EXPLORING THE DESIGN, DEPLOYMENT AND USE OF HERMES: A SYSTEM OF SITUATED DIGITAL INTERACTIVE OFFICE DOOR DISPLAYS

Daniel Fitton

B.Sc. Hons. Lancaster University

Computing Department,

Lancaster University,

England.

Submitted for the degree of Doctor of Philosophy,

2006

Abstract

This thesis explores the design, deployment and use of a system of interactive display-based ubicomp prototypes deployed outside office doors in the Computing Department at Lancaster University, referred to as the Hermes system. The Hermes system provided a groupware application supporting asynchronous messaging facilities, analogous to a digital form of Post-it notes, to help support awareness and coordination. Occupants of offices equipped with Hermes displays (display owners) were able to manually share personal context in the form of short textual messages (e.g. “Gone for coffee” or “Running 15 minutes late”) or images. One novel aspect of the work on Hermes was longitudinal deployment outside of the lab which allowed exploration of adoption and use from door display owners.

A key aim of the work on Hermes was the involvement of display owners in the design process in order to avoid purely technology-led design. This was done through the use of a questionnaire, a semi-structured interview, informal feedback and discussion with display owners during deployment. This user-centred approach generated valuable feedback to generate new requirements and features to help inform the design which would not otherwise have been available. Additionally, the Hermes prototypes acted as a form of technology probe: logging enabled the collection of usage data and deployment of a technically simple prototype helped inspire new design ideas and feedback from display owners. The design of the Hermes system and analysis of use focused primarily on the owners of door displays.

In order for the user-centred and technology-probe based approach to be successful, owners were required to adopt the prototypes and use them as part of their daily routines. Therefore, crucial to the success of this approach during longitudinal deployment was refining the design and adding features to lower the cost of initial adoption and use. For example, adding features to help the prototype fit in with owners existing routines. Supporting adoption took precedence over areas such as design of the underlying system architecture and was the key metric when selecting features to implement from those suggested by owners or technically feasible. One particular challenge raised by the need to support adoption and maintain use during a longitudinal deployment was the requirement for high levels of reliability. This challenge was addressed numerous times and highlighted the need to help maintain a user’s trust, for example, by providing notification of failure in order to avoid trust-damaging experiences of unreliability.

The major contributions of this thesis are: 1) an exploration of the longitudinal deployment of a digital display-based ubicomp system providing asynchronous messaging within a university department, 2) an understanding of the adoption and appropriation of the system and 3) an understanding of the use of the system to share personal context in order to support awareness and coordination.

Declaration of Originality

The material presented in this thesis is the result of my own independent research, under the supervision of Dr. K. W. Cheverst, carried out in the Department of Computer Science at the University of Lancaster under the auspices of the EPSRC funded CASCO (code GR/R54200/01) and CASIDE (code EP/C005589) projects.

The work reported in this thesis has not been previously submitted for a degree, in this or any other form.

The thesis is partly based on the following publications[1]:

Cheverst, K., Fitton, D., Dix, A., Rouncefield, M.: Exploring Situated Interaction with Ubiquitous Office Door Displays. Proceedings of the Workshop on Situated Interaction at CSCW '02, New Orleans, USA (2002)

Cheverst, K., Dix, A., Fitton, D., Friday, A., Rouncefield, M.: Exploring the Utility of Remote Messaging and Situated Office Door Displays. Proceedings of Human Computer Interaction with Mobile Devices and Services (MobileHCI 03). Udine, Italy (2003) 336-341

Fitton, D., Cheverst, K.: Experiences Managing and Maintaining a Collection of Interactive Office Door Displays. Proceedings of the European Symposium on Ambient Intelligence (EUSAI). Eindhoven, The Netherlands (2003) 394-409

Cheverst, K., Dix, A., Fitton, D., Rouncefield, M.: 'Out To Lunch': Exploring the Sharing of Personal Context through Office Door Displays. Proceedings of the Australasian Computer-Human Conference (OzCHI 2003), Brisbane, Australia (2003) 74-83

---

[1] All joint publications were written with group discussion and the majority of the text was written by the 1st author unless otherwise stated.

Cheverst, K., Fitton, D., Dix, A.: Situated Office Door Displays. In: O'Hara, K., Perry, M., Churchill, E., Russell, D. (eds.): Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies. Kluwer (2003) 141-169

Fitton, D., Cheverst, K., J, F., Dix, A.: Supporting Interaction with Office Door Displays. Proceedings of workshop on Multi-User and Ubiquitous User Interfaces (MU3I) at IUI/CADUI, Madeira (2004) 19-23

Fitton, D., Cheverst, K., Rouncefield, M., Dix, A.: Probing Technology with Technology Probes. Equator – Record and Reuse Workshop, London (2004)

Fitton, D., Cheverst, K., Kray, C., Dix, A., Rouncefield, M., SaslisLagoudakis, G.: Rapid Prototyping and User-centred Design of Interactive Display-based Systems. IEEE Pervasive Computing **4** (2005) 58-66

All aspects of the design and development of the Hermes system were my own independent work, however, several of the design ideas and choices during the development of the Hermes system, primarily during Phase 1 (presented in section 3.7), were discussed with Dr. K Cheverst and Prof. A Dix prior to implementation. Several features were explicitly requested by owners of door displays and this is mentioned in the text where it occurred. The development approach used in Hermes, of iterative design and phased deployment beginning with the development team, was inspired by work on the Portholes project [Dourish '92b] and was first published in [Cheverst '03d]. The quantitative and qualitative analysis of use in Hermes as described in this thesis was my own independent work. The results of my work on quantitative analysis of context sharing, presented and discussed in section 5.7, was first published in [Cheverst '03c] where in addition to being involved in the group discussion I performed all the tagging and technical analysis of the Hermes 2 logs to provide data for the paper. Additionally, several of the issues discussed in section 6.9 were based upon the issues discussed in [Cheverst '03d].

Acknowledgements

I would like to thank everyone that has offered me their help and support throughout this work. In particular I would like to thank my supervisor Dr. Keith Cheverst for giving me the opportunity to begin a career in research, but more importantly for his time, encouragement and endless cups of tea. I would also like to thank all the owners of the Hermes door displays that helped to make this work possible, and my parents for their help at every stage in my academic career.

Last, but by no means least, I would like to thank my wife, Jessica. Without whom I would not have begun this work and without her continual kind words, encouragement and support this thesis would not have been completed.

Contents

Figures

Tables

Introduction

1.1 Overview

We encounter **situated**[2] information in almost every aspect of our lives, from notice boards covered in messages and posters to digital displays that tell us if our flight has been delayed. While today the majority of this information is presented on either static signage or transient paper media, improvements in technology mean that there are increasing numbers of interactive situated **digital displays** providing us with information. Examples include displays allowing travellers to buy tickets in train stations, interactive exhibits found in most modern museums and even television sets in the home providing interactive services. Additionally, new types of situated digital display are emerging enabled by improvements in technology such as large displays deployed at public events which allow simple interaction via SMS messages [Virgin Mobile Telecoms '04]. This particular use of SMS messaging represents a new messaging paradigm enabled by situated digital displays, that of person-to-place[3] messaging rather than the traditional person-to-person.

While situated digital displays in our environment are becoming more prevalent and the technology to support them is improving and becoming cheaper, many issues surrounding the application and adoption of such systems remain under explored. The emergence of situated digital displays as a research area is receiving growing interest (for example [Brignull '06]) the importance of which is highlighted in [O'Hara '04]:

"In recent years, more and more information is being presented on dedicated digital displays situated at particular locations within our environment. At their most basic, digital display technologies allow information to be more easily updated dynamically and remotely. However, these new kinds of interaction technologies also allow people to use these situated displays in novel ways both as for the individual's purposes and in the support of group work."

---

[2] The first use of each of the terms discussed in section 1.5 is highlighted in bold.

[3] A term was first used by The Appliance Studio in a 'TxtBoard' press release [Appliance Studio '02].

