proposal (top of Figure 1). A composition proposal is a plan for connecting devices together.

A composer is likely to generate a number of alternate proposals. In this case the composer, named "DFS1", implements an exhaustive depth first search algorithm. DFS1 is a good place to start because it has excellent completeness, meaning it always finds all possible compositions. But DFS1 has no notions of optimality; it does not know which compositions are better. Also, DFS1 has the highest possible space complexity, meaning it has the highest memory usage. Because processor cycles are plentiful, DFS1 has acceptable time space complexity- in the worst cases it completes in a second or two.

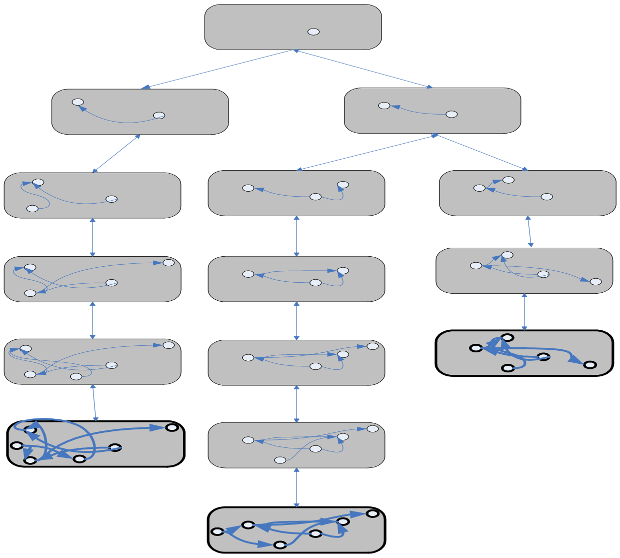

Figure 2. The Search Tree

Figure 2 represents a search tree that the DFS1 composer may follow. The search tree starts with a composition containing a single device instance. This initial composition is considered incomplete if there are unsatisfied inputs or outputs. If this device could be used alone, then this would be considered a complete composition. Regardless of whether the composition is complete, the composer adds additional devices to the base composition to generate the next compositions. In this tree there were two possibilities, resulting in two diverging search paths. The algorithm continues until there are no more possible devices from the environment that can be added to an open input our output.

Another weakness to DFS1 is that it is a centralized planning. It runs on a single device that can see all the other devices. In ad-hoc mobile computing, there can be no guarantee that such a device is present.

4. THE USER EXPERIENCE

The dialog between the system and the user would be:

- System: "Here are the nearby devices and services."
- User: "I would like to use these things together."
- System: "Here is a list of things you can do with this combination of devices. Which would you like to do?"
- User: "I would like to do this."
- System: "Here is your user interface."

The user specifies a goal by selecting several services or objects on the screen. I've thrown in objects because it is common to use data files with services (e.g. a document with a printing service). Next, the system automatically computes ways that they can be used together. Next, the system proposes a choice of client applications for the user. In addition an expert user can optionally inspect and modify the proposed composition of services.

For example, if the user chooses a 'Media Library' device and a 'Video Screen', the system will bring in a 'Media Server', 'Media Receiver' and 'Media Controller'. The 'Media Server' will stream the 'Media Library' content onto the network. The 'Media Receiver' will receive the stream and display the content to the 'Video Screen'. A 'Media Controller' client application will appear on the device that the user is holding. For brevity I've glossed over a couple of details here but, in general, this is how things will work.

5. SUMMARY AND FUTURE WORK

I described how automatic device composition can function in a service browsing environment. I believe this is currently possible using established techniques and by putting together components that we have already built. When the system is assembled it should make it easy for casual users to compose and use complex configurations of devices and their services. Yet many interesting topics will remain for us to explore.

An obvious question is "In a collection of specialized devices, where does the intelligence reside?" One answer is that there is some centralized planning agent. But centralized planning is contrary to the nature of distributed ad-hoc mobile computing. An alternative is multi-agent planning[14] in which the intelligence is distributed across all the machines. In such a solution I imagine that each machine resolves only its immediate inputs or outputs. The machine would propagate additional requirements to its immediate neighbors. For example, instead of connecting to a Media Server input; the requirement would be to connect to a Media Server input that connects to a specific Media Library.

In Michael H. Coen's Hyperglue paper**Error! Bookmark not defined.** he points out that context is a valuable input to composition plans. I will explore how context can be used to reduce search space by evaluating the optimality of search paths. In addition I am interested in using context changes to trigger useful configuration changes.

Based on the available functions and other information such as context, it might be possible to generate a 'Situational Application'. If all the services in a composition have self-describing interfaces then it might become possible to present a list of available functions to the user. For example a 'Media Receiver' may have functions for 'Play', 'Stop', 'Rewind' and 'Fast Forward'. It may be possible to compute that these functions should have corresponding buttons on the user interface.

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Finding the Path from Here to There: Some Questions about Physical-Mobile Design Processes

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ABSTRACT

The mobile phone can be seen as the only truly ubiquitous computing platform today. Because of this, the mobile environment will serve as a spring board on which many new ubiquitous services will grow. This paper raises a number of questions which we think need to be addressed in the process of designing, implementing and testing such services. Apart from helping in the process of creating new, useful and usable services, we hope to generate a critical dialog about issues that must be solved at the design stage before any real implementation actually occurs. It is our hope that through the dialog these issues will be focused on in a critical manner and some of the questions might be answered, others edited and new questions might arise.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]:, *User-centered design, Interaction styles, Prototyping, Evaluation/methodology.*

General Terms

Design, Experimentation, Human Factors.

Keywords

Physical Mobile Interaction, Mobile UI, Mobile UX

1. INTRODUCTION

The mobile phone (with more than 2 billion units in the field as of September 2005) is the only truly ubiquitous computing platform today [1][15] and will stay so in the near future. Because of this, the mobile environment will serve as a platform on which many future services will be built and as a spring board on which a new breed of ubiquitous services will grow. This paper raises a number of questions about such services that we think are important to keep in mind while such developments are occurring. These questions arise out of our motivation to help in the development of *New*, *Useful* and *Usable* services. The paper will end with a description of a project we are working on which deals with some of these questions.

New service scenarios are being discussed widely these days, with many falling under the umbrella of Location Based Services (i.e. localized way-finding, advertising and ticket sales) and Information Search and Browsing services. In our efforts to raise the questions that we think are important we have opted to focus on two generic scenarios which share a lot in common. We have chosen these scenarios because they enable us to focus on a number of issues that are widely applicable to many additional scenarios.

Amazon-on-earth

This focuses on situations in which ecommerce transaction services are merged with location based information browsing , product comparisons, collaborative filtering (for relevant recommendations) , referrals, user annotation, and physical security systems. Smith et. al have shown some examples of partial systems at work [12].

Traveler-Services

This scenario focuses on situations in which mobile traveler needs (way-finding, tourist information, collaborative filtering, referrals, and annotation) and are interfaced with ecommerce transaction services .

In both cases, information browsing and searching services need to be coupled with social networking services, ecommerce transaction services and physical security systems to enable a scenario to be enacted to its fullest. In the first case it will enable a customer to find and buy a physical object in the real world (a book, a CD, a chair, a ticket). The second scenario will also enable the customer to find and buy objects, although they might be time limited voice translation systems or a tour guide, as well as traditional merchandise.

2. THE QUESTIONS WE RAISE:

Describing the above scenarios is one thing, with only our imagination and creativity next to our knowledge of the field being obstacles to new ideas. But turning the above scenarios into real services in the real world is a much more difficult endeavor. We argue that most of the difficulty does not lie in any technical detail but more in the design and implementation of user experiences which will allow people to use such services easily and comfortably. The technology must support whatever model is deemed to be best, and will obviously bring up some major implementation issues, but if a good enough process of design, evaluation and reiteration occurs, the technical implementation will be more streamlined and focused. We think that the questions below will allow us to focus on many of the problems that must be solved at the design stage before any real implementation rollout actually occurs. In putting these questions down on paper, we hope to start a dialog in which the issues will be focused on in a critical manner and some of the questions might be answered, others edited and new questions might arise.

