Formative Studies for Dynamic Wayfinding Support with In-Building Situated Displays and Mobile Devices

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ABSTRACT
There is a significant disparity between wayfinding support services available in outdoor and in-building locations. Services such as Google Maps and in-car GPS allow users to examine unknown outdoor locations in advance as well as receive guidance en-route. In contrast, there is relatively little digital technology to support users in complex building architectures, e.g. institution buildings where users are generally limited to using traditional signage or asking for directions at the reception. However, recent advances in pervasive digital display technology are enabling a new range of possibilities and are making this topic increasingly subject to study. In this paper, we describe five formative studies involving 39 participants using situated digital displays, a Person Locator Kiosk, and personal mobile devices. We report our findings by gaining insights and feedback from users in order to develop wayfinding assistance for visitors in an in-building environment.

Categories and Subject Descriptors
H.5.2 [Information Systems]: User Interfaces – *Graphical User Interfaces (GUI);* I.3.7 [Computing Methodologies]: Three-Dimensional Graphics and Realism – *Virtual Reality*

General Terms
Design, Experimentation.

Keywords
In-building navigation, dynamic signage, situated displays, requirements, 3D fly-through, digital 2D map.

1. INTRODUCTION
Advances in modern wayfinding support technology have allowed users in outdoor environments to access several services such as Google Maps, Nokia Maps, in-car satellite navigation systems and roadside digital signage. Users are able to gain familiarity of a location prior to arrival (e.g. by observing a Google Map at home) as well as receive guidance along a route (e.g. by enabling GPS on a mobile phone or using satellite navigation whilst driving). While this form of support is available in outdoor locations, it is not the case for indoor environments where users are generally restricted to using traditional in-building wayfinding information. Wayfinding in indoor environments is also affected by graphic and architectural communication as well as aspects such as the spatial organization of the setting and the circulation system (i.e. how to get to a certain point in the building) [16]. It is apparent however, that advances in pervasive digital display technology are enabling new possibilities for supporting indoor wayfinding and making this a timely topic of study.

In this paper, we describe our investigations into how digital display systems and personal mobile devices might offer useful and usable wayfinding assistance to visitors of the Infolab21 building in Lancaster University. To achieve this we have carried out five formative studies (4 user studies and 1 questionnaire study) with 39 participants in total. The details of each of these studies and the insights received from them are discussed in detail in section 4. Our studies have involved the following components:

1. An experimental set-up consisting of the Hermes2 digital display deployment (see figure 1) and the Hermes2 Person Locator Kiosk within Infolab21.
2. Personal mobile phones.
3. Wayfinding content such as digital 2D maps and 3D fly-throughs.

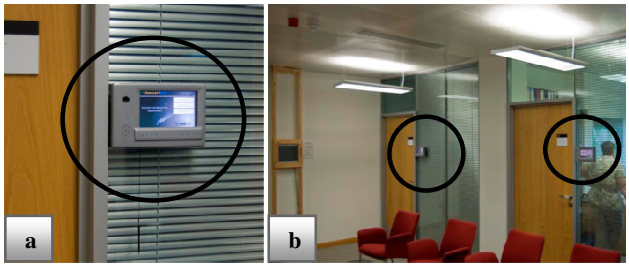

Figure 1 – (a) typical Hermes2 digital display (b) deployment environment in Infolab21

We investigated user attitudes toward the use of 2D and 3D wayfinding content, whether users found it useful to download this information to a mobile phone to view along their route (similar to a car satellite navigation system) as well as receive additional wayfinding assistance from Hermes2 digital displays. Furthermore we explored how such a digital display deployment might offer users useful and usable wayfinding support. We also carried on from our investigations in [9] by exploring whether Hermes2 display owners were willing to share their door displays

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to show wayfinding related content. In [9] we found that display owners wanted to be given the means to stipulate when necessary that an important message set by themselves on their door display would not be occluded by wayfinding content such as a graphical directional arrow.

Participants in each user study were asked to interact with the Hermes2 Person Locator graphical user interface presented on a touch screen display as a Kiosk (developed to a level of fidelity which allowed us to gain necessary insights and feedback) at the start of their wayfinding task. A wayfinding task involved the user locating a lecturer's office in the Computing Department from the foyer area outside the department. The Person Locator allowed users to select from a list of staff members, view a digital 2D map and/or a 3D fly-through and request graphical directional arrows to show along their route. As we did not use a location model, our approach was based around a Wizard of Oz setting where the wayfinding content shown to users was pre-determined rather than dynamically generated.

The five formative studies have presented us with insights for developing wayfinding assistance for visitors in an indoor environment (e.g. the Infolab21 building). We also addressed the following research questions concerning wayfinding in an in-building environment:

1. In what ways can users be supported along their route? E.g. in areas without situated displays, in cases where users become disoriented or if users generally wish to view wayfinding content.
2. How can users benefit from the use of 2D and 3D wayfinding content at the start of their wayfinding task? E.g. viewing a digital 2D map and/or a 3D walkthrough before locating a lecturer's office.
3. How can we support concurrent use of the Hermes2 displays amongst users? How can users be associated with relevant navigational signage on the displays?
4. To what extent are Hermes2 display owners prepared to share personal information (e.g. a message set on their door display "At the Infolab café, back in 30 min…") and share their door displays to show wayfinding-related content to support users?

The sections in this paper are structured as follows. Section 2 describes related work. Section 3 will describe the experimental set-up used in the formative studies. In section 4 we describe the methods and results from the five formative studies. Section 5 will discuss the findings and Section 6 will conclude the paper and describe future work.

2. RELATED WORK

2.1 Situated Display Applications that Support Wayfinding

In this section we observe the following studies which relate to our objective in gaining insights for developing wayfinding assistance within Infolab21. Kray et al. [11] focused on producing a location model by using the GAUDI system, which is a prototype pervasive wayfinding system consisting of a set of wireless autonomous displays connected to a navigation server. The aim of GAUDI was to support public navigation by using wall-mounted adaptive displays which show directional signs (e.g. in the Lancaster University campus). Displays are represented as nodes connected by edges in the location model, annotated with location-specific information and the calculation of routes are based on the A* algorithm. Similarly, in [10] we see a focus on investigating requirements and constraints toward developing a location model to support navigation in an indoor environment with an infrastructure of digital displays. For instance, this would be applied in the context of the Hermes2 display deployment (which would provide dynamic signage) within Infolab21 combined with the use of mobile devices to improve navigation. In [9], we addressed the issue of display control between Hermes2 display owners and investigated whether display owners would be willing to share their displays to show wayfinding content such as a graphical arrow. A questionnaire-based user study revealed that display owners were positive toward sharing their display to show wayfinding-related content given that they maintained appropriate control, i.e. they wanted to be given the means to stipulate when necessary that an important message set by themselves would not be occluded by wayfinding content such as a graphical arrow.