As mentioned in the quote from [O'Hara '04], interactive situated displays can be used in the support of group work (the areas of Computer Supported Cooperative Work (**CSCW**) and **groupware** are discussed later in this chapter). One important aspect of CSCW required to support coordination in group activity is **awareness** [Dourish '92a]. An interesting research question is how situated digital displays can be used to support awareness, this is demonstrated by the large number of display-based system supporting awareness discussed in section 2.2.

The **properties** of digital displays can provide many interesting **affordances** compared to traditional paper-based media used to support coordination and awareness. For example, a digital equivalent of a paper note used to display the message "Back in 5 minutes" could automatically countdown as time passes. For a visitor who notices the time in the message counting down every second, one perceived affordance[4] might be that of accuracy: that the constantly updating digital equivalent is more accurate that its unchanging paper counterpart. The properties of a digital system (compared to paper-based media) afford the design of **functionality** such as the dynamically changing message (described previously) and remote interaction: a digital system could remind the author when five minutes had passed with an SMS message sent to his or her mobile phone.

This thesis describes the requirements for, design, implementation, deployment, management, evolution, use and evaluation of a prototypical system of interactive displays situated next to office doors, referred to as the Hermes[5] system. Hermes was designed to support asynchronous messaging and has been used to investigate how such a system, allowing explicit sharing of information, could be used to help support awareness and coordination between staff, and between staff and students in the Computing Department at Lancaster. Hermes has also been used to explore the affordances of this digital approach over traditional paper-based messaging mechanisms used on office doors. An office door is an interesting place to study interactions which typically fulfils many functions:

"Office doors are more than entrances to rooms, they are entrances to a person's time and attention. People can mediate access to themselves by choosing whether to leave their

---

[4] A discussion of different meaning of the term affordance is provided in section 1.5.

[5] The initial Hermes system is referred to as 'Hermes', while its successor described in Appendix J is referred to as 'Hermes 2'.

door open or closed when they are in their office. Doors also serve as a medium for communication, where people can broadcast individual messages to passersby, or accept messages from others who stopped by when the door was closed." [Jeffrey '02]

An office door can be categorized as a 'semi-private' place, containing both private elements (as it 'belongs' to the occupant of the office) and public elements (as it is part of the corridor and visible to all passers-by). This particular place has some interesting impacts on the sharing of awareness information by office occupants. For example, while an office occupant may find it necessary to display a message addressed to a specific person or group on his or her door, the author is unlikely to include personal or sensitive information (as any passer-by can read the message).

In order to explore this domain a technology driven approach has been combined with a user-centred design[6] approach. In order to help support adoption, door display owners (the main group of users considered in this work) were involved in the design process to lower their barriers to use. This was done by, for example, investigating owner's existing routines and adding or modifying functionality to fit in with these. One example of this was the addition of e-mail integration in order to support adoption from a door display owner who's existing routine involved notifying others via e-mail if she was away from her office for extended periods (enabling her to adopt Hermes at very little additional cost). The term 'adoption' is used to imply use of technology in ways intended by its designers and the term 'appropriation' implies *"unexpected or unanticipated uses of technology"* [Dourish '99].

The Hermes door displays provided a groupware application enabling office occupants to display information using short textual messages and image files. The application also enabled a visitor to an office to leave messages for the occupant, authored in a manner similar to traditional paper Post-it notes. One aim of the Hermes system was to produce a prototype performing a small number of tasks well in order to provide an **information appliance**. The following scenario, used in the design of the Hermes system, was specifically motivated by the anxiety felt by one lecturer (and developer) of being delayed during his daily commute to work and missing appointments with students:

A lecturer travelling to work by car is unexpectedly delayed by road works and will be late for a meeting intended to be held at his office. Realising this, he uses his mobile phone

---

[6] The meaning of this term is discussed in detail in section 2.3.1

to send an SMS message to his office door display to inform visitors to his office that he will be thirty minutes late. When students arrive at his office for the meeting they read his message and, after discussion, decide the meeting would be best rescheduled for the following day. A member of the group uses the door display to leave a message to this effect.

In order to analyse adoption issues, the Hermes system was deployed for 'real world' use. This also allowed it to be used to explore a number of pertinent ubiquitous computing (ubicomp) issues, in the context of a situated display system, from hardware to human factors (the issues raised on each of these levels is discussed in detail in section 7.2).

The remainder of this chapter firstly discusses the place of situated display-based systems in the areas of CSCW and groupware (section 1.2) and ubiquitous computing (section 1.3) research. Following this, a brief summary of current trends in display technologies is presented (section 1.4). Next the definition of key terms used in this thesis are discussed. This chapter concludes by defining the aims (section 1.5) of the research and summarising the contributions of this thesis (section 1.7).

1.2 CSCW and Groupware

CSCW is a well-established field which began formally many years ago, it is defined in [Rodden '91] as:

" a generic term which combines group working with the enabling systems support and applications."

Groupware is part of the broader field of CSCW and is defined by Ellis *et al* [Ellis '91] as:

"the class of applications, for small groups and for organisations, arising from the merging of computers and large information bases and communications technology. These applications may or may not specifically support cooperation."

An additional dimension to CSCW and groupware systems, required to help support coordination, is the sharing of awareness information between members of a group [Dourish '92a] [Gutwin '95]. Systems supporting awareness may require information to be explicitly shared by a member of a group (as is the case with the Hermes system) or passively collect and distributed information (as is the case with systems such as Portholes [Dourish '92b]).

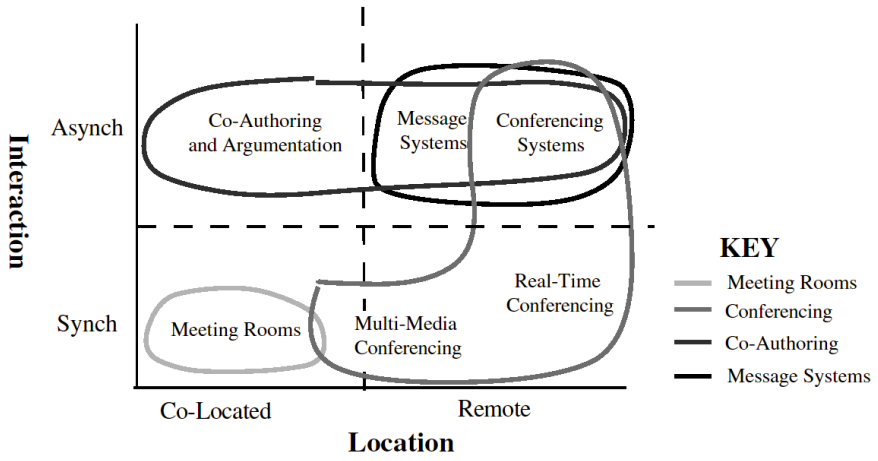

Figure 1-1: A Classification Space for CSCW Systems.

CSCW systems are commonly classified using the dimensions of interaction and location as shown in Figure 1-1 [Rodden '91]. When considering the Hermes groupware application (providing asynchronous messaging facilities to help support explicit sharing of awareness), such a system could potentially provide interaction methods which occupy all areas of the classification space shown in Figure 1-1:

Asynchronous, Co-Located – a visitor co-located with a door display uses it to author a message for the office occupant, the message is then delivered to the occupant via e-mail.

Asynchronous, Remote – a door display owner sends a publicly viewable message to his or her door display via SMS.

Synchronous, Co-Located – if a message left by a visitor at a door display (while the office occupant is, for example, busy on the phone inside his or her office) is received by office the occupant immediately (e.g. by the message appearing on his or her e-mail window), then he or she might rush to finish the phone conversation and go to greet the visitor.

Synchronous, Remote – if a door display was equipped with a microphone and speaker a visitor could potentially communicate with a (remote) office occupant via his or her mobile phone[7].

[7] It should be noted that this is an area of the design space which was not supported by Hermes but could potentially be supported by Hermes 2 (see Appendix J).