2.1 The List:

Table 1: The List of Questions

Market Research	1. What do people view as *useful* services within an enabled environment?
Psychological / Person level Research	2. How do we create *usable* and unobtrusive user interfaces for such services? 3. How should we deal with the *constraints* of the human information processing system when designing for usability in the field?
Social Research	4. How do we deal with rules of *Etiquette* when users engage in private interaction in public spaces? 5. How does the *physical design* of a mobile phone affect the user experience in public spaces ? 6. How do *legal limitations* affect the services offered (privacy, security, trade secrets)?
Field Studies / Market Research	7. What will people actually *do* with their cell phones in enabled environments? 8. Are there any social or gender based *differences* which have an effect on usage patterns of offered services?
Technology	9. How do we best *interface* a mobile phone to internet based collaborative technologies and services?

2.1.1 What do people view as useful services within an enabled environment?

This is a seminal marketing question. If you design a service that helps people do something that is useful to them, there will be a bigger chance that they will actively use the service. Not wanting to get into the large body of research and writing around such issues [9][10], we offer the thinking that any service that is offered in the mobile world should be related to a specific target audience's goals and needs. This leaves a wide array of options (entertainment, personalization, ecommerce, and many more), but any design must take into account the target users profile (what types of phones they use, what type of data plans they buy, what types of services they currently use, etc). Designing a service without answering these questions can bring about a large waste of time and resources. Answering them does not promise success, but at the very least lowers the chances for failure.

2.1.2 How do we create usable and unobtrusive user interfaces to such services?

It is obviously not enough to have answered the questions about what a target audience might find useful. In order to succeed a service must be *usable*. Usability in the case of a physical environment must take into account the ambient stimuli in the environment (sound, motion, lighting, temperature). Trying to type an SMS while standing in a moving bus is not easy, unless the device has specifically been designed for such scenarios. Trying to hear important information in a noisy environment is difficult. Trying to read information from a screen in certain lighting situations can be very hard. A key concept here is "tradeoff". Improving something on one dimension most usually comes at a cost somewhere else in the system (i.e. a louder speaker can help one hear better but will be annoying to others as well being more power hungry). There are no secrets here: after prioritizing the needs of your users in regard to a service, tradeoff decisions can be made which can raise the chances for a usable service.

2.1.3 How should we deal with the constraints of the human information processing system when designing for usability in the field?

This question is very much related to the previous one, but focuses on the characteristics of the human perceptual and cognitive systems in order to help in creating more usable systems. Thus, knowing the limitation of human hearing helps us in designing audio cues as well as compression algorithms. Knowing the characteristics of human vision helps us design more usable screen designs. There are many "cookbook" guides that simplify the design process (e.g. [4]) although we must take into account that cookbooks are usually too generalized and thus stand a chance of missing critical elements in specific circumstances. The real world (as opposed to the psychological or psycho-physical laboratory) has surprises up its sleeve in many cases (try viewing something on a misty screen or entering a number with freezing or sweating fingers while running) which must be taken into account.

2.1.4 How do we deal with rules of Etiquette when users engage in private interaction in public spaces?

The first three questions have had countless papers and books written about them. The use of mobile devices in social settings seems to be younger, but academic papers have started showing up [6] next to the growing amount of lay press about it . Most earlier papers dealt with more basic etiquette issues (e.g. answering a call while in a meeting or with friends, speaking loudly, or the distance one should keep between themselves and others while talking on a phone [5][7]. We feel that these issues will become more extreme as new forms of interaction methods appear on the scene. While one can opt to speak in a low voice in a public setting, how will they use a service that forces them to use physical gestures (e.g. moving the phone, touching a target area, taking pictures) in public spaces? Will etiquette change or will such interaction models fail in certain places? This area seems ripe for research to help us understand the problems at hand.

2.1.5 How does the physical design of a mobile phone affect the user experience in public spaces ?

As discussed above, rules of etiquette might cause certain interaction methods to be abandoned, even though they might offer a more efficient and easy to use experience. We believe that the area of physical form factor design can have an effect in such cases. Can a form factor be designed that will allow users to engage in more efficient and pleasurable interaction models, while enhancing a feeling of privacy? We think that the answer is positive, although we have not seen any efforts in this direction yet. Most phone form factor designs are, correctly, focused on basic ergonomic issues such as key placement and size, character typography, screen size and resolution, next to overall form factor size and shape for easy handling, sexiness, as well as strength and weight. We hope that as new scenarios appear, the industrial design community will partner with our community in exploring these issues. We have in place a relationship with the industrial design department at the Bezalel Academy of Design in Jerusalem and are planning just such a project with them.

2.1.6 How do legal limitations affect the services offered (privacy, security, trade secrets)?

Legal limitations have always touched on the use of mobile communication technology, but as our mobile devices become more capable of capturing, storing and transmitting rich digital media (high resolution photos, audio recordings, and video) they become more susceptible to be seen as endangering people's privacy (in Japan camera phones are called "up-skirt devices" [14]), as well as being seen as serious security threats (commercial and military). Many places have put in place "remove battery" rules, or even the total exclusion of mobile phones from sensitive meetings- not only because they can be used by meeting participants to capture material, but because they can be used from afar to capture data. [2][8]. Another area that might come into the focus of lawmakers is the use of mobile phones for price comparisons and recommendations while inside stores, with the subsequent transaction taking place at another store (physical or online). Some stores will see this as endangering their earnings and might put in place electro-magnetic or other forms of screening. Market forces might help create an ecosystem in which both types of processes live side by side, but there will be a period in which such scenarios will be the focus of numerous clashes.

2.1.7 What will people actually do with their cell phones in enabled environments?

A lot of time is spent is designing and thinking about new services, but because of the difficulty and costs associated with deploying them, many of them finish life as academic exercises. As was the case with SMS, a seemingly unimportant service exploded when the number of users of cellular networks passed a certain threshold. Today over 1 Billion SMS messages are sent per day [13] and are an extremely important income stream for all providers. The point of this is that only by studying usage patterns of real users in real settings will we get a real feeling for what happens when users use new mobile services. This makes our job more difficult, since such field studies are expensive and relatively rare. We hope that large manufacturers and service providers can help fund such activities.

2.1.8 Are there any social or gender based differences which have an effect on usage patterns of offered services?

As an extension of the last point, it is clear that different parts of the general population have different interests and needs. Learning about and understanding these needs is crucial to designing and deploying services for these sub-populations. A careful exploration of the differences between age groups, gender and education in relation to these issues will help in the design of fitting services. Much work has been done in this space, but rarely, if at all, around issues of new ubiquitous services.

2.1.9 How do we best interface a mobile phone to internet based collaborative technologies and services?

This is a major technical question, and even though we have stated earlier that the design of new scenarios should not be driven by available technology, it is obvious that the technology available will have an effect on the way services are created and deployed. It is our belief that the mobile services infrastructure should not diverge from the general online services technologies being developed for the non-mobile world. The divergent technologies that exist today for delivering mobile services cause serious design, implementation and deployment problems for anyone wanting to roll out a service. Additionally, since there are numerous end devices out there (numerous models from numerous manufacturers on numerous networks), a major middleware tier needs to be put into place to enable easier and quicker rollout of usable services. Too much time today is spent on trans-coding (digital media as well page scripting) and dynamic layout (to best fit the multiple screen resolutions and color depths available). Creating a standard device abstraction layer will enable quicker and easier development of services which can be rolled out and tested. Today these issues are dealt with by multiple commercial entities, none of which can deal with the multitude of conflicting operating system and device limitations in a timely fashion.