Muller et al. [15] investigated (by carrying out two separate field studies in an outdoor location) pedestrian navigation support through use of (deployed) situated public displays and mobile devices as well as factors concerning user acceptance and usability in this particular context. During the studies, users were able to interact with situated displays designed for advertisements to receive wayfinding support along with using a mobile device in a shopping scenario. A key finding that Muller et al. have presented is that users tend to use a mobile device for wayfinding support while they are walking, however if they become disoriented they are more willing to use a public display to view for example, a map.

Liu et al. [13] focused on developing wayfinding support for individuals with cognitive impairments. This involved the use of a prototype interface suitable for use on a handheld device which presented wayfinding information with different modalities, i.e. involving combinations of text messages, audio and images. The user studies revealed that participants were able to successfully use the different types of modalities; however, different participants had different preferences in their preferred modalities.

Lijding et al. [12] describe a system named "Smart Signs" which involves using in-building situated displays to provide route directions to users. The system aims to accommodate several different factors when communicating route information, including a user's mobility limitations, weather and emergency situations such as fire or medical needs.

2.2 Mobile Phone based Wayfinding Support

In addition to situated display wayfinding support, we are also interested in combining the use of mobile phones. It is already apparent that services such as Google Maps and Nokia Maps along with GPS-enabled mobile phones have made it trivial for users to receive wayfinding support along their route. Users can also view wayfinding content as both 2D and 3D representations. Chittaro and Nadalutti [1] looked at how an interactive 3D location-aware model of a building can be used to provide users with evacuation instructions through a mobile device. Two informal user evaluations revealed that 3D location-aware models are promising in presenting navigation instructions in an indoor environment. Frohlich et al. [6] focused on Points of Interest in a location and found that users appreciated the ability to access geo-spatial information by using a mobile device. They also found

that different users had different preferences, that is, some preferred a traditional map view whereas others who have poor map reading skills preferred augmented reality.

In [8] we addressed the issue of mapping the physical and virtual planes (mapping between physical world and a mobile guide) during interaction with a context-aware mobile guide. The paper evaluated two mobile guides, GUIDE [4] and Trammate. By carrying out three field trials with 60 participants, we proposed several interaction paradigms [8] as possible and useful abstractions for use in designing context-aware mobile guides, for instance the Chaperone paradigm can behave as an expert system that may take initiative away from the user during interaction (e.g. system corrects the user when she makes a wrong turn on a route)

Limitations can also arise when using a mobile device, especially regarding restrictions with the size of the display, lower resolution, differences in input type, hardware limitations, and so forth [2]. Using a mobile phone while navigating in a public location can also affect a user's concentration and she may become likely to be distracted by activities in the environment. Tamminen et al. [18] state that cognitive resources can be in competition while a user is using a mobile phone in a public location and attention can become fragmented.

2.3 Implications of 2D and 3D Spatial Representations in Wayfinding Support

Different spatial representations convey different types of spatial knowledge, that is, landmark-recognition, route-finding knowledge and survey knowledge [7]. Essentially, by experiencing a location from an egocentric point of view (e.g. a 3D representation) users are able to gain landmark-recognition and route-finding knowledge. By observing a location from an exocentric (bird's-eye) perspective, users can gain survey knowledge, which allows users to apply different configurational relationships of a location into a single model [19]. However, users can also gain survey knowledge from extensive immersion in a 3D environment with an egocentric view [19]. By considering the different types of information both 2D and 3D spatial representations convey it is clear that combining both types of information would be beneficial when providing users with wayfinding content.

3. THE EXPERIMENTAL SET-UP

To investigate whether users find it useful to view wayfinding content such as a digital 2D map and/or a 3D fly-through as well receive wayfinding assistance along their route with the use of mobile phones and digital situated displays, we used an experimental set-up consisting of the Hermes2 digital display deployment and the Hermes2 Person Locator. The following subsections will describe the two components of the experimental set-up and the wayfinding content used in more detail.

3.1 The Hermes2 System

3.1.1 *Background of the Hermes2 System*

The Hermes2 system was designed to enable awareness in the workplace, for instance, by adapting the idea of sticking a note on a door saying "Out for coffee", or "Back in 5 minutes". The first version of the digital display system, known as Hermes [5], was first deployed in 2002 initially as PDAs, fixed adjacent to office doors of lecturers, research assistants, PhD students and administrative staff all of whom were members of the Computing Department at Lancaster University. In 2006 the Computing Department moved to a newly constructed building and a new set of working prototypes were deployed. The new deployment, known as Hermes2, included several hardware improvements over the old system (e.g. larger displays) and consists of forty displays in two corridors.

3.1.2 *Functionality of Hermes2 System*

Display owners are able to set a temporary text or multimedia message to show on their display (e.g. a photograph of a conference location) by using their personal web portal, by SMS using a mobile phone or by e-mail (see figure 2 for system architecture). They are also able to view messages left by visitors using their personal web portal. Visitors can leave text messages using an on-screen keyboard, a scribbled message (using a scribble component), a video message and an audio message, for example a visitor might find that Dr. Smith has gone for lunch by reading his temporary message and she decides to leave a text message using an on-screen keyboard such as "Hi, it's Sarah, came to see you at 12.30…"

Figure 2 below shows the architecture of the experimental set-up consisting of the Hermes2 system as well as the Hermes2 Person Locator (discussed in section 3.2).