1.3 Ubiquitous Computing

Over the last 50 years the relationship between computers and users has gone through three major changes [Weiser '91]. From around 1940 many users shared a single (mainframe) computer, from around 1980 every user had his or her own (personal) computer. Mark Weiser [Weiser '91] saw a third 'wave' of computing where many computers hidden in the environment would help us achieve tasks seamlessly. When Weiser first presented his vision of ubiquitous computing (ubicomp) in the early 1990's he outlined how this new computing paradigm raised new challenges for human computer interaction, as computers would now be *"interwoven in to the fabric of everyday life"*.

Weiser's vision included seamless integration of computing technology into an environment and more natural interactions with technology. One method to achieve such integration is the use of situated displays to allow presentation of information and interaction in an ambient manner. In [Weiser '91] three sizes of display are discussed (inch, foot and yard scale) the largest (yard) scale displays are intended to be situated in a single location and function like a blackboard. The smaller foot and inch scale displays are intended to replace the sheets of paper and Post-it notes (respectively) that proliferate office environments.

A major challenge in the development of ubicomp systems is the integration of (often novel) prototypical computing technology into an environment, artefacts, clothing etc. [Schmidt '02]. This inherently raises challenges on a range of levels spanning low level hardware issues, such as **reliability**, to higher level human factors issues, such as **trust**. The Hermes system, presented in this thesis, acted as a vehicle to identify and explore challenges at these various levels. It is important to note that failure at any of these levels was likely to adversely affect end-user experience and reduce the effectiveness of the Hermes system to investigate its aims (these aims are discussed later in section 1.5 of this chapter).

1.4 Relevant Digital Display Technologies

Of particular relevance to the work presented in this thesis is the area of digital display technology. Advances in this area have enabled and assisted the development and deployment of interactive display-based systems.

Flat-panel TFT (Thin-Film Transistor) LCD (Liquid Crystal Display) displays have replaced CRT technology in many applications and are almost exclusively used for mobile phone, digital camera, PDA and laptop screens. This is largely due to their slim profile, completely flat screens, lower power consumption and, recently, falling cost. Plasma Display Panels (PDPs) are a similar technology, but provide larger sized screens with higher contrast ratios and wider viewing angles. For extremely large video displays, for example the twenty-

five meter square BBC Big Screens [Philips '05], LED (Light Emitting Diode) screens are used where each pixel is made up of a group of coloured LEDs. TFT and Plasma displays can easily be equipped with technology to support user interaction via the surface of the screen. Some examples of this technology require a special 'pen' device to be used (such as the screens found on many Microsoft Tablet PC devices [Microsoft '05b]) while other technologies allow the user to interact by touching the screen directly, often by equipping the screen with a transparent resistive membrane.

One promising new technology is that of Organic LEDs (OLEDs) [Ortiz '03] which offer brighter and sharper images than conventional LCD technology, while consuming less power and providing a thinner form-factor (due to the lack of a backlight). Another relatively new display technology that fits well with the paradigm of ubiquitous computing is that of e-paper ([E Ink Corporation '05], [Xerox '05]): a flexible material that appears very similar to a traditional piece of paper but can display computer generated images and text. Current prototypes provide a high contrast, wide viewing angle, lightweight, low power (no power is required to maintain an image on e-paper, just to change what is displayed) versatile display medium.

1.5 Definition of Terms

Several key high level terms are used throughout this thesis and this section provides clarification on the definitions intended.

Situated

While the term situated implies a specific physical place, it is not just the physical place which must be considered. The situated nature of information such as text is highlighted by the following extract from [Mitchell '05]:

"Literary theorists sometimes speak of text as if it were disembodied, but of course it isn't; it always shows up attached to particular physical objects, in particular spatial contexts, and those contexts-like the contexts of speech-furnish essential components of the meaning."

An important aspect of something that is situated (situated information and situated digital displays are of most relevance to this thesis) is that because it appears within a specific context this raises a host of additional issues. When discussing the design of CSCW systems supporting collaboration, Harrison and Dourish summarise:

"…a place is a space which is invested with understandings of behavioural appropriateness, cultural expectations, and so forth."[Harrison '96]

O'Hara *et al* discuss the situated nature of displays in the introduction to [O'Hara '04] and the issues they raise include privacy, ownership, identity, control, relevance, assumed audience, interpretation of information, behavioural aspects and spatial positioning.

One example of the impact of a behavioural issue, in the context of situated digital displays, is that interacting with technology in a public place is highly visible to others and raises a host of potentially discouraging social issues. These issues are highlighted in [Brignull '03] when discussing the results of a user trial of the Opinionizer system (Opinionizer is discussed further in section 2.2.5):

"…over half of the users interviewed reported that they experienced embarrassment and did not feel relaxed. Some commented that they felt under pressure not to make typing mistakes, not to be hesitant while interacting, since they knew they had an audience of onlookers. Some of the participants also experienced pressure to provide a comment that was socially accepted as humorous and clever by their peers."

An example of a cultural expectation, impacting the interpretation of information, would be the assumption that a message placed on an office door has been authored by the occupant of that office. Another example might be that if a publicly visible message on an office door is not specifically addressed it is intended for any visitor to that office

Digital Display

The term digital display is used to refer to an electronic medium for presenting information controlled by a computer.

Property

A property is a basic attribute of an object. For example, properties of Post-it notes are that they are made of paper and can be temporarily fixed to a range of surfaces. Properties of a digital display are likely to include the ability to manipulate individual pixels to display information and might include input via a touch sensitive screen.

Functionality

Functionality is the capacity of an object to perform a specified action. For example, one piece of functionality provided by a modern mobile phone is the ability to send a SMS message.

Affordance

This term has several key meanings and requires careful clarification. The term affordance originates from Gibson [Gibson '77] [Gibson '86] where an affordance is the actionable properties between the world and an actor (a person or animal). The definition is

set in an ecological context, for example “A path affords pedestrian locomotion from one place to another…”. The affordance is a relationship between the actor and environment enabled by the properties of each. For example, the properties of a pedestrian are that it is bipedal and has limited climbing abilities and the properties of a path are that is has a level rigid surface: therefore the path affords pedestrian locomotion. For affordances in this context only existence is important, it is immaterial whether an actor perceives that a path affords locomotion or not.

The term affordance is discussed in a design context by Norman in Design of Everyday Things [Norman '02] (formerly published as Psychology of Everyday Things in 1988) as a means to use visual clues to convey how a device is operated. For example, door handles are part of our everyday lives and we understand what they are for and how to use them, attaching one to a door gives a very strong indication as to how a door is opened: helping the user to perceive that the door affords opening by operating the handle. An affordance in this context does not necessarily have to exist (consider a locked door) and is also dependent on the experience of the user (consider a user who has never seen or operated a door handle before). After publishing Psychology of Everyday Things in 1988, in response to misuse of the term affordance, Norman published [Norman '99] where he stated that he had previously been discussing *perceived* affordances and he termed affordances as described by Gibson as *real* affordances.

Affordances in the context of software design are also discussed by McGrenere and Ho [McGrenere '00] which they define as:

“The functions that are invokable by the user are the affordances in software.”

This broad definition includes almost every piece of functionality that is part of a software application on high and low levels: from, for example, a word processor providing the affordance of authoring a document to a command typed into a console providing the affordance of listing files in a directory.

In [Hartson '03] Hartson discusses the origins and use of the term affordance in HCI and expands on existing work to describe four different types of affordance (see Table 2-1). Affordances as described by Gibson become *physical* affordances and perceived affordances (as described by Norman) essentially become *cognitive* affordances. *Functional* affordances are at a higher level than physical affordances and specify functionality of which a device is capable.