3. A PROJECT WE ARE WORKING ON

We are currently working on a number of projects that deal with mobile services. Some of them (i.e. the cell phone as a personal networked musical instrument) do not explore interaction with the physical environment and are therefore less relevant. One relevant project focuses on creating an Amazon-on-earth test-bed through which we will be running user studies. Once the initial service loop works, we will install it in an active "store" on campus (one of the university libraries) and explore specific usage scenarios (browsing, searching for books, viewing recommendations, creating recommendations, and lastly, checking out the book). We hope to have some initial findings ready for presentation at the workshop.

4. SUMMARY AND CONCLUSIONS

This workshop paper has tried to raise a number of questions which we feel are important and relevant in the process of designing, implementing and deploying new physical-mobile services. The questions are grouped into five classifications: Market research, Psychological/Personal level studies, Social level studies, Field studies and the Technical infrastructure. In each of these groups there are many questions to be focused on and answered. We hope that by raising our questions, a critical discourse will develop around them and help drive some research directions and partnerships.

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Understanding Real World Practices: a Place-Centred Study of Mobile Workers

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ABSTRACT

This paper discusses a case study reflecting on the importance of designing interfaces for specific interactions within specific situations and locations. The study focuses on sales representatives and their work practices during the transition form a paper based system to an electronic system based on a PDA / Phone. We argue that, in order to design effective mobile technologies, it's necessary to go beyond the basic considerations of functionality and even usability of a system. There is a need to focus on en-placed activities according to the features, possibilities and boundaries that each of their work-places offers them.

Categories and Subject Descriptors

H.4.0 Information Systems Applications, general. H.5.2 User Interfaces: Theory and methods

General Terms

Design, Human factors

Keywords

Nomadic work; mobile computing; en-placed activity.

1. INTRODUCTION

This paper briefly presents the findings of a case study featuring the introduction of a hand-held device to support a group of mobile "nomadic" users. The aim of the study was to understand the impact of the technology on workers' situated practices and activities, and to suggest future solutions for the design of mobile interactive artefacts. Whereas the people we studied conduct their activities through a number of different locations, we look at their practices as situated in place, and therefore shaped by the features, resources and limitations that the physical environment presents to them [2], thus highlighting the limited possibilities of interaction which can be preformed within them.

In the paper, we will introduce our case study of sales representatives for a major Irish joinery company. We will present a brief account of our ethnographically-based study of their work practices before and after the introduction of the technology. We will highlight the necessity of evaluating the system beyond standard usability heuristics and guidelines, and show the necessity to examine the interactional boundaries that can come to the fore in certain emplaced activities.

2. MOBILITY

2.1 Mobile workers and mobile devices

Several studies have been conducted with the aim of evaluating and reflecting upon the introduction of mobile technologies to support work. Different aspects of the impact of mobile technology on work have been examined. For example, Kakihara and Sorensen [4] argue that to understand fully the impact of newly introduced technology, it is necessary to articulate multiple aspects of the notion of mobility [4].

Brodie and Perry [1] examine mobile workers in multiple locations (for example offices, hotels, trains, etc), and discuss how these environments present their own features in terms of resources and constraints over human interaction, communication and collaboration

In a case study similar to one presented in this paper [5], the authors describe the introduction of an electronic record keeping system in a building site, replacing the paper-based allocation sheet. The new system was intended to be a mobile resource for the foremen to support in-situ discussion with other people. Despite the good intentions of designers, the laptop was used only as a stationary record-keeping device. Although it was found useful by the workers, the notebook did not become a support for the mobile dimension of the work, as intended. The case study we are presenting describes another attempt to replace an extant paper-based system with a computer-based one which had similar outcomes. We aim to highlight the need to fully understand the possibilities, limitations, and scope around that of the; locations that are used as work places, the mobile worker and the tool they use.

2.2 The "NomadS" Project

The NomadS project aims at studying the practices of mobile, nomadic workers as they transverse a number of locations and make them into workplaces. We aim at highlighting the constraints that they encounter while doing so, thus investigating how each location supports actions and activities in different ways.

Our work focuses on a particular group: sales representatives for "Irish Joiners", a manufacturing company operating in Ireland and the UK. The majority of the "reps" work is contacting old and new customers, taking orders, communicating them to headquarters and handling any issues that arise. Their workplaces include building sites, the car, offices (most of them maintain a home office) and other customer sites.

When the company decided to fund the development of a mobile tool to support the sales representatives, a small group of reps were selected for a trial of the new system. We became involved in the project taking on the role of evaluators of the new system and of advisors regarding its future re-designs and developments.

We wanted to gain a better understanding of their work *in situ* as it stood before any new device was introduced. On this basis, we aimed at comparing the findings arising from the first phase of the study (prior to the introduction of the new handheld device), with those of subsequent studies carried out once the device had been introduced and in use for a period of time. Our aim was to gaining a strong knowledge of their activities, their role within the overall practice of the company, how and who they communicated with etc.

3. METHODOLOGY

We conducted informal interviews that took place in situ at the reps' workplaces. The relatively small number of participants selected meant that we could explore their activities in rich detail, using in-depth interviews and shadowing techniques [3]. We interviewed and observed six different individuals, with different attitudes, different approaches to the use of technology and different strategies in carrying out their daily activities.

We visited their office at home, we overheard phone conversations with builders, clients and fitters, we asked questions and we encouraged users to speak openly about their thoughts and impressions, we went into their cars observing all the activities during travel time. Finally we went out to the building sites with them, observing how and in which conditions the measuring activities take place. This approach to conducting the study allowed us to see and experience their working lives, their problems and their needs.

4. THE STUDY: PHASE 1 - THE PAPER-BASED SYSTEM

In the following sections we provide an overview of the sales representatives' activities through the three main places where they carry out their work: the building site, the car and the home office. We will integrate observations with quotes from the interviews conducted with the reps involved in our study to highlight the main issues related to their workpractices.

4.1 The Building Site

As the measurements of door and window opes are taken on the building site, they generally tend to be written in an untidy manner onto what is called an 'elevation sheet'. Therefore the elevation sheet is only a "shorthand" copy of data which will be subsequently transferred to a Contract Book. The contract books – which are completed subsequently- are filled out in more detail and with more time and effort taken to make them legible adding information such as material, opening type, vent location etc.

From the observational data, it is possible to see that there are some crucial problems with the system used until now by reps. For example the measuring activity relies on artefacts such as the elevation sheet and an electronic measuring tool called the "Digi-Rod". This means that the reps have not only to copy the information twice, from the elevation sheet to the contract book, but that they find it difficult to carry out the measuring in adverse climates where they have to change the tools in hand all the time.
This was noted during one of the shadowing exercise gives great detail into the reps activities, and they can then be questioned about their thoughts of being in such situations while experiencing them.

"Measuring is an important part of the job, it takes a lot of time.(…) I'm alone on site I don't have any support, I have the elevation book and a pen in-between my legs and the Digi-Rod in my hands, so I'm measuring and I'm writing and I'm measuring and I'm writing".(Jane, 35)

Jane gives an excellent description of her activities on the building site and of the problems that the current procedure presents. The tools needed to take measurements and their records are bulky and unsuited for a location such a building site.

[The elevation sheet] "is very heavy to carry but I need also to write notes and you need a copy for each builder. I'll take it home and then I'll transfer the information from this to the contract book to get the official copy to fax to the main office. The elevation book can be a little bit messy, because obviously you are outside and it could be raining." (Jane)

The building site is a place where measuring often occurs in bad weather conditions, and the elevation sheet can be easily ruined.

4.1 The Car

Company cars are a very important place of work for Irish Joiners' sales representatives. They are used for the storage of tools, documents, samples and catalogues and for having private phone conversations with customers and the main office. The car becomes a hub for communicating with stakeholders, as well as a safe storage environment and a means of transport.