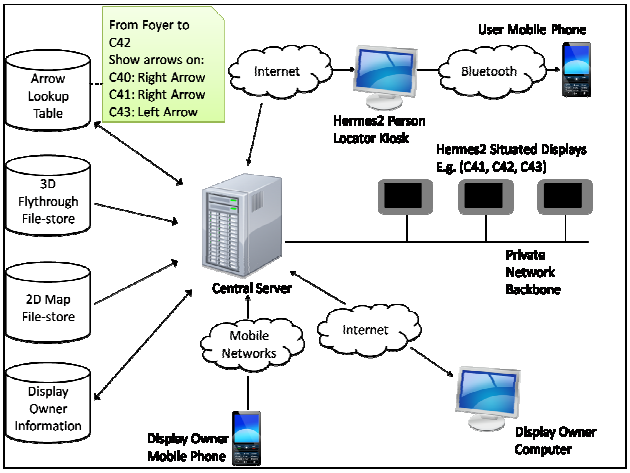

Figure 2 – System architecture of the experimental set-up

3.1.3 *Description of the Hermes2 Application*

There are currently two different versions of the Hermes2 application but both versions are based around a Model View Controller model where the Model involves a MySQL database (which holds for example, display owner details), the View involves the graphical user interface and the Controller provides functionality for the messaging (e.g. a scribble component which allows users to send scribbled messages).

The first version has been designed and developed to be highly customizable (to support student research projects, etc.) and consists of a middleware which provides services such as access to configuration information, and software components that provide functionality [5]. This was designed to allow users to securely add or modify components of the system. The architecture consists of a Java-based implementation on the client side (the graphical user interface). The server is responsible for running the Hermes2 clients and messages set by display owners as well as visitors [3]. The server also hosts a MySQL database, which stores information based on component configuration,

owner preferences and system logs (e.g. actions carried out by users on the graphical user interface).

The second version (and the one used the study described in section 4.5), is a web-based AJAX application developed in ASP.NET and combines C# server-side functionality. The client-side incorporates Javascript, XML, HTML and Web Services as a communication layer. This version of the Hermes2 application has similar functionality; however visitors are not able to leave video or audio-based messages. Six out of forty displays are currently running this application.

3.2 The Hermes2 Person Locator

3.2.1 *The Hermes2 Person Locator User Interface*

The Hermes2 Person Locator is part of a prototype system designed to explore (in our user studies described in section 4) whether users would find it useful to view wayfinding related content at the start of their wayfinding task. It was also designed to enable users to receive wayfinding support along their route (similar to the idea of an in-car satellite navigation system) by allowing them to download wayfinding content to a mobile phone as well as receive assistance from Hermes2 digital displays. The Person Locator graphical user interface was presented on a touch screen display set up as a Kiosk, which was connected to a laptop that ran the Person Locator application. Two versions of the graphical user interface were developed.

The first version of the Person Locator (see figure 3a), written in Java, allowed users to select from a list of staff members, press a button to view a digital 2D map and/or another button to view a 3D fly-through. Both the map and the fly-throughs were pre-determined (see sections 3.2.2.3 and 3.2.2.4 for details) as we did not use a location model. Users were also able to download this information to a mobile phone. The graphical user interface underwent several modifications based on user feedback (see section 4 for Conducted Studies) as well as design choices to explore aspects such as whether users would find it useful to view a lecturer's Hermes2 temporary message at the start of their wayfinding task.

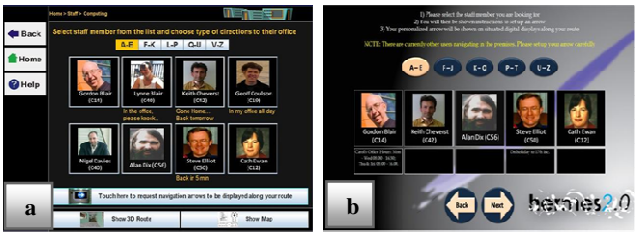

Figure 3 - (a) First version of the Hermes2 Person Locator (b) second version of the Hermes2 Person Locator

The second, web-based, version of the Hermes2 Person Locator (figure 3b) was written in ASP.NET. The graphical user interface displayed a list of staff members represented by photographs along with their Hermes2 temporary message below. Users were able to select a member of staff and request a graphical directional arrow to be shown on Hermes2 displays along their route. We developed a second web-based version of the Person Locator as it allowed more flexibility in terms of communication with the web-based version of the Hermes2 application running on the digital displays (as described in section 3.1.3). Being web-based, users can also access this version of the Person Locator graphical user interface via a Hermes2 display.

3.2.2 *Functionality of the Hermes2 Person Locator*

3.2.2.1 Supporting User Navigation with Mobile Devices

To explore whether users would find it useful to download the digital 2D map and/or the 3D fly-through to view along their route to a lecturer's office, we included a Bluetooth-based download feature in the first version of the Person Locator. After viewing the map or the 3D fly-through users were able to download this information to a mobile phone, which we supplied to avoid technical issues (see figure 9b). We used an external Java library known as Bluecove and the files were transferred by using OBEX object push. The map files were transferred in JPG format and the fly-throughs as 3GP (see sections 3.2.2.3 and 3.2.2.4 for details).

An alternative to allowing users to download wayfinding content using a mobile phone would involve a printer next to the Hermes2 Person Locator Kiosk. After a user views a digital 2D map on the graphical user interface, she may wish to print out a copy of this map using the printer. However, this solution can produce additional costs such as for the printer, toner cartridges, paper, etc. Users may also discard the map after having used it.

3.2.2.2 Supporting User Navigation with Dynamic Signage on the Hermes2 Displays

In order to explore whether users would find it useful to view graphical directional arrows on the Hermes2 situated displays along their route, the first version of the Hermes2 Person Locator included a low-fidelity implementation of this feature. Users were able to request the arrows to be shown along their route by using the Person Locator graphical user interface; however the arrows were manually triggered to show on the displays.

Figure 4 – Graphical directional arrow on a Hermes2 display

In the second version of the Person Locator, we explored the utility of personalizing (e.g. sketching a personal symbol) a graphical directional arrow by using touch (see figure 5) prior to requesting the arrows to be shown on the Hermes2 displays. We were interested in whether this would help associate users with the relevant arrow (especially in cases where multiple users are concurrently using the displays to navigate) as well as introduce a sense of entertainment. The personalized arrow would then be saved as an image in a file directory on the Hermes2 server. Based on the user's selected location (i.e. a selected lecturer's office), the arrow is then shown on specific displays. A user's selected location is compared in a lookup table stored on a database on the Hermes2 server (see figure 2 for system architecture). If a user selects, for example, office number C44, an arrow with right orientation will be shown on offices C41, C42, and so forth. The arrows were also shown on the Hermes2 displays with a degree of transparency in order to meet display owner feedback received from [9] (see section 2.1).