Affordance type	Description	Example
Cognitive affordance	Design feature that helps users in knowing something	A button label that helps users know what will happen if they click on it
Physical affordance	Design feature that helps users in doing a physical action in the interface	A button that is large enough so that users can click on it accurately
Sensory affordance	Design feature that helps users sense something (especially cognitive affordances and physical affordances)	A label font size large enough to read easily
Functional affordance	Design feature that helps users accomplish work (i.e., the usefulness of a system function)	The internal system ability to sort a series of numbers (invoked by users clicking on the Sort button)

Table 2-1: Summary of Affordance Types from [Hartson '03]

The use of the term affordance in this thesis stems from the need to explore functionality enabled by the digital approach used in Hermes with paper-based messaging mediums which it was intended to augment. For example, consider a small digital interactive display designed to emulate a Post-it note. It is very likely the message on the digital equivalent could be manipulated remotely via a range of interaction methods: therefore the digital equivalent affords remote interaction (compared to a paper Post-it note). This use of the term is similar to Hartson's functional affordance and McGrenere and Ho's software affordance. This use is also similar to Gibson's original definition, the possibilities for action enabled by the properties of an object, in that the additional properties of a digital system enable additional functionality. Affordances were used in this work to help motivate and design functionality to be added to the Hermes system. Where use of the term differs from this meaning it is qualified as appropriate.

Awareness

In the context of supporting collaboration through awareness in the design of CSCW systems, awareness is defined by Dourish as:

"Awareness is an understanding of the activities of others, which provides a context for your own activity" [Dourish '92a]

In [Dix '97a] three kinds of awareness are described within the context of a CSCW awareness framework, these are:

- who is there – Awareness of *who* is around and their availability for cooperative activity.

- *what* has happened – Awareness of what has changed in a shared environment.
- how did it happen – Awareness of the occurrence of actions in time that affected a change in a shared environment.

The primary kind of awareness the Hermes system supported was the type 'who is there' shared by door display owners when leaving their offices .

Reliability

In Sommerville [Sommerville '01] software reliability is defined as *"... a function of the number of failures experienced by a particular user..."*, Sommerville goes on to define a failure as *".. a situation in which the software does not deliver the services expected by the user."*. The term reliability is used in this sense throughout this thesis, however the term is applied to systems involving both hardware and software.

Trust/Dependability

Trust is defined in the Oxford English Dictionary as *"confidence in or reliance on some quality or attribute of a person or thing, or the truth of a statement"*. In the context of this thesis, the term trust is used to describe a user's confidence in the ability of the services provided by a system to function correctly. For example, a door display owner may or may not trust that if they send a message to the Hermes system via SMS it will appear on his or her door display. Trust in this sense is directly linked to users experiences of factors such as reliability, and is therefore closely related to the notion of dependability.

Dependability is a term encompassing many individual characteristics of a system used to refer to whether the services provided by that system can be trusted to function correctly, defined by Laprie as:

"Computer system ***dependability*** *is the quality of the delivered service such that reliance can justifiably be placed on this service." [Laprie '85]*

Laprie also defined two main measures of dependability as reliability and availability (continuity of correct service).

Information Appliance

The notion of an information appliance is discussed in detail in [Norman '98] and defined as:

"An appliance designed to perform a specific activity..." [Norman '98]

As an information appliance only performs a single activity (or task) its design can suit this activity and its users very well (as the design is not compromised or overcomplicated

by attempting to support other activities). For example, the average personal computer is designed to support a wide variety of different activities and therefore its design must be a compromise to accommodate each activity to a small extent (resulting in complexity for the user). Conversely, a digital camera typically only supports a single or small number of related tasks (take a picture, view pictures that have been taken) and therefore the design can focus on making these tasks simple for a user to perform.

1.6 Aims of Research

The work presented in this thesis explores the development of a prototypical situated interactive display system to act as a vehicle for exploring issues pertinent to ubicomp research. More specifically, it explores issues associated with the use of a groupware system in the form of a collection of digital office door displays designed to support cooperation and coordination between members of the Computing Department at Lancaster University. This overall goal is broken down into four interrelated aims:

1. To explore the design, development and deployment of a prototype interactive digital office door display system to support asynchronous messaging. To do this using a development approach which involves technology driven and user-centred design, including both qualitative and quantitative investigation of use in order to refine the system and observe emerging requirements.

2. To use the prototype office door display system to investigate the different affordances enabled by a digital approach to supporting situated messaging in a university department, compared to traditional approaches such as paper notes and message 'whirlers'.

3. To design a prototype digital interactive office door display information appliance (and produce an associated set of requirements) that is intuitive to walk up and use without prior training.

4. To utilise the prototype digital office door display system to investigate issues of initial adoption and continued use through the long-term deployment, evolution and evaluation of prototypes 'in situ'.

1.7 Thesis Plan

The thesis develops in the following way. Chapter 2 (Related Work) surveys existing interactive digital display-based systems and discusses how these compare with the intended aims of this work (as presented in section 1.5). Chapter 3 (Design, Development and

Deployment of the Initial Hermes Prototype) recounts the design and development of the initial (Phase 1) Hermes prototype system by describing the deployment of two door displays and analysis of initial results. The evolution of the Hermes prototype is described in chapter 4 (Evolution of the Hermes Prototype). In Chapter 5 (Quantitative Analysis of Use) log files collected during the deployment are used to provide quantitative analysis of use, such as usage patterns and context sharing. Chapter 6 (Qualitative Analysis of Use) uses feedback from a door display owner questionnaire and interview in order to investigate qualitative aspects of use and present emerging issues. Chapter 7 (Conclusion) presents the conclusions of this thesis and identifies key areas for future work.

Chapter 2

Related Work

2.1 Introduction

This chapter presents a survey of existing display-based ubicomp and CSCW systems relevant to the work presented in this thesis.

2.2 A Survey of Existing Display-based Systems

In order to present and discuss the large number of relevant related systems three categories are used according of the size of the display(s) the systems use. These are based on the tab, pad and board categories of ubicomp devices developed by Mark Weiser and his colleagues [Weiser '91]. Systems in each of the three categories are discussed followed by a summary.

2.2.1 Tab-Sized Displays

Tabs are described as "*inch-scale machines that approximate active Post-It notes"* [Weiser '91] and used here to categorise devices with screens of similar size to those used in PDA (Personal Digital Assistant) devices.

Dynamic Door Displays

Research on the development of 'dynamic' door displays has been conducted at Georgia Tech [Nguyen '00] in order to investigate:

"…the function of information that is tied to the context of a specific location"

Nguyen *et al* developed a self-contained prototype based around a small PDA device with a wireless LAN card and iButton reader. The display was automatically updated to reflect the owner's current location and calendar information using the Context Toolkit [Dey '99]. Visitors to a dynamic door display could also leave voice messages for the owner or choose from a predefined list of short text messages. The dynamic door displays also enabled owners to share private information, using iButtons for authentication.

There appears to be no further published progress on this system at the time of writing. From [Nguyen '00] it appears that at least one prototype was deployed for use by occupants and visitors in a laboratory.

Smart Doorplates

In [Trumler '03a] Trumler *et al* identify four potential scenarios to demonstrate the application of 'Smart Doorplates' utilising location tracking and other context aware technologies, which primarily involve visitors attempting to locate office occupants. One of these scenarios is then selected for implementation, in which:

"doorplates act as signposts within the office building to direct visitors to the sought employee"

Trumler *et al* have built a prototype system using a Compaq iPAQ as a self-contained Doorplate device. The prototype uses RFID tag technology for 'person' tracking and additional sensors are used to detect if a Doorplate owner's door is open. System communication is based on the JXTA peer-to-peer platform in order to avoid central storage, and the work is described as an example of an autonomic computing system in [Trumler '03b].

The primary service provided by the Smart Doorplates is that of directing visitors to a desired person's office (equipped with a doorplate). If this person is not in his or her office, the doorplate can display his or her current location and direct the visitor as appropriate, a service is also provided to predict a person's next location. While it is clear that one or more prototypes have been developed, it is unclear whether these have been deployed outside of a 'lab' scenario. Further papers discussing this system (for example [Trumler '03b]) focus on the supporting infrastructure.

Roomwizard

RoomWizard [O'Hara '03] is a display appliance with a screen 6.4 inches in size situated outside meeting rooms, which provides functionality to book a meeting room (locally and via the web) and check if a meeting room is available. In order to conduct a field study the system has been deployed in a large organisation for use by two groups of employees [O'Hara '03], two buildings were equipped with five devices each.