"Customers ring me all the time. They never ask me 'Are you up on the scaffolding, are you measuring?'. They never say 'Can I talk with you, can you check something for me' But they ask me everything. So at least when I'm in the car, even when I'm driving, I'm looking through this information trying to give an answer. So I just carry everything." (Jane)

Jane's car is very much an "office on the move" for her. She deals with customer queries and sources relevant information in relation to them. The car is also where the reps plan the next phase of their working day while on the move from one building site to another:

Very different practices from those taking place in the building site occur in the car. Phone calls, information retrieval, scanning of appointments diaries are the main activities carried out in the car. There is a vast amount of paper work that the reps carry around with them during the movement, making the process of retrieving their information quite slow.

4.2 The Home Office

All the reps involved in our study have a home office where they spend about two days a week (usually Thursdays and Fridays), dealing with paperwork such as filling out the contract sheets with the information from the elevation sheet and plans and, most importantly, transmitting all the week's compiled order forms via fax to the Irish Joiners' headquarters.

"Friday is the day when I sit down in the office filling in the orders. (…) The fax is integral to everything. I need the fax to send my orders and I need the fax to photocopy my standard contracts. You need the fax for everything really. Which means, you can only do that when you are at home" (Pat, 42, 12 years with the company)

The paper based system does not allow reps to fax their orders anytime, anywhere. This activity is limited to one place, the office, and to specific days of the week.

4.3 Discussion

The first phase of field work provided us with a detailed understanding of the reps' work practices, the different procedures that they follow, and the locations where their work takes place.

The building site seems to be the location presenting most practical problems for the activities of measuring, dealing with paperwork and conducting conversations (particularly by phone).
One of the most striking issues emerging from the data is related to the working conditions that the reps are subjected to. They work on building sites all year around in every condition imaginable. Measuring is not always as straightforward as it may seem either as they may often need to manoeuvre themselves in between scaffolding and all other manner of debris and equipment found around the building site.

Another emerging issue is the reps' frustration and annoyance about the need to constantly re-enter item details from one source to another i.e. from the elevation sheet to the contract book, but also from the repetition of house details from the same building scheme that are entered in week after week for each new order. This is work, which for the most part takes place in their home office which means working there in the evenings or dedicating complete days to the task

"The paper based system seems to annoy and frustrate people all the time, it just seems to be endless; the amount of paper, and the amount of writing very similar information all the time." (Pat)

It is clear from both our observations and the interviewees' comments that the current work practice is in need of modifications, and that a technological aid could be very beneficial in this respect.
In the following section we will discuss the findings of the second phase of the study, focusing on how the reps' work was affected by the introduction of the PDA/phone tool.

5. THE STUDY: PHASE 2 – INTRODUCTION OF THE PDA

The main goals for the introduction of the electronic mobile device were to simplify and speed up the reps' activities, remove the repetitive nature of task of transferring information from one form to another, having the ability to fax orders anytime, anywhere and to create clearer orders for those that come in contact with them.
The initial intention for the use of the device was for the reps to carry it to the building site, this was so that the measurements could be recorded electronically during the measuring activity, therefore eliminating the need to transfer the measurements a second time.

With the previously mentioned factors in consideration it was decided to introduce a software system developed for the XDA2 operating on Windows Mobile 2003 for Pocket PC Edition. The system was developed over several months by a third-party company, in close collaboration with one of the reps. The aim of involving an end-user in the design was to organise the software in as simple a way as possible (as the end-users would vary considerably in their technical abilities) to minimise the disruption to their work practice during the transition from the old to the new system for both the reps and the Irish Joiners central office. Therefore the elevation and contract sheets generated from the XDA needed to be identical to those already in use.

We commenced the second phase of our study by conducting a usability study of the new Irish Joiners software using both heuristic evaluation and cooperative evaluation of the software in a laboratory setting, and also conducting observational studies during the reps' training on the software. Apart from a few small usability issues and some information layout problems, the reps all took to the device with great ease. Although with a number of functionality issues brought to the fore and a number of usability issues noted, there was very positive feedback given in relation to the system.

5.1 Discussion

In the following 5 to 8 weeks, we had kept in close contact with the developer of the system to be informed as to the extent of use of the new system, as to any problem that were noted during the early stages of use.

Once we began phone interviews at the start of the second phase of the studies, we collected data showing positive feedback regarding the device and the software system.
The possibility of conducting certain activities in a more flexible manner and through more than one location were certainly appreciated by the reps. There are certain types of houses that the measurement for the openings remain constantly the same and for these houses being able to change the number of the house on the electronic device and sending the order immediately is where the system has been of great success.

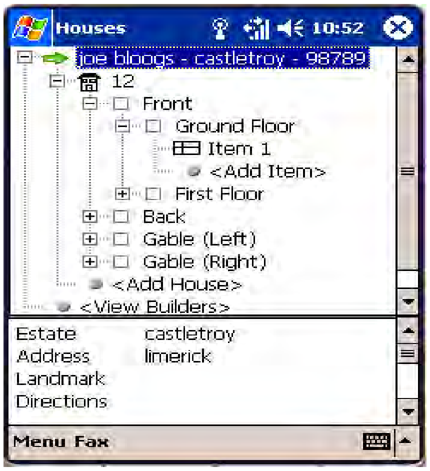
However, whilst the design of the interactive system was successful at both usability and functionality levels, it also appeared that the use of the device and of the software system was not quite the one that was originally intended, and this became increasingly evident once we observed the reps *in situ*.

Instead of using the device on the building site to record the measurements, they were reverting back to the old process of annotating measurements using the elevation sheet, and later transferring the measurements and details to the new system. When quizzed about their non-use of the XDA on site, they expressed a number of reasons for not doing so.
The environmental conditions and harsh physical conditions experienced on a building site do not lend themselves for the use of a somewhat fragile, small device that was not designed for such setting.

"I'd be nervous enough to about it – I keep it in the car with me. I don't bring it out on site with me I'd be afraid of it falling out of my pocket, I'd be afraid of my life to damage that thing" (Pat)

The reps are familiar with using a thick hard-wearing book to record measurements, and they hold little value to it even though it is their only record of measurements, placing it between their legs and on cold wet dirty surfaces. They afford it little of the values that they express towards the new electronic device.

Other issues noted are related to the design of the interface, which feature numerous drop-down menus, check boxes and a miniature onscreen keyboard. The interface layout and the effectiveness of interface metaphors such as the tree menu structure were not thoroughly considered to be used within the conditions of the users' workplaces. There was no consideration given to the fact that the elevation sheets are ruggedised for a specific purpose and is only used as rough work in recording item measurements and that the contract sheet is where the time is given to detailing each item individually. Instead the two were attempted to be incorporated, hence no quick and easy way of entering the measurements into the system without having to either go through numerous steps or entering exact details of each item which is not possible in the given situation.



Estate castletroy
Address limerick
Landmark
Directions

Figure 1. Current interface screenshot

Another reason for the limited use of the XDA is related to its use as a resource in dealing with customer requests:

"*I still use my own sheet because it's a handy record because you have them in the back of the car and if anyone ever rung me and said 'Pat this window here I'm not quite sure what size you've written or what your looking for', and I can whip it out there and then*" (Pat)

While the ability to check sent contracts was something that had been suggested as a useful feature of the XDA, it was not used in such a way. The device does not support this activity very well.
This is predominantly due to the fact that the screen size and to some extent the interface of the software limits the amount of information that can be viewed at any one time on the device. While the interface could be designed better the users find the practicality and physicality of flicking through orders useful.