Figure 5 – Example of a personalized graphical directional arrow on the Person Locator graphical user interface

We see a similar approach in associating users on a digital display by using a personal symbol in [17] where Streitz et al. explored the use of a Hello.Wall ambient display which uses light patterns to emit awareness information to users in order to enhance collaboration between distributed teams in the workplace.

3.2.2.3 Digital 2D Map Development

The digital 2D map was designed to provide users with an exocentric perspective of their route. As we were investigating whether users would find it useful to be able to choose an exocentric and/or an egocentric (e.g. a 3D fly-through) perspective, we included a specific section of the Infolab21 building on the map so that users would be able to find their way from their current location (the foyer area) to a lecturer's office in the Computing Department. Thus, the digital 2D map was not designed to be scalable to support wayfinding on multiple floors. Using a digital map also allowed us to appropriately annotate each route, e.g. by showing a dotted line to different destination offices based on the user's selection (see figure 6b).

Each 2D map was generated as a JPG picture file and stored in a file directory. Essentially, different digital map files were shown for different selected destinations. For the user studies, we only generated maps for the destination offices which users were instructed to locate. The presentation of the digital 2D map was static, however users were able to introduce interactivity by for example, downloading a JPG map file to a mobile phone and zooming in and out.

For determining a means of orienting the map (which way up it should face), we asked 3 users (in July 2008) to sketch "mental maps" of how they perceived the environment. Such mental maps would produce the notion of a "public image" shared by members of the Computing Department. Our approach here was based on the work of Lynch [14] who introduces the notion of imageability. Although Lynch's descriptions are in an outdoor context, they can appropriately be applied to indoor environments. The three resulting sketches showed similar orientation, which was then used as part of the user studies.

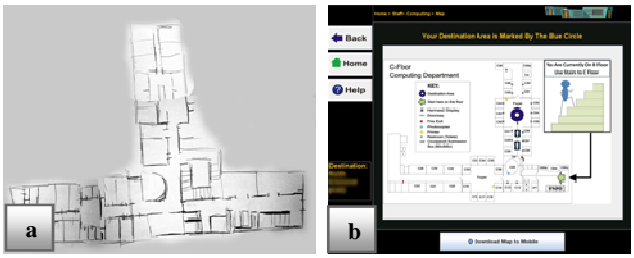

Figure 6 – (a) mental map sketched by user (b) digital 2D map presented on the graphical user interface

The map also included several navigational cues. The user's route was annotated by a dotted line, the destination location included a marker to direct user attention and landmarks such as the photocopy machine, printer and fire-exits were included and explained through a key. The user's current location was shown using a visual instruction (see figure 6b), as the map was designed to only direct users to one area (i.e. Computing Department on C-floor). However, as part of future development, a more effective solution would involve presenting step-by-step instructions, which users can navigate through by pressing a "Next" button (see section 6 for more detail).

3.2.2.4 3D Fly-through Development

The 3D fly-throughs allowed users to view their route from their current location (the foyer area) to a lecturer's office in the Computing Department with an egocentric perspective. The fly-throughs were presented as continuous media, that is, video clips of approximately 20 seconds (depending on the length of the route) in duration with options to pause and play.

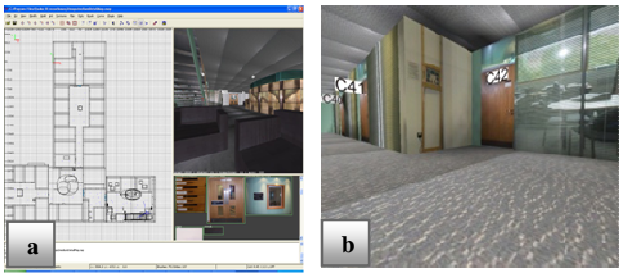

Figure 7 – (a) GtkRadiant modelling environment (b) screenshot of the 3D model running on Quake 3

The 3D model used in the fly-throughs was developed by using GtkRadiant (see figure 7a) and by using the Quake 3 game engine. In more detail, we developed a 3D model of the Computing Department on C-floor, Infolab21 and a small section of B-floor (the foyer area on the floor below). Quake 3 was then used to run the compiled 3D model (see figure 7b). We used GtkRadiant as a modelling environment due to its open-source implementation, which allows flexibility in terms of modifications, bug-fixes and so forth. The textures applied on each structure (e.g. walls, doors, etc) were composed of photographs taken inside the Infolab21 building, thus making the environment salient in terms of colour, form and appearance. Enlarged signs were also added to the environment outside the office doors to facilitate wayfinding for users, thus allowing each office to be clearly identified.

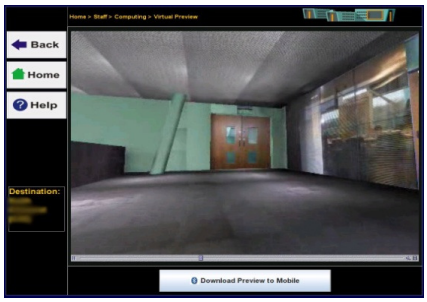

Figure 8 - 3D fly-through on the graphical user interface

The 3D fly-throughs were generated by recording (using an in-game recording program named Fraps) the Quake 3 character walking from one location to another, for example, from the foyer

area to Dr. Keith Cheverst's office. The recorded files were then converted into JMF-compatible MPG files to display on the Person Locator graphical user interface (see figure 8). Each of these files also had an equivalent file in 3GP format for downloading purposes. We used 3GP as it is generally a standard file format for mobile phones. Similar to the digital 2D map files only a certain number of files were generated, i.e. routes to the offices which users were instructed to locate.

4. CONDUCTED STUDIES

To investigate how digital display systems and personal mobile devices might offer useful and usable wayfinding assistance to visitors of the Infolab21 building, we employed a methodology based on the use of an experimental set-up and five user studies. During the studies we would observe what appeared useful and unuseful to carefully design each progressive user study. Table 1 below presents an overview of five formative studies carried out with 39 participants. Details of each study are included in the subsections that follow.