Ethnographical techniques were used to investigate 'meeting practises' before the installation of RoomWizard, and again during the deployment and use of the system. This enabled the identification and investigation of a set of issues arising from the use of RoomWizard, primarily showing that the system had significantly improved on the previous practices and provided unexpected functions such as enabling peripheral awareness and

navigation. O'Hara *et al* also make an interesting point that complex usage patterns built up around what was effectively a very simple appliance:

"Whilst the RoomWizard at first appears to be a simple electronic duplicate of a room reservation system, it is far more complex than this in use."

This observation reflects a key aim of this thesis (aim 3 in section 1.5), that of providing a simple information appliance *"single in function, open in use"* [Norman '98].

TxtBoard

A TxtBoard [O'Hara '05] is an eight inch display designed to be mounted on a wall in a home environment, incorporating a mobile phone to allow the reception of SMS messages. SMS messages received are shown using all available screen area, with a database to map senders to names and pictures, the frame is used to provide ambient notification of a new message. In common with Hermes, the system is designed in order to explore 'person-to-place' messaging.

The study of the use of TxtBoard over a two month period by a family is described in [O'Hara '05] where usage logs were analysed and users interviewed. This analysis identified several aspects of use, such as the importance of the location of the displays. O'Hara *et al* concluded that part of the success of TxtBoard was its simplicity:

"Nevertheless, TxtBoard succeeded in large part because it offered a minimal addition to the home: that is to say, that in offering so little, it made a difference that was worthwhile. In sum, this study of TxtBoard shows that less can be more."

The TxtBoard project has been extended through the HomeNote [Microsoft '06] prototype. HomeNote utilises a Tablet PC with a slightly larger screen area than TxtBoard, incorporates SMS interaction, and includes functionality allowing hand drawn messages to be shared via the touch sensitive screen. At the time of writing they intend to deploy prototypes in local households to further explore the idea [Microsoft '06].

2.2.2 Analysis of Tab-Sized Displays

The 'dynamic' door display project at Georgia Tech appears similar to the Hermes system in terms of enabling awareness and providing messaging functions, additionally the hardware used and functionality provided is also similar to that used in Hermes. Unfortunately, it appears that work in this project ended before any significant deployment or reasonable evaluation of the system took place.

The work on 'Smart Doorplates' also appears similar to the Hermes system and utilising a similar door display hardware configuration. However, the main aims of the work

on Smart Doorplates appear to be investigation of navigation and location awareness applications. This work seems to use a primarily technology driven development approach, focussing on 'proof of concept' demonstrators of the underlying architecture.

The RoomWizard system has been developed with a user-centred design approach, similar to the work presented in this thesis (see aim 1 in section 1.5). It appears that use was effectively mandated and the system became part of the daily routine of its users (evident from user interviews). The functionality of the RoomWizard system is simple, in common with the aims of the work presented in this thesis (see aim 3 in section 1.5), and interestingly, O'Hara *et al* found that complex usage patterns built up around it.

The TxtBoard system was deployed for use outside of the lab for a relatively long period of time similar to the aim of the work presented in this thesis (see aim 4 in section 1.5). In order to analyse use, system logs and user feedback were used, this qualitative and quantitative investigation is also similar to aims of the work presented in this thesis. Additionally, O'Hara *et al* identify that simplicity was one of the keys to the system's success which is similar to the aim of providing an information appliance described in section 1.5 (aim 3).

2.2.3 Pad-Sized Displays

Pads are described as *"foot-scale ones that behave something like a sheet of paper (or a book or a magazine)"* [Weiser '91] and used here to categorise devices with screens of similar size to usual desktop monitors.

OutCast

In [McCarthy '01b] McCarthy *et al* describes three situated display applications to explore the idea of sharing information: UniCast, OutCast and GroupCast. The OutCast displays are most relevant to the work presented in this thesis, located outside office doors and intended to provide:

> *"…a personal yet shared display on the outside of an individual's office."*

Content on OutCast displays is intended for nearby co-workers, including information about the owner intended for others to view (emulating the practise of putting photos etc. on office doors) and can include information from the display owner's calendar entries, web pages and location. The OutCast system utilises a twenty inch flat-panel touch sensitive monitor embedded in a cubicle (office) wall and connected to a PC situated inside the owner's office. All three systems use infrared badges for location detection.

Deployment of this system has included over fifteen UniCast displays and one each of the GroupCast and OutCast displays (at the time of writing) [McCarthy '01a]. Analysis of use of UniCast displays over several months has reported that the most used applications were the ability to view local web cams and retrieve the location of others. Informal feedback from users of the OutCast system revealed that they were typically used by visitors when the owner was away from his or her office, with the most popular features being access to location and calendar information. Additionally, due to uncertainty over trust, the 'Text Message' function (used to leave a textual message of the 'owner' of a display) was used the least with users preferring to use paper Post-it notes.

Uni Board

A WWW message board for on-door communication [Segawa '99] has been developed at the Iwate Prefectual University, Japan. The design was motivated by a message board on a door in a graduate hall of residence (which they state was used extensively) and provided a simple white-board application intended to be attached to a door, with additional web clients. The system, named 'Uni Board', allowed local or remote users to draw on a shared space (only the owner of the message board could erase messages) which was publicly visible both in person and via the web.

It appears that a single Uni Board was deployed [Segawa '99] and has received use for 'several months', it also appears use of the system has been logged in order to analyse use, although no reports describing this use are currently available.

Door Awareness System/LabraDoor

In [Jeffrey '02] Jeffery *et al* carried out observational study of the use of office doors at Carnegie Mellon University and make some very relevant and interesting remarks about the nature of office doors and how they are used (an extract highlighting this is included in section 1.1). These observations were then analysed and used during a brainstorming session in order to construct and explore design ideas is primarily concerned with augmenting the exiting use of doors.

It appears two prototypes were constructed that explored the use of office doors as *"mediators of interruptions"* and *"a medium for aesthetic and informational personalization"* respectively. The first, a 'Door Awareness System', exploited the fact that some office owners use the office doors to mediate access to themselves by altering how much the door was open: this context was sensed and made available via a web site. The second, 'LabraDoor', used a projector located inside an office to project onto the rear of a window in an office door (covered with a translucent material). This produces a large display area viewable from the

outside of the office, information projected onto the office door is of three main types: virtual notes, digital art (such as web pages, personalized graphics, etc.) and awareness information. The presentation of awareness information utilises a system called ‘StatusLight’ which utilised a simple traffic-light metaphor in order to enable users located in the office to stipulate interuptability.

At the time of writing, the ‘Door Awareness System’ has been deployed at three offices, while the ‘LabraDoor’ system has only been deployed on a single office door (the office of a group of PhD students, including some of the researchers working on the system). No reports describing usage are currently available.

Interactive Family Message Board

The Family Message Board [Browne '01] is a situated display appliance providing both asynchronous and synchronous communication between geographically separated households within a family. Communication is achieved via hand written notes (input using a touch sensitive screen) arranged on the ‘Message Board’, the spatial arrangement of these notes is consistent between remote ‘Message Board’ displays.

The system is intended to act as a technology probe [Hutchinson '03] to aid understanding of the communication needs of geographically distributed families, in order to design systems to help fulfil these needs. This is intended be done through logging of use, and various other methods to elicit user feedback, such as interviews, comments, suggestions and other written feedback. The initial functionality provided was intentionally simple:

“As a Technology Probe, the design needed to allow families to find innovative and unexpected uses for it without being encumbered by restrictive functionality. “

Their intention was that the design would evolve as usage patterns emerged. Both of these approaches (simple initial functionality and user-centred evolution of the design) were used in Hermes.

SPAM

The SPAM (SMS Public Messenger Service) system [Cheverst '03a] supports coordination and awareness between staff at geographically separated sites, in an organisation providing housing for former psychiatric patients. It allows communication between dedicated peripheral displays using SMS, enabling SMS messaging to a place rather than a single person. A key advantage of this technology is that members of staff (and patients) need only use their mobile phone to send messages to the system. Messages received at a location are displayed chronologically in a list. When a new message arrives it is hidden and a regular auditory and visual notification given until a user ‘reads’ the message (by pressing on the

screen). The new message is then displayed and the sender receives notification that his or her message has been ‘read’.