The most relevant issues emerging from the second phase of the study highlight the limits of the new system in supporting the reps' situated work practices. Whereas the software provides certain benefits to them and certainly reduces the amount of repetition which characterised the paper-based procedure in certain circumstances, the system has not been adopted for use in all the locations transversed by the reps in their job. The situatedness of work practices is something that needs great consideration and deliberation when designing systems that will ultimately be used within them

Due to the constraints of this paper I'm limited to selecting only a number of issues that were observed during our study, which was more in-depth than revealed here. However I hope to present and discuss more of the issues that were noted during the workshop

6. CONCLUSIONS AND FUTURE WORK

The study has shown that, the new interactive system is effective in terms of usability and functionality. However its introduction has not been entirely a success, as it has not had the desired effect on supporting their activities due to a lack of consideration of situated and en-placed aspects of activity during its design. The practicalities of users' working practices and contextual conditions were not taken into account during the design of the system.
While it is something that can often be neglected, it is important to see how users react to certain devices in certain situations, in our case because of the perceived fragility of the device they were unwilling to use in their rugged work on site
Through our studies we hope to have highlighted and stressed the need to fit activities to place, taking into account the qualities and constraints of the environment as they are linked to the person's practices, tasks and knowledge is of paramount importance

Through our studies we have identified a number of requirements for design leading us onto the redesign of the device for use onsite. As the measuring activity is of high importance we have noted the need for reps to transmit this information from the digi-rod to the final electronic device to be of highest priority. We are currently in the process of developing a Bluetooth enabled digi-rod to allow for the measurements to be transmitted seamlessly from one device to the other. This will complement the redesign of the interface to support the quick and easy transmission of this data to the appropriate items stored on the device.

Another requirement we are addressing is to change the perception of fragility of the device, with such extras as cases, pouches and rubber sleeves. There is also that matter of colour to be considered, as we have noted there is a number of though items used on the building sites which have the colour orange which we hope will lend its appropriation to a more ruggedisied device

We hope to have emphasised that there should be more focus on stressing the en-placed activities and how to support them within the real-world. I hope to discuss some of the issues that I have noted and expand on them during the workshop, while also getting valuable feedback on them and our concept in relation to similar work carried out by other attendees.

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Public Display Advertising Based on Bluetooth Device Presence

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ABSTRACT

Public electronic displays can be used as an advertising medium when space is a scarce resource, and it is desirable to expose many advertisements to as wide an audience as possible. Although the efficiency of such advertising systems can be improved if the display is aware of the identity and interests of the audience, this knowledge is difficult to acquire when users are not actively interacting with the display. To this end, we present *BluScreen*, an intelligent public display, which selects and displays adverts in response to users detected in the audience. Here, users are identified and their advert viewing history tracked, by detecting any Bluetooth-enabled devices they are carrying, such as phones and PDAs.

1. INTRODUCTION

Public electronic displays[1] are increasingly being used to provide information to users, to entertain (e.g. showing news bulletins), or to advertise products within public environments such as airports, city centres, and retail stores. Within these displays, advertisers typically utilise a variety of delivery methods to maximise the number of different adverts displayed, and thus increase their overall exposure to target audiences [3]. However, these methods are typically naïve and do not take into account the current audience.

The prevalence of ubiquitous sensing technology is growing, with both Radio Frequency ID (RFID) tags and smart cards being increasingly used as a means of tagging items or providing access mechanisms to offices or secure areas within buildings. Combining these technologies with public displays, we can create intelligent displays that no longer display advertisements without knowing about the current audience but now adapt their content to suit this audience.

In this paper, we introduce *BluScreen*, a novel approach to advertising in public spaces that takes advantage of the large number of existing wireless-enabled devices, such as mobile phones and PDAs, to improve advertisement selection on public displays. Our approach is based around a multiagent system which drives each *BluScreen* display and is responsible for determining appropriate content for each display such that the novelty of the chosen content is maximised, given the current audience.

2. RELATED WORK

There are several approaches to community-based public display interactions currently being investigated, however they each look at the study from different perspectives and attempt to utilise these displays to serve different purposes.

The first of these approaches, GroupCast [2], demonstrates the use of public displays which respond to the local audience, detected using infrared badges, to display content that can start or enhance conversation between groups of individuals. To identify appropriate content to be selected, profiles are defined for each user and common areas of interest are identified for all users passing by the display. *BluScreen* differs from this project in that it seeks to maximise exposure to the current audience as opposed to matching content to shared interests, which would prove difficult without prior knowledge of user preferences. Some problems with this approach were encountered, including how to capture a user profile that is large enough to find intersections of user preferences whilst being small enough that a user would actually take the time to fill it out.

A BlueBoard [4] is a large public display designed to support fast, lightweight encounters with users in order to provide access to their personal content, with authentication performed by swiping a badge through a badge reader. Once authenticated, tailored content (such as personal calendars) will be shown to each user, however, unlike GroupCast and *BluScreen*, this content does not dynamically change and must be navigated using a touch-screen interface.

Other display systems support interaction through mobile phones to influence the content of the display. For example, the Hermes Photo Display [1] uses Bluetooth-enabled phones to allow users to share photos with each other by uploading and downloading photos to and from the display. No specific client software is required on the phone, as the system utilises the fact that many modern mobile phones can already share multimedia via Bluetooth. Although this display can be used to share photos; as with the BlueBoard, the presented content is static, and requires direct user interaction (i.e. via a touch-screen) to browse the photos.

Along with the Hermes Photo Display, the MobiLenin [5] system allows a group of people equipped with mobile phones to interact with a public display, except HTTP over GPRS is used as opposed

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[1] An electronic display can change the advert presented over time.

to Bluetooth. The system enables its users to jointly author a music video by voting for the next action which should be taken in the video, the most popular of which is shown on the display. This is known as interactive art and, as with the GroupCast project, aims to encourage social interaction between people. Through experimental evaluation, it was shown that the system successfully generated a strong social setting and enticed social interaction within the group of users. Users interact directly with the MobiLenin system, whereas interactions with *BluScreen*, are passive and not user-initiated, although mobile phones are still used to influence the content of a display, according to a device's presence.

3. THE BLUSCREEN SYSTEM

BluScreen is a distributed advertising framework in which advertisements are selected efficiently to maximise their exposure to as wide an audience as possible. This is achieved using an underlying decentralised multiagent system in which advertising space is allocated to the advertising agent (representing an advertisement) willing to pay the most for the available airtime through an auction. In the *BluScreen* system, a display's audience is identified using existing ubiquitous consumer devices, thus enabling its immediate widespread use.

3.1 Detecting the Audience

The prevalence of small, wireless devices (such as phones and PDAs) provides an interesting means of detecting the users surrounding a display. Many modern mobile phones are equipped with Bluetooth, a short-range wireless technology where devices communicate with peers in close proximity, and *BluScreen* exploits the fact that many mobile phones are Bluetooth enabled, supporting detection by a Bluetooth sensor[2]. By associating a Bluetooth-enabled device with a user, the detection of these devices by intelligent screens enables a display's audience to be estimated and its content to be modified to suit the current audience.

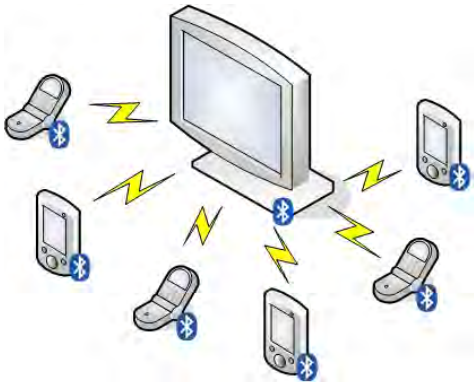

Figure 1: A *BluScreen* Display Detecting its Audience

Furthermore, if we assume that the duration of the user's and the display's collocation event relates to the user's interest in the material we can find which advertisements are less popular and eventually stop them from being displayed any longer or decrease their likelihood of being displayed to the uninterested user.

3.2 MultiAgent System

The multiagent system that selects appropriate content for each networked display can be decomposed into a variety of agents, each responsible for a particular task, running on some networked node. The roles these agents undertake mainly relate to the selection of advertisements although the responsibilities of other, assisting agents include content synchronisation between displays and the collection and subsequent sharing of Bluetooth data. The system primarily contains various advertisers and publishers (i.e. a display which will show an advertiser's material), each represented by agents. A publisher's agent will perform the initiation of Vickrey [6] auctions to allocate its current advertising space to the advertising agent that values the space the highest, based on the Bluetooth activity from the previous advertising session.