Table 1. Overview of the formative studies conducted

#	Objective	Users	Technologies Used
1	User study - exploring use of mobile phones and viewing 2D/3D wayfinding content	8 (4m, 4f)	First version of the Hermes2 Person Locator, mobile phone
2	Follow-on study to first study	6 (3m, 3f)	First version of the Hermes2 Person Locator, mobile phone
3	Questionnaire – Exploring whether Hermes2 display owners are willing to share personal information and their door displays to support wayfinding	12 (8f, 4m)	Questionnaires were issued to 6 administrative staff, 4 researchers and 2 lecturers in the Computing Department
4	User study -Exploring the combined use of mobile phone and situated displays	10 (5m, 5f)	First version of the Hermes2 Person Locator, mobile phone, Hermes2 system
5	User study – exploring user attitudes toward use of dynamic signage	3 (1f, 2m)	Second version of the Hermes2 Person Locator, Hermes2 system

4.1 General Approach

Our formative studies (apart from the questionnaire based study) involved an experiment configuration where users were presented with a touch screen display as a Kiosk that displayed the Hermes2 Person Locator graphical user interface (which ran on a laptop connected to the Kiosk). To avoid technical issues, users were supplied with a mobile phone to download wayfinding content. The Kiosk was set up in the foyer area (e.g. see figure 9a) next to the entrance within the Infolab21 building, a predominantly office based environment, where the system is originally intended to be used. To maintain ecological validity, we recruited users who were unfamiliar with the environment (apart from one user in our fifth study). However, this caused difficulties with the recruitment process, thus limiting the total number of users for each study. A realistic setting was further maintained by limiting the number of instructions given to users, i.e. users were presented only with a scenario where they were asked to locate a specific lecturer in the Computing Department. This approach can be advantageous as well as disadvantageous. For instance, it would allow us to identify user preferences in a relatively unbiased setting; however, it may cause users to overlook certain aspects that are being investigated.

Evaluation methods used during the user studies included protocol analysis, observation, semi-structured interviews and questionnaires. The first version of the Hermes2 Person Locator was used in the first, second and fourth user study. The second version of the Person Locator was used in the fifth study and the Hermes2 system was involved in the fourth and fifth user study.

4.2 Studies 1 and 2 - Exploring Mobile Phone use with 2D and 3D Wayfinding Content

In our first formative study we focused on exploring user attitudes toward viewing a combination of 2D and 3D wayfinding content (i.e. a digital 2D map and a 3D fly-through of a user's route) and whether users would find it useful to 'take away' (i.e. download) this information using a mobile phone to view along their route. The study took place in August 2008 with eight participants (4 male, 4 female) with an average age of 23.25 years. Five of the users had a low level of computer literacy, one had average literacy and two users had high literacy.

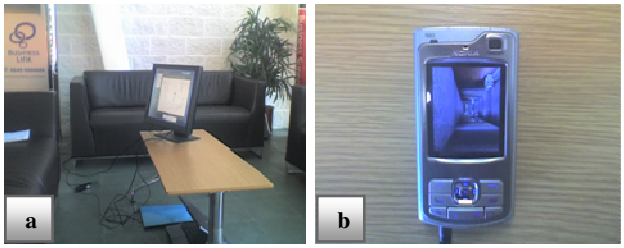

Figure 9 – (a) User study set-up with the Kiosk (b) Mobile phone used in the user studies

The study showed that users were very positive towards a system that allowed users to choose both types of wayfinding content based upon their preference. These relate to expectations (before viewing the digital 2D map or the 3D fly-through), past experiences, familiarity, curiosity and general individual preferences.

"The advantage of the map is that you can see everything but the [3D fly-through] helps you see what you need to see" (PM)

"The [3D fly-through] provokes more curiosity and interest." (DZ)

"The [3D fly-through] is better than I initially expected" (KS)

"I'm generally useless with maps because I have problems orientating and it's more useful if things are presented to me in perspective" (GL)

Insights toward the use of mobile phones to support wayfinding were limited as we allowed users to choose whether or not to download wayfinding content to a mobile phone. As the routes which users were given were relatively short, users did not feel the need to download the 2D digital map or the 3D fly-through to a mobile phone. Thus we carried out a follow-on study where we encouraged users (with possibility of objection) to download wayfinding content to a mobile phone in order to find their way to a lecturer's office. The graphical user interface of the Hermes2

Person Locator was also modified as users overlooked the button which allowed them to view a 3D fly-through (next to the button for the digital 2D map). The placement of the two buttons was switched, thus allowing the 3D fly-through to be more visible to users.

The follow-on study was carried out in January 2009 with 6 users (3 male, 3 female) with an average age of 22.5 years. Three of the users had an average level of computer literacy while three had low literacy.

Results indicated that by downloading wayfinding content to a mobile phone, users felt a sense of security and reassurance while walking along their route. By observing users it was apparent that they referred back to the information on the mobile phone as they were walking. Two users matched office door numbers in the physical environment to the information (e.g. the digital 2D map) on their phone.

"I felt more secure by having the 3D fly-through on my phone" (CF)

"The phone allowed me to refer back to the map" (JC)

4.3 Study 3 - Exploring Implications of Sharing Hermes2 Situated Displays to Support Wayfinding

To explore whether Hermes2 display owners were prepared to provide information (e.g. their temporary message set on their door display, their photograph, etc.) and allow their door display to share content (e.g. a graphical arrow) that would assist visitors trying to find their way to a staff member's office, we issued questionnaires in March 2009 to six administrative staff, four researchers and two lecturers (8 female, 4 male) with an average age of 32.4 years. The questionnaire included general questions as well as Likert scale based questions.