This work has been guided and informed through ethnographic study [Cheverst '03a] and the system is also designed to act as a technology probe with all use of the system logged for later analysis [Fitton '04b]. The main requirements for this system were found to be strong dependability and ease of use and as such it was designed to be simple with additional functionality only added as new requirements emerged (for example blocking of senders due to sending offensive messages). The SPAM system has been deployed and has received use since October 2002.

Ariadne

The commercially available Ariadne [Modulex '05] product is a range of wall-mounted display systems from ten to forty inches in size that provide configurable indoor signage and other simple information display functions. Each unit has an embedded web server in its housing and the display is a web page configured over a network. A typical placement is outside a meeting room where an Ariadne display can be updated to show when the room is in use.

This system provides digital signage with some models including the ability to play media clips. None of the displays allow local (i.e. co-located with a display) interaction and it is perhaps unlikely that the embedded hardware used would be powerful enough to support such features.

2.2.4 Analysis of Pad-Sized Displays

McCarthy *et al* investigated the use of deployed UniCast and OutCast displays using both quantitative and qualitative analysis. However, qualitative analysis revealed that the functionality enabling messages to be left by visitors for OutCast display owners (analogous to one of the aims of this work, see aim 1 in section 1.5) was the least used functionality, as users did not trust that it was reliable.

In [Segawa '99] it appears that one aim of the Uni Board system was similar to that of this work, namely deploying a prototype and logging use for later analysis (see aim 1 in section 1.5). However, they favour a technology led design approach and appear more interested in investigating interaction with displays from inside a web browser.

The work at Carnegie Mellon University makes some interesting points about the use of doors as ‘interruption gateways’ and a ‘medium for communication’. However, while user-centred design techniques were used to develop prototypes (in common with this work, see

aim 1 in section 1.5), the focus appears to be the production of 'proof of concept' demonstrators rather than longer term deployment and evaluation.

Research on the Family Message Board has demonstrated how the use of prototypes as technology probes can provide user-centred design in the 'field'. Browne *et al* initially developed a simple prototype, in common with the aims of this thesis (see aim 3 in section 1.5), they then intended to deploy and use various methods (such as logging, interviews, comments, suggestions) to understand use, which is again similar to the aims of this thesis (see aim 1 in section 1.5). It appears that when designing a technology probe it is important to start with a prototype providing relatively simple functionality, investigating the adoption and usage patterns which emerge and using this to adapt the design. The SPAM system was also designed to act as a technology probe. The design was heavily influenced by previous ethnographic investigation and required relatively little redesign after deployment.

The Ariadne system is an interesting product in terms of providing well-engineered situated displays ready for deployment. However, the display systems are not interactive and provide little more than signage. The availability of such a product does indicate that situated digital displays are becoming an acceptable and desirable part of the everyday environment.

2.2.5 Board-Sized Displays

Boards are described as *"yard-scale displays that are the equivalent of a blackboard or bulletin board"* [Weiser '91] and used here to categorise devices using large displays (commonly using plasma screen or projectors) often referred to as Large Display Groupware Applications (LDGAs).

The Notification Collage

The 'Notification Collage' (NC) [Greenberg '01] is a groupware notice board application designed to support awareness and (to a smaller extent) collaboration between co-located and distributed colleagues. It allows a small community to post media (live video, notes, web pages etc.) to a shared space that is updated in real-time, enabling synchronous video conversations. The system runs on individual PC's (typically on a second monitor) and on a single large seventy-two inch shared display.

Experiences learned from the initial deployment of the system are presented in [Greenberg '01] from which thirteen specific 'points' emerging from use are distilled (e.g. the fact that users desired both local and remote access to the NC). Similar to the aim of work on Hermes (see aims 1 in section 1.5) users were able to send asynchronous messages to each other (via 'Sticky Notes'). The Sticky Notes were accessible to all users of the NC enabling them to be used for 'broadcasting' messages.

IM Here

The IM Here [Huang '04] system combines a traditional desktop instant messaging application with a large shared public digital display to explore issues of adoption in the context of LDGAs. Visitors to the IM Here public display (who are not automatically identified) can communicate with other users running the IM Here instant messaging application on desktop computers. Additionally, content input by an administrator is presented on the display in order to promote group awareness.

An initial study of existing LDGA research was used to identify five factors affecting adoption, for example, the task(s) the system is intended to support, low barriers to use, etc. The IM Here system was then designed and deployed (for twenty-four users) using the five issues as guidelines. An evaluation conducted during six weeks of use is provided in [Huang '04] where analysis of usage logs and user interviews are used for qualitative investigation of use (together with some brief quantitative analysis).

The Opinionizer

The Opinionizer system [Brignull '03] was developed in order to explore the difficulty in enticing users to interact with interactive public displays. It allowed opinions to be added to a public display in order to encourage face-to-face socialising between bystanders, with the primary aim being to encourage interaction with the display. The system uses a laptop keyboard for input and the user interface was projected onto a wall display.

In order to explore four main goals (relating to interaction) two user studies were carried out at a book launch party and a welcome party for postgraduate students. As part of these studies, interviews with users and observations of use were carried out. From these studies two ‘thresholds’ were identified which users must cross in order for interactions to take place: ‘focal awareness’ and ‘participation’. They conclude that in order to cross the participation threshold there must be low barriers to use and that the form of interaction needs to be very lightweight.

The Plasma Poster

The Plasma Poster [Churchill '03] was designed to *“promote communication information sharing in public places”* and was inspired by traditional notice boards where paper messages can be attached. It allowed users to post content (in the form of text, URLs, images and video clips) via e-mail and a web interface to large (interactive) plasma screens equipped with a touch sensitive surface. The supporting software infrastructure (the Plasma Poster Network) was primarily implemented in Java and used a MySQL database for storage.

Similar to the work presented here, Churchill *et al* are investigating a range of different ‘interfaces’ to allow interaction with the system.

In common with the work presented in this thesis, a user-centred design approach was followed. The results of two user studies were used to produce a set of design requirements to encourage use of the deployed system, for example where to locate the displays and functionality the system should provide. Additionally, an iterative rapid prototyping approach was used. Three Plasma Posters have been deployed within the building where the authors work and use of the system is logged. In [Churchill '03] quantitative analysis of use of a ten month period is presented, showing the daily and monthly interactions each of the three deployed prototypes received. Qualitative analysis of use was also carried out with twenty-three users being given a survey and follow-up interview, which demonstrated a positive attitude towards the system.

Vista

The Vista prototype [Wichary '05] uses a fifty inch plasma screen to display an application intended to encourage socialising and discussion by presenting information about professional activities within a workplace. It is designed to be deployed in ‘coffee-corners’ where colleagues take coffee breaks. User-centred design principles have been used throughout the development of this system, which resulted in four design iterations with four prototypes being produced (video, visualisation, Wizard of Oz and high fidelity). Demonstrations and user studies with potential users were carried out at each stage of the design process.

The interactive prototype was deployed for four days, with all use logged and a portion being observed. Similar to this work, both quantitative and qualitative analysis of use was carried out. Witchery *et al* make numerous references to the fact that their user-centred design process was very time consuming, which impacted upon the development process. The approach used by Witchery *et al* included a range of user-centred design and prototyping techniques.

Semi-Public Displays for Small Co-located Groups

The work on ‘Semi-Public’ displays by Huang and Mynatt [Huang '03] explored the design and deployment of a large touch-enabled SMART Board™ display located in an academic lab. The intention of the display was to support awareness, foster coordination and encourage collaboration between members of the lab by providing a shared space where relevant information was displayed. Four applications were continually displayed in the shared space. The first provided reminders of information extracted from weekly status e-

mails sent inside the group, the second provided a shared space for drawing and writing, the remaining two applications provided awareness of the location of group members and attendance at scheduled meetings. The design space and domain were analysed during the design process and questionnaires were carried out to users both before and after deployment.