Advertising agents will place bids based on the novelty their advertisement will give to the Bluetooth devices they predict will be present during their advertisement's showing. These agents will therefore place high value on devices that have never seen their content before, relatively high value on devices that have seen some portion of their content and no value on devices that have seen all or most of the content. The effectiveness of this selection mechanism in maximising exposure is evaluated empirically in section 4.2 of this paper.

3.3 System Prototype

A prototype of the *BluScreen* system was deployed in the department of Electronics and Computer Science at the University of Southampton and consisted of two networked, intelligent *BluScreen* displays. Both of these displays have been deployed in the same building, one on the 4th floor and the other in the lobby (as shown in Figure 2). These displays have been provided with an initial set of advertisements and, as Figure 3 shows, are managed through a web-based interface that is available for each *BluScreen* display. This web-based interface provides archived statistics on which advertisements were shown throughout each day, how much they paid in auction for the airtime and, when shown, how successful these advertisements were.

Figure 2: The Lobby *BluScreen* Display

4. EVALUATION

The deployment of the prototype system enabled Bluetooth data to be collected from the two networked displays and subsequently analysed to identify patterns and see exactly how many users have their Bluetooth phones or PDAs on discoverable mode.

4.1 Bluetooth Results

During the 3 month period 8th February 2006 to 8th May 2006, Bluetooth data was collected and analysed. In this period, 458 unique devices were detected between the two deployed displays. As Figure 4 shows, 433 of these devices were detected in the lobby and 143 were detected on the 4th floor display, giving an overlap

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[2] Only Bluetooth devices in discoverable mode are detectable.

Agent Statistics for 18/05/2006

Advertisement Information

Advertisement Name	Wave
Advertisement Type	Standard Advert

History for "Wave" on 18/05/2006

Start Time	Duration	Valuation	Bid	Reward	Profit	Utility
10:26am	1 mins 46 secs	3	0.2	4	3.8	1

Figure 3: The Web Interface for Managing a Display

of 118 devices which were seen at both locations. This implies that the remaining 25 devices seen on the 4th floor but not in the lobby were either nearby static devices that never left the building or were devices such as laptop computers which occasionally visited adjacent offices and would be switched off when carried through the lobby and out of the building.

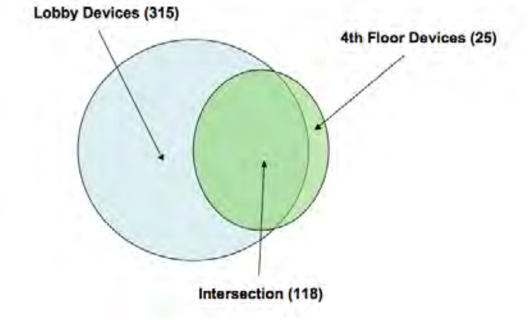

Figure 4: The Number of Bluetooth Devices Detected

Table 1 classifies these detected devices into three classes: *occasional*, whereby devices are observed for only a short time (such as visitors, etc.); *frequent* representing devices that regularly pass by the display; and *persistent* which represents devices that are regularly found in proximity to the sensor (such as laptops, etc.) that do not represent individuals passing the screen. Of the 458 unique Bluetooth devices detected, 163 were detected with some degree of regularity, indicating that there are a large number of frequent users for the system to work with.

Device Type	Unique Samples	Devices
Occasional	< 25	289
Frequent	25-2000	163
Persistent	> 2000	6

Table 1: Number of Bluetooth Devices Observed at Different Frequencies over a 3 Month Sample Period

Analysis of the Bluetooth data enabled events to be grouped by their time of day and day of week of occurrence. Figures 5 and 6 show these results.

As Figure 5 shows, the majority of the Bluetooth events occur between the hours of 10am and 5pm, the times at which it would be expected that the department would be busiest. This clearly shows a correlation between human activity and Bluetooth activity, reenforcing the choice to associate a device with an individual. During the quiescent, late night periods, although there is very little activity, there is still some activity. This can be accounted for by any devices in nearby offices that are never switched off. Figure 6 shows that the least activity occurs over weekends, which again would be expected within an office environment.

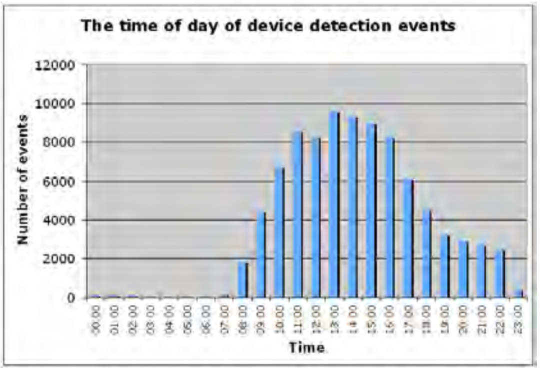

Figure 5: The Time of Day of Bluetooth Events

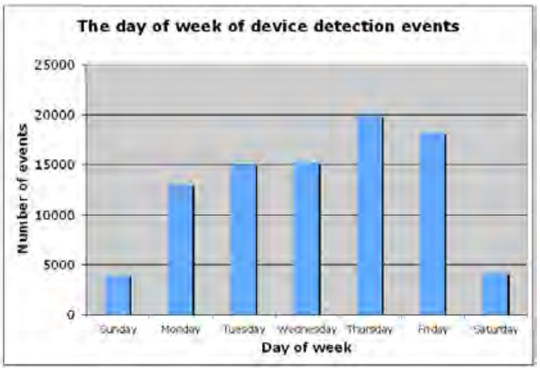

Figure 6: The Day of Week of Bluetooth Events

4.2 System Effectiveness

To test the effectiveness of *BluScreen* in comparison to other, widely used advertisement selection techniques for public displays, a model of devices moving between networked screens was built[3] based on the following assumptions:

- Device presence is measured in discrete sample-intervals, to simulate observations made by the Bluetooth sensor;
- The duration of an advert is assumed to be equal to a whole number of sample-intervals;
- An advert is considered as *fully seen* only when a device has been present for the whole duration of the advert;
- Devices can arrive at any point during an advertising cycle, whereby the probability that a device will arrive is P_{arrive};

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[3] Although the deployed prototype could be used to test the auction mechanism based on observed real-world events, factors such as the location of the screen, variances in the advertised material, and the number of detectable devices can affect the resulting performance.

- The probability a device may leave without observing the subsequent advert is P_{depart}. A device will automatically leave if it has *fully seen* the subsequent advert;
- A device may only be present at one display at any one time, i.e. displays are sufficiently far apart that they never detect the same device;
- Both P_{depart} and P_{arrive} assume a uniform distribution.

The performance of the distributed multiagent system under the modelled conditions was compared to three alternate advertisement selection mechanisms: ***Round-Robin*** selection, ***Random*** selection and ***BluScreen Local*** selection. ***Round-Robin*** is a familiar mechanism used to repeatedly cycle through a number of adverts (in order). The ***Random*** mechanism randomly selects a new advert to display at the beginning of each new advertising cycle, independently of what has been previously selected. The ***BluScreen Local*** approach uses the same multiagent system but without communication with other networked displays and was included to measure the benefits of using networked displays with pooled information as opposed to standalone displays. Figure 7 illustrates how many advertising sessions were required until each simulated device had been exposed to each advertisement in full, where 10 advertisements must be shown to each device across a network of 4 displays with N_d, the number of target devices, being varied. All of these results have been averaged over 250 runs, tested for statistical significance using a t-test and were found to be significant, for $N_d \geq 10$ at the 5% level.