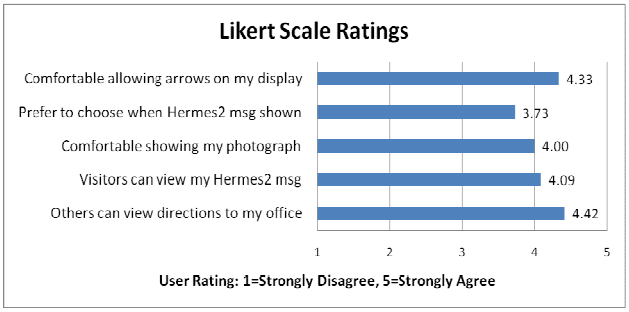

Figure 10 – Average Likert scale ratings from questionnaire

The Likert scale ratings from the questionnaire (figure 10) shows that display owners were generally comfortable with allowing visitors to view directions to their office (i.e. as a 3D fly-through or on a map) as well as sharing their Hermes2 temporary message and their photograph on the Hermes2 Person Locator graphical user interface.

"Practical [to allow visitors to view my temporary message on the graphical user interface] in case I go home, ideally I could use my mobile phone/computer to set that message, for example if I decide in the morning to work from home" (BA)

Display owners were also willing to share their displays to show a graphical directional arrow to assist users in their wayfinding task. Similarly, in [9] display owners also responded with either "Agree" or "Strongly Agree" (mean = 4.67) on the Likert scale for the question "generally happy for my Hermes display to be used to support the navigation system" [9].

4.4 Study 4 - Exploring Combined Use of Mobile Phones and Hermes2 Situated Displays

Another user study was carried out in March 2009 to investigate whether users found it useful to use a mobile phone and situated displays to assist them along their route. The study involved ten users (5 male, 5 female) with an average age of 24 years. Four users had an average level of computer literacy, three users with high literacy and three with low literacy. An extra button was added on the Person Locator graphical user interface which allowed users to request directional arrows to be shown on the Hermes2 displays along their route (as introduced in section 3.2.2.2).

Results from the study showed that the user interface caused limitations as seven out of ten users were unsure what to expect from the button which allowed them to request directional arrows on the Hermes2 displays. As only one user used and understood this feature, no significant results can be drawn. However, after describing the directional arrow feature to users during the semi-structured interviews, users showed a significant amount of interest toward using the Hermes2 displays along with mobile phones for wayfinding assistance. For instance, four out of ten users stated that they would use both a mobile phone showing wayfinding content as well as the Hermes2 displays with directional arrows. Three out of ten users would only use the displays and the remaining three would only use a mobile phone.

Users also found it helpful to be able to view a staff member's Hermes2 temporary message on the graphical user interface at the start of their wayfinding task.

"The [Hermes2 temporary message] saves wasted trips and especially useful if they aren't in all day, so you don't hang around waiting for them" (SB)

4.5 Study 5 - Exploring Use of Dynamic Signage on Hermes2 Situated Displays

We further investigated the use of Hermes2 digital displays in providing wayfinding support in a formative study carried out in July 2009 involving three users (1 female, 2 male) with an average age of 23.3 years. Using the second version of the Person Locator graphical user interface users were able to select a lecturer (see figure 11) and personalize a graphical directional arrow (by sketching a symbol), which they would be able to view on Hermes2 digital displays along their route.

Figure 11 –Study set-up in the foyer area outside the Computing Department

We also asked the users to touch each arrow on the displays along their route in order to disable them as they walked by and to also

provoke thought based on the types of interaction they might prefer. As we did not involve many users for this study, we spent a significant amount of time with each user (approximately 1 hour).

The feedback we received from users can be categorized based on the placement of the situated displays, wayfinding related content shown on the displays and the types of interaction that users would prefer.

4.5.1 *Placement*

The user study revealed all three users had different preferences regarding the placement of the Hermes2 digital displays to receive wayfinding assistance along their route (i.e. through graphical directional arrows). For instance, one user (CS) would prefer to see the displays along the floor.

"I think seeing them on the side is slightly awkward, probably for two reasons. One, when you're walking straight, you don't tend to look, you know, laterally to either side… People tend to look forward or down slightly… What would probably be more kind of ergonomic, although slightly difficult, would be to have them on the floor somehow so you can simply glance down and see where you're going and you won't run into people…" (CS)

Another user (EC) expected to see a situated display on the top (close to the ceiling) whereas VC was comfortable viewing the displays to the side. It was apparent however, that all three users were able to successfully follow the arrows on the displays to their destination regardless of their stated preferences.

We asked users whether they would like to see the graphical arrows on a particular side of the corridor (e.g. on the side of the corridor where the user's destination office is located) and two users (EC and VC) confirmed that they would normally assume their destination office would be located on the side of the corridor which is showing the graphical arrow.

"Normally I would assume if the arrow is on the right or if it's on the left the [destination] office would be on that side, because you wouldn't have an arrow on the right and suddenly you have an arrow saying this way and it's opposite the actual office" (EC)

CS on the other hand, would like to see arrows shown on all displays (i.e. on both sides of the corridor) along his route.

As there are areas within Infolab21 without Hermes2 displays, two users (EC and CS) who were both unfamiliar with the environment had difficulty finding their way until they reached the first Hermes2 display showing a graphical arrow. All three users agreed that it would have been useful to view wayfinding content at the beginning of their wayfinding task in order to establish the position of their current location and their destination location. Thus, the first version of the Person Locator was demonstrated to users, and they confirmed that it would be useful to view wayfinding content such as a digital 2D map and/or a 3D fly-through as well as download this content to a mobile phone. Users also stated that if this type of support was unavailable at the start of their wayfinding task, the digital displays would need to be placed throughout the entire route to provide assistance.

4.5.2 *Wayfinding Content*

All three users stated that they would find it useful to receive assistance along their route by viewing wayfinding related content on the Hermes2 displays (e.g. by touching the arrow on a display).

"If [the display] tells me that I need to walk five minutes towards this place, if I pass five minutes or if I'm near five minutes I would know…"(EC)

"*If it's a building I don't know, then how many more doors I have to pass by, maybe it's very good to know that. You are left with three more arrows and then two so that you know that you are reaching the office" (VC)*

Users CS and EC who stated that their field of view is normally directed to what is in front of them, stated that flashing arrows on the Hermes2 displays would be useful in directing attention.

"A flashing arrow would help attract my attention and I could see maybe from a distance then where the next one is. It might be more useful…" (CS)

Users also stated that they would find it useful if they were able to view wayfinding content such as a digital 2D map or a fly-through on the Hermes2 displays. EC would prefer to view a 3D fly-through on the displays and both VC and CS would prefer to see a digital 2D map.