Similar to the work described in this thesis, a questionnaire (using a five-point Likert scale) was administered during deployment and they describe how informal feedback from users during deployment was valuable. From [Huang '03] it appears that the system was in place for two weeks before the post-deployment questionnaire was administered, which investigated initial response to the four features. The results of this questionnaire showed that the two features providing reminders of information extracted from e-mails and visualising attendance at scheduled meetings were successful, while the other two features required further work.

Dynamo

Dynamo [Izadi '03] provided a shared multi-user surface designed for multiple large situated displays (and projectors), intended to support:

"…the cooperative sharing and exchange of a wide range of media that can be brought to the surface by users outside from their familiar organizational settings."

Users 'carve' (mark and appropriate) regions of the display area to interact with, allowing them to share, send and arrange documents with other users interacting with the display surface. Dynamo also had a notion of state and carved regions could be saved for future reference, it is possible to use the system without registering, though only authenticated users could save state.

The system has been developed using an iterative development process incorporating feedback from users exposed to early prototypes during user studies, two such user studies are described in [Izadi '03]. The first study, held during a design workshop, was used to investigate the novel interaction techniques provided by the system while the second study involved participants working together to produce a poster (however, this latter study may have been influenced by the issue of "social embarrassment" [Izadi '05] where shy participants might not want to interact with the system in front of others).

BlueBoard

The BlueBoard [Russell '03] system used a 1.3 meter interactive touch sensitive display equipped with an RFID badge reader for authentication. It was designed for both personal (e.g. checking calendars) and collaborative use (e.g. whiteboard functionality). Additionally, the BlueBoard can be used to a limited extent without authentication. The

system was designed to provide very easy to use functions (analogous to an information appliance) enabling people to walk up and use it with little or no prior knowledge.

It appears a single BlueBoard has been developed, which was used to conduct a field study at a workshop with 163 potential users. Participants were given badges to authenticate themselves with the display and (in common with the Hermes system presented later in this thesis) users (owners in the case of Hermes) were given a short introductory demonstration before being freely allowed to use the display. Use of the BlueBoard was videotaped and six users were given a formal interview. Analysis of these results produced sets of observations from group and individual use specific to interaction with large displays, for example the problem of control, etiquette, reaching over large distances on the screen etc.

2.2.6 Analysis of Board-Sized Displays

While the Notification Collage system provided asynchronous messaging functionality similar to the aims of this work (section 1.5), the notification collage is essentially a synchronous media space where video and textual collaboration takes place. Discussion of salient experiences and issues drawn from an initial deployment are presented, some of these are applicable to the work presented in this thesis; such as the value of remote interaction and asynchronous messaging functionality.

In [Huang '04] the IM Here system provided an additional channel of communication for a traditional instant messaging application via a client on a shared public display. This system was deployed and logging of use enabled qualitative analysis of use over a six week period. The five factors affecting adoption and how they affect the design of IM Here seem highly relevant to the work presented in this thesis, for example, the users of IM Here responded well to the low barriers for use (primarily lack of a login).

The work involving the Opinionizer system identified some potentially valuable guidelines to encourage interaction with large public displays. In common with the aims of this work the system used qualitative analysis in order to identify usage issues, however the deployment domain was very different: social gathering in public places.

While the Plasma Poster system aimed to fulfil a different purpose to the work presented here, the development and evaluation techniques are similar. For example, an iterative prototyping approach together with user-centred design techniques were used to inform the design process. In common with the work presented here, logging was used to quantitatively analyse use and this was combined with qualitative analysis. Work on the Plasma Posted highlighted the difficulties of designing a display-based prototype system for deployment and use outside of the lab and how user-centred design techniques can be

important for successful adoption. Vista is similar to Plasma Poster in its purpose and development approach, however, a more principled user-centred design approach was used in Vista. For example, in Vista much time and resources were used to design and evaluate three different kinds of prototypes (video, visualisation and Wizard of Oz) before deign of the high fidelity prototype began.

The work on Semi-Public Displays by Huang and Mynatt explored the use of a shared display inside a large academic lab which effectively had a closed users group (the members of the lab). The deployment of displays described in this thesis contains elements of a 'semi-public' nature, for example, the majority of visitors to a display might have been colleagues of the display's owner. The work on Semi-Public Displays did highlight the importance of using questionnaires and informal discussion with users to gain feedback on a deployed prototypical system 'in situ'.

The Dynamo system has been developed using a user-centred development approach (involving multiple user studies) to evolve and inform the design, very similar to the approach used in Hermes. It is clear that this approach produced interesting and useful feedback about interaction methods during the user studies, which may otherwise have gone unnoticed.

In common with the Hermes system presented in this thesis, the BlueBoard system is designed to support a relatively small subset of features in order to provide an information appliance. Additionally, a large field trial was held in order to carry out qualitative investigation into use and it is interesting to note that a short demonstration was used, apparently successfully, instead of any form of user guide.

2.2.7 Summary

Table 2-1 summarises the related work discussed in the previous sections using seven categories selected to help compare the aims this thesis with the aims of related work:-

Place – the place for which the prototype has been designed.

Functionality – a brief overview of the main functionality the prototype provided.

Length of deployment – how long the prototype has been deployed for use.

Number of prototypes – the number of display-based prototypes that have been developed.

Design process – a brief summary of relevant processed used during the design of the system.

Interaction methods – the available local (co-located with display) and remote (separated from the display) interaction methods.

Screen size – the size of the screen used in the display-based system.

In cases where information in a particular category was unavailable or unclear, this is denoted by a dash. As one aim of this work was longitudinal deployment and use outside of the lab, the categories of 'place', 'length of deployment' and 'number of prototypes' were included to establish the extent to which this kind of deployment has been explored previously. In order to compare the aim of this thesis to maintain simple functionality and user interfaces with existing related work, the category of 'functionality' was included. The 'design process' category was included in order to compare the aim of this work to use a technology driven and user-centred approaches with the approaches used in related work. Additionally, as one of the motivating scenarios for Hermes included remote interaction (via SMS) with an office door display the 'interaction methods' category was included to highlight the local and remote interaction methods explored in the related systems.

From Table 2-1, it is clear that a range of situated display-based systems have been developed, primarily supporting awareness, messaging or collaboration. It is interesting to note that there are very few examples of deployments lasting longer than preliminary user studies, and even fewer that have involved the deployment of more than one prototype. Additionally, very few examples in Table 2-1 provide a range of interaction methods even though this is potentially a key area of functionality enabled by a digital approach compared to traditional paper-based display systems (though this is application dependent). A range of design processes have been used in the various related systems, many incorporating user-centred design or ethnographical approaches in order to investigate use. In common with the work carried out in this thesis, the majority of related systems where the design approach is included in Table 2-1 have employed quantitative and/or qualitative analysis of use.