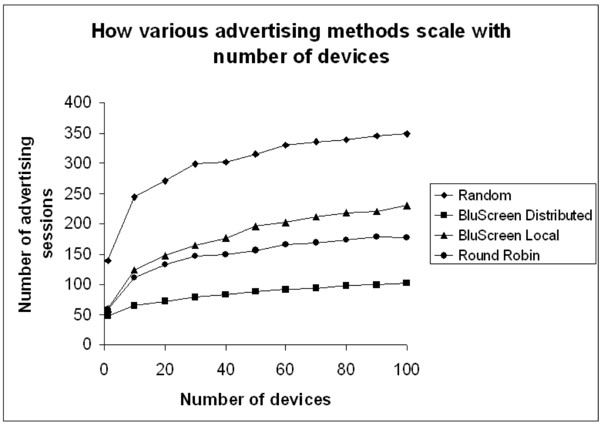

Figure 7: How Various Advertising Methods Scale with Number of Target Devices

As Figure 7 shows, the approach discussed in this paper (***BluScreen Distributed***) outperforms all other advertisement selection techniques, for $N_d \geq 10$ and demonstrates excellent scaling as the number of target devices is increased. The commonly employed ***Round Robin*** approach required up to 75% more advertising sessions than ***BluScreen Distributed*** selection before all advertisements had been displayed to all devices - this shows the significant improvements that can be achieved by using data readily available from Bluetooth scanning rather than naïvely advertising with no information about the current audience.

5. FUTURE WORK

The work to date has concentrated on building the foundations for a multiagent system which will maximise exposure of each advertisement. Future work on this project will attempt to improve the selection mechanism further by attempting to learn user profiles to improve the relevancy of content displayed, and learn activity patterns for each user so that, for instance, a user that tends to stay around a display for a long amount of time during the lunch hours will be advertised to during this time, hoping that advertising will be better received at this time of day. Also, experiments will be carried out to determine how representative of a display's audience we can consider Bluetooth to be, how we can gauge the success of an advertisement and whether this success can be estimated by continued device presence.

6. CONCLUSIONS

We have presented a system in this paper which is capable of improved advertisement selection for public displays, ensuring an advertisement receives maximum exposure. With our system, the ubiquitous mobile devices carried by individuals interact with the environment in a non-intrusive manner, simply supporting the exposure of their owners to novel advertisements. The collection and analysis of Bluetooth data from the deployment of a prototype has enabled us to show that Bluetooth is a viable means of determining the current audience within a particular physical space and that Bluetooth devices themselves can be used as a proxy for human presence.

7. ADDITIONAL AUTHORS

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Exploiting incidental interactions between mobile devices

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ABSTRACT

Not all human–computer interactions are directly derived from the concious intention of a user. There are a class of interactions which occur as a side effect of the user's current goals but which nevertheless, provide a useful modality for interacting with mobile applications. This paper discusses the use of these '*incidental interactions*' in mobile applications, particularly those that rely on the notion of co-presence. This paper presents three projects that exploit incidental interactions: The first, *Amigo*, is a application that uses Bluetooth to construct a representation of a user's social network and associate these with calendar events; the second project, *Co-presence Communities*, takes the Amigo concept further by mining the co-presence data to discover reoccurring group meetings; and finally, *BluScreen* is a pervasive public display that utilises co-presence data to provide feedback to an agent-based marketplace, which is responsible for allocating the time slots for each presentation.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]: Interaction styles; H.4 [**Information Systems Applications**]: Miscellaneous

Keywords

Incidental interactions, Co-presence, Mobile social applications, Bluetooth

1. INTRODUCTION

Traditional literature in the field of human–computer interaction assumes that the user has a particular goal in mind when they start interacting with a computer. This is often characterised by Norman's interaction model [11], which consists of two primary phases: execution (including planning) and evaluation. That is, the user begins with a goal in mind, executes a plan to achieve this and then evaluates the results against the intended state. This model accounts for the majority of computer interfaces but it has the disadvantage of requiring the user's attention for the planning, execution and evaluation phases. Whilst this may not be a problem when the user is fully occupied by the task, there are circumstances where the user is neither capable, nor required, to switch their attention to the computer. This 'attention scarcity' is more prevalent with mobile phones, where the user is typically required to devote at least part of their attention to other tasks. In contrast, applications on a desktop computer are assumed to be the main and primary focus of the user.

This paper advocates an interaction model for mobile devices that co-opts the user's intentional actions for one task, as inputs towards an entirely different goal. An example, elaborated throughout this paper, is the goal of building a representation of your social network. A traditional system would allow a user to input the names of their contacts and perhaps note when, where and how they maintained that relationship[1]. Our proposal, explored throughout this paper, is that the goal of building the social network representation should be a by-product of the *actual social interactions.* So, the action of a user meeting someone would automatically update the corresponding entries in their profile.

This paper begins with an introduction to '*incidental interactions*' (in Section 2) and specifically to Co-presence as a form of interaction (Section 3). Section 4 provides a brief description of three current research projects which employ incidental interactions. In particular, Section 4.1 presents *Amigo*, a web-based social networking site, that uses information derived from incidental interactions. Section 4.2 introduces *Co-presence Communities* as an extension of the Amigo project that provides a richer analysis of a user's social network. *BluScreen*, in Section 4.3, is a public display that uses the incidental interactions of viewers to influence the future content. Finally Section 5 concludes this paper.

2. INCIDENTAL INTERACTIONS

In contrast to the Norman model of intentional actions, Dix has proposed *'incidental interactions'* to describe those actions that are co-opted by a system to serve a different goal from that which the user was currently undertaking [3]. Dix defines incidental interaction as the situation "*where actions performed for some other purpose, or unconscious signs, are*

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[1] indeed, this is the model for all 'social networking services' currently available on the Internet

interpreted in order to influence/improve/facilitate the actors' future interaction or day-to-day life" [2]

This emphasises the user's focus on one task, whilst the system is surreptitiously using those interactions to actually fulfil a different goal. The canonical example of an incidental interaction is the interior light of a car: When the user opens the car door, the interior lights are activated. The user's goal is to enter or exit the car, but the system uses the interaction with the car door to fulfil the unstated goal of illuminating the car interior. Note that 'incidentalness' does not imply that an action or subsequent goal is unintentional, just that the user may have previously specified it to the system and not be consciously thinking about it whilst performing the actions. Incidental interactions also differ in the feedback that the user receives. Whereas a traditional application would provide direct, explicit feedback to the user regarding their actions, feedback from an incidental interaction will often be minimal, unobtrusive and delayed. The de-emphasis of explicit user interaction and feedback provides incidental applications with a strong requirement for autonomous software, and an obvious connection to the field of agent-based computing [10].

3. CO-PRESENCE

Co-presence refers to the spatio-temporal conditions under which people can interact with each other. Goffman defined it as the condition when people "*sense that they are close enough to be perceived in whatever they are doing, including their experiencing of others, and close enough to be perceived in this sensing of being perceived*" [7]. Co-presence (or more formally, *corporeal* co-presence [14]) is the condition under which two or more people are in the same place, at the same time. In general, co-presence is not an intentional action by itself but rather a by-product of some other goal, which makes it a useful form of incidental interaction.

Humans experience co-presence through one or more sensory inputs but, since computational systems lack that capability, it is necessary to develop a technological solution to co-presence detection. If we take Goffman's view of co-presence, then any technological co-presence sense should be roughly equivalent to human sensory inputs. The class of technologies called Personal Area Networks (PAN) provide a good match with Hall's work on our sensory abilities [8]. In particular, the effective range of PANs corresponds to the distance at we can perceive individual characteristics in people. Most wireless PANs, such as Bluetooth, are effectively confined to a single room due to their short-range and limited wall-penetration abilities. Bluetooth also the advantage that it has been widely adopted in mobile devices, from laptops to PDA's and mobile phones. For the purposes of this work, the wireless 'bubble' formed by a Bluetooth device is used as a co-presence sensor and the presence of that device is assumed to indicate the presence of its owner. Whilst it is also assumed that there is one-to-one correlation between a mobile device and human owner, it is also accepted that individuals without mobile phones (or without Bluetooth activated) will not be discoverable.