"[a map on the display] that says you are here and your destination is here would be very useful and then when you get to the next [display], touch it, you are now here and your destination is here…" (CS)

We asked users whether concurrent users using the digital displays for wayfinding support would affect the sketch they made on their directional arrow (i.e. the displays would show more than one arrow). All three users stated that they would want to sketch something that they would remember and in addition, CS and VC would prefer to choose a unique color to associate themselves with.

"If I could do both, that would be better for me. I think that way it would be easier to identify MY arrow" (CS)

4.5.3 *Interaction*

All three users confirmed that they would prefer the arrows to appear automatically as they approached the Hermes2 displays as well as disappear after they have passed by. This would be far more effective and less time consuming than having to touch each arrow in order to disable it as they walked by. Hence, all users would feel comfortable being tracked by the displays.

VC and CS had privacy-related concerns regarding office occupants when interacting with the displays.

"Say the person is inside at work and you just come here and touch your arrow on the display, they might think, what are you doing?"(VC)

"…when looking to the side I'm always looking into people's offices and if they're sat there typing it might be off putting for them."(CS)

Furthermore, users CS and EC would only interact with the displays if they are disoriented or unsure of their current position along their route.

"Only if I found difficulty I would use [the 3D fly-through] again on the display" (EC)

5. DISCUSSION

In this section we discuss the key findings and insights gained by carrying out the five formative studies, which are interrelated with the research questions regarding wayfinding in an in-building environment, introduced in section 1.

By presenting both 2D and 3D wayfinding content users were able to choose the type of information to view based on their preference. User PM in our first study wanted to gain an overall understanding of the location (by viewing the digital 2D map) as well as view his route in perspective (by viewing the 3D fly-through). However, user expectations and familiarity caused limitations in some cases, for example we found that one user (KS) in our first formative study only viewed the digital 2D map as he was most familiar with maps. KS had expected the 3D fly-through to be exceedingly complicated; however, after having demonstrated this to him, KS felt the 3D fly-through would have been more useful.

It was evident that by downloading wayfinding content to a mobile phone, users felt secure as they were able to refer back to this information throughout their route. We also found that this feature would be far more useful in larger and more complex environments. Limitations were caused by the destination locations (or lecturer's offices) we instructed users to locate, which involved relatively short routes. For instance, in our first formative study, where we allowed users to choose whether or not to download wayfinding content, seven out of eight users did not feel the need to do so. Users also stated that the environment was relatively simple to navigate in. Thus in future studies it would be beneficial to provide users with longer routes.

The feedback received from users in the fifth formative study based on the placement of displays, wayfinding content that users would like to see and interactions that users would prefer, has given insight into how a pervasive digital display deployment such as Hermes2 might provide useful and usable wayfinding support. For instance it would be useful to provide users with wayfinding content on the Hermes2 displays along their route in addition to graphical directional arrows. This includes digital 2D maps, 3D fly-throughs as well as information based upon the user's progress, which would especially be useful in larger in-building environments where it may take more than five minutes to walk to an office. For instance, this may involve the amount of time users have left or the number of remaining arrows on the displays before the destination is reached. Users also found it useful to personalize their arrow on the Person Locator graphical user interface, for example two users stated that they would prefer to sketch their personal symbol as well as choose a unique arrow colour. This creates an association between the user and the relevant directional arrow, which can account for circumstances where multiple users are concurrently finding their way in the environment by receiving this form of wayfinding assistance from the Hermes2 displays. It must however, be considered that users may feel they are being intrusive to the office occupant when interacting with the displays for wayfinding purposes rather than meeting with the occupant.

We found that due to the gaps in the layout of the Hermes2 displays (i.e. areas without displays) it is essential that users view wayfinding content such as a digital 2D map and/or a 3D fly-through at the start of their wayfinding task. This would allow them to form an understanding of their current location and their destination location and point them in the appropriate direction until they reach the first Hermes2 display showing a directional arrow. It was also apparent from our fourth and fifth user studies that users would find it useful to use a mobile phone showing wayfinding content along their route to compensate for the gaps in the Hermes2 display layout.

The studies revealed that users would find it useful to receive wayfinding assistance from the Hermes2 displays; however it was essential to investigate the attitudes of Hermes2 display owners in allowing their display to show wayfinding-related content. The questionnaire based (third) user study demonstrated positive attitudes from display owners (see figure 10). Display owners were willing to share personal information such as their temporary message and their photograph for users to view on the Hermes2 Person Locator graphical user interface. In addition, as supported by the questionnaire study carried out in [9], display owners were willing to allow their displays to show wayfinding-related content.

6. CONCLUSIONS AND FUTURE WORK

In this paper we have investigated how digital display systems and personal mobile devices might offer useful and usable wayfinding assistance to users in the Infolab21 building. To achieve this we have carried out five formative studies using an experimental set-up consisting of the Hermes2 digital display deployment and the Hermes2 Person Locator Kiosk. Furthermore we have involved the use of mobile phone technology and wayfinding content such as a digital 2D map and a 3D fly-through.

Results from the formative studies showed that users found it useful to view a digital 2D map and/or a 3D fly-through based on their preference, which was influenced by factors such as past experiences, expectations, familiarity, curiosity and general individual preferences. However, it was apparent that in some cases familiarity can cause limitations as a user may choose to view a digital 2D map and later realize a 3D fly-through would have been more useful.

As the 2D map presented to users was designed for the purposes of the formative studies, as part of future work, this would need to be scaled so that it provides wayfinding support on multiple floors. Users can be presented with instructions which they can navigate through by using a "Next" button and this can be accompanied by images as well as text (e.g. a photograph of a staircase followed by instructions to use the stairs). Once the user reaches for example, the doors to the Computing Department, they can then be shown a 2D map. The 3D fly-through can also be extended from its current form as continuous media to allowing users to be able to navigate (e.g. by using keyboard input) in the Quake 3 environment (as described in section 3.2.2.4) on the graphical user interface and follow a route represented by a green line to their destination location. This would allow the user to observe the surrounding environment as well allow more flexibility in terms of pace.

The user studies have also shown positive user attitudes towards receiving wayfinding assistance using a mobile phone coupled with situated digital displays. Viewing wayfinding content such as a 3D fly-through on a mobile phone allowed users to feel reassured along their route. Users also confirmed that using a mobile phone would be useful in areas without displays (e.g. if users requested directional arrows to be shown on the displays).