A Bluetooth sensor attached to an individual allows the computation of co-presence to be embodied within the real–world [4]. This embodiment means that through the medium of real-world interactions, the user can participate in co-presence systems, without resorting to activities outside of their normal daily routine. This aligns well with Dourish's argument that embodiment "*does not simply mean 'physical manifestation.' Rather, it means being grounded in everyday, mundane experience... [embodiment] is the property of our engagement with the world that allows us to make it meaningful*". The real–world embodiment facilitated by a co-presence modality (i.e., that the interaction is "grounded in everyday, mundane experience") neatly matches the characteristics of an incidental interaction, which should result from some other real–world goal (that "mundane experience").

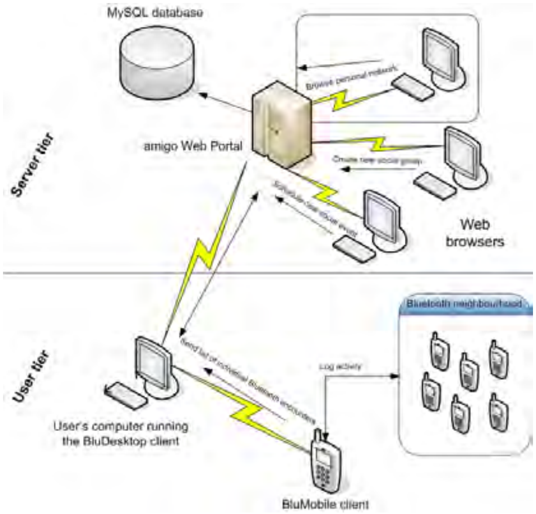

Figure 1: The Amigo architecture consisting of BluMobile client, BluDesktop and the Amigo web service

4. CO-PRESENCE PROJECTS

The three recent projects described in this section utilise a co-presence interaction modality in a similar way to previous applications (such as the selection in [1]). In particular, the Serendipity application [5] detects co-presence between two individuals using Bluetooth-enabled phones, attempts to match their two profiles and, if successful, provides an introductory service. This has obvious dating applications but the actual usage scenario was to enhance corporate collaboration. Moving beyond the immediate interaction, Eagle & Pentland have used Bluetooth phones as mobile sensors from which to determine a user's activity and location [6]. In another direct example of incidental interactions from co-presence, the Jabberwocky device used Bluetooth to determine a user's 'Familiar Strangers' [12]. This also demonstrated how a user might come to subvert the co-presence interaction by deliberately straying away from their usual patterns to seek out new pastures and avoid their familiar strangers.

4.1 Amigo

Amigo is an social networking service built upon real interaction data collected by Bluetooth phones. It keeps a history of co-presence encounters and a calendar of events, and uses these to infer social relationships and attach occurrences of co-presence with particular diary entries. Amigo consists of three main components: a client application, BluMobile; a desktop application, BluDesktop; and the central Amigo web service. The architecture is sumarised in Figure 1.

The BluMobile client is a J2ME application that can be installed on a Bluetooth-equipped mobile phone (a W800i was used in our trials), and regularly scans for other Bluetooth devices in the vicinity. These encounters are logged to the phones internal memory and may be displayed in a textual or graphical form. However, the main purpose of BluMobile is not the visualisation of these co-presence encounters, but as a means of collecting the co-presence data. Due to the storage and processing limitations of mobile phones, the co-presence data is then transferred to the user's PC for processing by the BluDesktop client. BluDesktop acts as the user's main store of co-presence data, calendar entries (in RDF iCal format[2]), and social network representation (in FOAF format[3]). The representation of the user's social network is built from the co-presence data, using the simple rule that any person who has been co-present with the user for more than a specified total amount of time (default: 1 hour) is considered a 'friend' [4]. Anyone who doesn't meet the criteria of 'friendship' is just considered to be a casual encounter. A mapping between calendar events and the people associated with it is constructed by considering any person who was co-present with the user for more than a specified percentage of the event's duration (default: 20%) to be related to that event. These event-person connections are used to form a representation of the event's social group. The resulting user profile, which incorporates the social relationships and event groups, is created as an RDF document and uploaded to the Amigo web service. This profile is used by the Amigo site to provide a mechanism for browsing the profiles of those members of the user's social network (where authourised) or the co-presence history by events, time or device.

Amigo is an example of an application based upon incidental interactions because the act attending of a social event (e.g. Salsa dancing) has the incidental effect of building up a representation of the social group around that event. Another functionality of BluMobile is the ability to be notified, through an audio or vibration alert, when one of your 'friends' comes into range. Admittedly, this isn't a terribly useful feature with the typical 10 m range of Bluetooth, however it does highlight the incidental effect of a co-presence interaction: as the user approaches a friend (for whatever intentional reason), their phones will incidentally vibrate.

4.2 Co-presence Communities

Co-presence Communities is a project that aims to discover socio-temporal patterns from co-presence data (much like Amigo) but relies on the user to add contextual information (whereas Amigo utilises calendar information). An initial algorithm for discovering these co-presence communities has been developed that incorporates a feature extraction routine and conceptual clusterer [9]. However, the details of that algorithm are outside the scope of this paper.

Figure 2: The BluScreen installation

A **Co-presence Community** is formed by the repeated co-presence between a *group of individuals* at approximately *the same time period*; a Monday morning project meeting or a daily coffee break at 3:00 would be two examples. These co-presence communities are probabilistic representations that cluster together co-presence events on both temporal (start and end times) and membership dimensions. A community may be stable to a varying degree across these two dimensions. For example, the co-presence community formed by weekly project meetings would have stable membership and temporal dimensions (the same group of people at the same time interval). In contrast, the community formed on a commuter bus might have a stable temporal dimension (because you always catch the same bus) but an unstable membership (because it's not always the same people on that bus). By obtaining these community memberships via wireless sensors, it is be possible to build a dynamic, self-updating model of the people that a user is normally in the proximity off at any given time.

AIDE, the Ambient Information Dissemination Environment, is one possible application of co-presence communities. AIDE allows users to distribute content in a peer-to-peer manner, using their co-presence communities as a self-updating distribution list. The advantage of co-presence communities for this application is that they allow dissemination in different contexts: sharing jokes with strangers on the commute home (i.e., a time-stable community) or disseminating the latest call-for-proposals to a research group (a fully stable community formed by weekly meetings). AIDE ambiently determines which community a detected device belongs to and transfers the selected content in the background, based on the source user's specified preferences. With the AIDE application, the user is expected to pursue their normal goals and the dissemination of their content (being a longer-term goal) is carried out as a side-effect of their daily routine.

4.3 BluScreen

BluScreen is another project that derives its functionality from the incidental interaction between co-present devices. However, in this case, the co-presence activity is used to auction off display time for a pervasive public display to autonomous advertising agents [13]. Figure 2 shows one of the BluScreen installations mounted near a major thoroughfare.

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[2] http://www.w3.org/2002/12/cal/ical.rdf

[3] http://xmlns.com/foaf/0.1/

[4] A 'friend' in this sense is the simple binary relationship provided for by the FOAF representation rather than any deeper sociological construct

The user's interaction with the screen (such as pausing to view the contents) is co-opted by the BluScreen to incidentally provide feedback to the agent marketplace about your implied preferences, and thereby change the content you receive in the future.

5. CONCLUSIONS

This paper has concentrated on a class of interaction which is not normally considered interesting in HCI research: those interactions that are incidental rather than being explicitly intentional. These incidental interactions are more important to mobile applications since the user's attention can be productively directed at other tasks. The examples and projects discussed in this paper are all based on co-presence interactions: Amigo uses them to build up a semantic representation of a user's social network; Co-presence Communities exploit the interactions to build a more comprehensive social model and, through the AIDE application, allow content to be disseminated without repeated, explicit, intentional actions; finally, the BluScreen project uses the co-presence interaction between viewers and a pervasive display device to enhance the quality of the displayed content. For some mobile applications, the focus needs to be moved away from the traditional modalities of the mobile phone and towards less attention-demanding, more autonomous, and more context-aware, interactions.

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