We have received a significant amount of feedback regarding how users would want to receive useful and usable wayfinding assistance from Hermes2 situated displays. It was apparent that different users would prefer to view the displays in different locations (e.g. along the floor) although no difficulties were experienced in viewing the displays in their original location. Users would also benefit from viewing wayfinding content (e.g. a digital 2D map) on the display along their route. Furthermore, we

found that users would generally interact with the displays in case they were disoriented, however it must be taken into account that they might feel intrusive to the office occupant while using a display for wayfinding assistance. Results also demonstrate that Hermes2 display owners are willing to allow their displays to show wayfinding related content.

The feedback and insights we received from our studies demonstrate positive user attitudes for an in-building wayfinding system that combines different technologies, i.e. the Hermes2 digital displays and mobile phone technology as well as a digital 2D map and a 3D fly-through as wayfinding content. It has also allowed us to form an understanding of the supporting components that are required for a wayfinding service in an in-building environment, such as the Infolab21 building.

Our next formative study will combine the functionalities of the two versions of the Hermes2 Person Locator and investigate concurrent use of the Hermes2 digital displays by users to receive wayfinding assistance along their route. Furthermore, as part of future work, we aim to work with signage companies by exploring requirements for wayfinding support in complex buildings such as hospitals with a focus on improving user experience.

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8. REFERENCES

[1] Chittaro, L. and Nadalutti, D. 2008. Presenting evacuation instructions on mobile devices by means of location-aware 3D virtual environments. In *Proceedings of the 10th international Conference on Human Computer Interaction with Mobile Devices and Services* (Amsterdam, The Netherlands, September 02 - 05, 2008). MobileHCI '08.

[2] Chittaro, L. 2006. Visualizing Information on Mobile Devices. *Computer* 39, 3 (Mar. 2006), 40-45.

[3] Cheverst, K., Dix, A., Fitton, D., Rouncefeld, M., and Graham, C. 2007. Exploring Awareness Related Messaging through Two Situated Display based Systems. *Human-Computer Interaction, 22*, 1, 173-220.

[4] Cheverst, K., Mitchell, K., and Davies, N. 2002. The role of adaptive hypermedia in a context-aware tourist GUIDE. *Commun. ACM* 45, 5, 47-51.

[5] Fitton, Dan. 2006. Exploring the Design, Deployment and Use of Hermes: A System of Situated Digital Interactive Office Door Displays. PhD thesis. Lancaster University.

[6] Fröhlich, P., Simon, R., Baillie, L., and Anegg, H. 2006. Comparing conceptual designs for mobile access to geo-spatial information. In *Proceedings of the 8th Conference on Human-Computer interaction with Mobile Devices and Services* (Helsinki, Finland, September 12 - 15, 2006). MobileHCI '06, vol. 159.

[7] Golledge, R. G., Dougherty, V., and Bell, S. 1995. Acquiring spatial knowledge: Survey versus route-based knowledge in unfamiliar environments. *Annals of the Association of American Geographers*, *85,* 134–158.

[8] Graham, C., Cheverst, K. (2004) Guides, locals, chaperones, buddies and captains: managing trust through interaction paradigms. *3rd Workshop 'HCI on Mobile Guides' at the Sixth International Symposium on Human Computer Interaction with Mobile Devices and Services,* September 13, 2004, Glasgow, Scotland UK.

[9] Kray, C., Cheverst, K., Fitton, D., Sas, C., Patterson, J., Rouncefield, M., and Stahl, C. 2006. Sharing control of dispersed situated displays between nomadic and residential users. *Proceedings of MobileHCI '06*, pp. 61–68, New York, NY, USA, ACM Press. 2006.

[10] Kray, C., Cheverst, K., Harrison, M., Hamhoum, F., Muller, J. 2008. Towards a location model for indoor navigation support through public displays and mobile devices. *MIRW 2008*.

[11] Kray, C., Kortuem, G., and Krüger, A. 2005. Adaptive navigation support with public displays. In *Proc. of the 10th international Conference on intelligent User interfaces* (San Diego, California, USA, January 10 - 13, 2005). IUI '05.

[12] Lijding, M. E. M., Meratnia, N., Benz, H.P. and Matysiak Sz´ostek, A. 2007. Smart signs show you the way. *I/O Vivat*, 22(4):35–38.

[13] Liu, A. L., Hile, H., Kautz, H., Borriello, G., Brown, P. A., Harniss, M., and Johnson, K. 2006. Indoor wayfinding: developing a functional interface for individuals with cognitive impairments. In *Proceedings of the 8th international ACM SIGACCESS Conference on Computers and Accessibility* (Portland, Oregon, USA, October 23 - 25, 2006). Assets '06. ACM, New York, NY, 95-102.

[14] Lynch, K. 1960. The image of the city. Cambridge, Mass: MIT Press.

[15] Müller, J., Jentsch, M., Kray, C., and Krüger, A. 2008. Exploring factors that influence the combined use of mobile devices and public displays for pedestrian navigation. In *Proceedings of the 5th Nordic Conference on Human-Computer interaction: Building Bridges* (Lund, Sweden, October 20 – 22, 2008). NordiCHI '08, vol. 358.

[16] Passini, R. 1996. Wayfinding Design: Logic, Application and some Thoughts on Universality. *Design Studies*, 17, pp. 319-331.

[17] Streitz, N.A., Röcker, C., Prante, T., Stenzel, R., & van Alphen, D. 2003. Situated interaction with ambient information: Facilitating awareness and communication in ubiquitous work environments In: D. Harris, V. Duffy, M. Smith and C. Stephanidis, Editors, Human-centered computing: Cognitive, social, and ergonomic aspects, Mahwah, June (2003), pp. 133–137.

[18] Tamminen, S., Oulasvirta, A., Toiskallio, K., and Kankainen, A. 2004. Understanding mobile contexts. *Proc. Mobile HCI 2003,* 17-32.

[19] Thorndyke, P. W., and Hayes-Roth, B. 1982. Differences in spatial knowledge acquired from maps and navigation, *Cognitive Psychology*, *14*, 560-589.