Name	Place	Functionality	Length of Deployment	Number of Prototypes	Design Process	Interaction Methods		Screen Size
						Local	Remote	
Dynamic Door Displays	Office Door	Awareness (location & calendar) messaging (voice & text).	-	1	-	iButton, Touch screen	None	PDA (~4")
Smart Doorplates	Office Door	Location awareness and navigation.	-	1+	-	RFID, Touch screen	None	PDA (~4")
Roomwizard	Meeting Room Door	Management of meeting rooms.	Long Term	Many	Observation of the domain.	Touch screen	Web	6.4"
TxtBoard	The Home	SMS person-to-place messaging.	2 months	1+	Prototyping to explore the domain.	Touch screen	SMS	8"
OutCast	Office Door	Awareness (calendar entries and location).	-	1	-	Touch screen, IR badges	None	20"
WWW Message Board	Dormitory Door	Messaging via hand-drawn pictures.	Months	1	-	Touch screen	Web	-
LabraDoor	Office Door	Sharing of interruptability information, notes and digital art.	-	1	Multi-phased exploration of the domain.	None	Web	Large (projected onto a door).
Family Message Board	The Home	Messaging via hand-drawn pictures.	-	-	Use of prototypes as technology probes.	Touch screen	Other message boards	17"
SPAM	Shared Offices	SMS person-to-place messaging.	3 years	2	Use of prototypes as technology probes.	Touch screen	SMS	12"
Ariadne	Meeting Rooms	Signage/room management.	-	-	-	None	Web	10-40"
Notification Collage	Research Lab	Shared media space.	-	1	Trial lab-based deployment and observation of use.	None	PC-based application	72"
IM Here	Office Scenario	Instant Messaging on a large public display and promoting awareness.	6 weeks+	1	Informed by study of existing work. Qualitative and quantitative evaluation of use.	Keyboard	Desktop IM, the web.	Large plasma screen.
Opinoinizer	Social gatherings	Encourage socializing by the public sharing of opinions.	2 one day userstudies	1	Low-fidelity prototyping and observation. Qualitative and quantitative evaluation of use.	Laptop keyboard	None	Large screen projection.
Plasma Poster	Public spaces in an office scenario	Sharing of content (text, URLs, images and video).	10 months+	3	Users studies, iterative rapid prototyping. Qualitative and quantitative evaluation of use.	Touch screen	E-mail and web.	Large plasma screen.
Vista	'Coffee-corners' in an office environment	Presents information to stimulate conversation.	4 days	1	Iterative user-centred design, qualitative and quantitative analysis of use.	Touch screen	None	50" plasma screen.
Semi-Public Displays	An academic lab	Support awareness, foster coordination and encourage collaboration between members of the lab.	2 weeks	1	Analysis of design space and domain, questionnaires and informal feedback.	Touch screen	None	Large touch-enabled SMART Board™.
Dynamo	Public spaces for meetings	Cooperative sharing and exchange.	2 user studies	1	Iterative development incorporating feedback.	Keyboard, mouse, laptops and PDAs	None	Multiple large screen projections.
BlueBoard	Public spaces in an office scenario	Personal access to information and group collaboration.	-	1	Large-scale field study with observation of use.	Touch screen, RFID tags	None	50" plasma screen.

Table 2-1: Summary of Related Work.

2.3 Relevant Design Methodologies

This section provides an overview of design methodologies relevant to the design approach used in the Hermes system, including the approaches using the related systems described in section 2.2 and summarised in Table 2-1. Firstly a discussion of the origins and meaning of user-centred design is presented, followed by an overview of different prototyping approaches. Next, participatory design, as an example of a user-centred design approach, is briefly described and finally an outline of ethnography is given including a discussion of cultural probes and technology probes.

2.3.1 User-Centred Design

As can be seen from Table 2-1 only one system (Vista) is explicitly listed a utilising a user-centred design process. However, user-centred design is a broad term which encompasses a range of design approaches within the area of human-computer interaction. Central to the idea of user-centred design from [Norman '86] is the focus on supporting the needs of the user through the system's interface, exemplified by the following extract:

"The needs of the user should dominate the design of the interface, and the needs of the interface should dominate the design of the rest of the system" [Norman '86]

In [Sommerville '93] Sommerville *et al* discuss the role of sociologists in designing interactive systems, and define user-centred design in a pragmatic context which helps describe what the process might involve:

"In user-centred design, end-users become part of the design team and are continually available to comment on and to evaluate proposed designs. They may themselves suggest appropriate user interface designs."

Building on the ideas from Norman, in [Noyes '99] a practical approach is taken to carrying out user-centred design and the term is defined as including a flexible approach incorporating a range of techniques to ensure users are involved in the design process:

"..we assume that the definition of 'user-centred design' can change during the design process, from soliciting user opinion, to designing to accommodate work activities, to designing to accommodate the capabilities of people who are going to use the system."

One key technique allowing a design to be communicated to users in order to aid involvement in the design process, synonymous with user-centred design [Norman '86] [Dix '97b] [Noyes '99], is that of iteratively refining a design using prototypes. More specifically, in order to ensure that user's needs are met users are exposed to prototypes embodying the

current design in order to generate feedback. This feedback is then used to refine the design and potentially to generate a revised prototype (prototyping is discussed further in the following section).

One particular design approach which is heavily user-centred is participatory design (PD), this is discussed in section 2.3.3.

2.3.2 Prototyping

Prototyping is usually a low-cost technique to allow a user to evaluate a design and is used heavily in iterative design [Dix '97b], refining a design based on feedback from a prototype. Three main approaches to software prototyping exist [Sommerville '01]:

i) Evolutionary Prototyping - whereby an initial implementation is refined until it is satisfactory,

ii) Throw-away Prototyping – whereby after a prototype is evaluated it is discarded and another developed from scratch,

iii) Incremental Development – whereby individual system components are developed using evolutionary prototyping within an overall system architecture.

Prototyping is an important aspect of user interface design ([Lauesen '04], [Preece '02], [Dix '97b]) and a range of different techniques are possible depending on required fidelity, for example:

i) Paper prototypes – whereby the design is simply sketched onto paper,

ii) Screen prototype – whereby the design appears as it is intended on a computer screen but provides little or no functionality,

iii) Wizard of Oz – whereby a human has to (secretly) carry out functionality not yet implemented in the system in order to give an impression of a fully functional prototype,

iv) Functional prototype – whereby a fully functional system is generated, most likely though a rapid prototyping [Fitton ‘05] approach.

Prototyping was used in the work on Vista (with four prototypes of different fidelities being produced), Opinoinizer (using a paper prototype) and Dynamo (utilising ‘intermediate’ versions of the system as functional prototypes in user studies).

2.3.3 Participatory Design

Participatory design is a term used to describe an approach originating from Scandinavia [Muller '91] in which the prospective users of a system actively participate in its

design (for a recent overview of specific examples of PD approaches in use see [Torpel '05]). In addition to collaboration with users during design process, another goal of PD is to use an iterative design process where techniques are used to:

"…provide the opportunity for the users to "experience" the new technology and for developers to "experience" the new work practice." [Blomberg '90]

These techniques include brainstorming, storyboarding, workshops and paper prototyping [Dix '97b]. In addition to including users in the design process, PD has an additional aim of improving the working environment of the user through the introduction of technology. This approach has not been widely used outside of Scandinavia in un-adapted form, primarily due to the additional challenges of including users in a design process to such a degree and organisational issues [Muller '91], [Blomberg '90].

2.3.4 Ethnography

Ethnography originates from the fields of anthropology and sociology and essentially involves a researcher observing and recording tasks a user carries out in his or her workplace:

"…ethnographic field work typically involves participant observation, a combination of observation and in-situ question asking, carried out while participating in the ongoing activities and events of a community." [Jordan '96]

The key advantage of ethnography is that it does not rely on a user articulating the tasks they carry out, which can be problematic [Sommerville '01]. Ethnography can help provide a deep understanding of a domain to aid understanding of requirements, and can help inform requirements. Traditional ethnographical techniques include direct observation, video analysis, interviews and diary studies. In both RoomWizard and SPAM ethnographical techniques were used to help understand the domains prior to deployment of technology.

2.3.5 Probes

Generally, probes are devices designed to investigate the unknown by collecting and returning information. Cultural probes [Gaver '99] are a technique used to help understand users and inspire design ideas for *"technologies that could enrich people's lives in new and pleasurable ways." [Gaver '99]*. A cultural probe pack (given to participants in a cultural probe study) specifies evocative tasks or questions and includes suitable mediums to record information. For example, a probe pack might contain a camera and a diary and the participant asked to take photographs to illustrate specified topics and record certain information. This technique can be adapted to collect ethnographic information in sensitive settings [Hemmings '02] where traditional ethnographic techniques are not suitable (for example with psychiatric patients).

Technology probes [Hutchinson '03] are similar to cultural probes in that a pack containing materials to help inspire design ideas and record information is given to participants. However, technology probes are based around the deployment of a working prototype, simple enough to be flexible in its use (to allow *"innovative and unexpected uses"* [Hutchinson '03] to be found), which collects usage data in-situ that can be used to uncover information about users and inspire new design ideas. As discussed in [Hutchinson '03], a technology probes explores three main goals:

"…the social science goal of collecting information about the use and the users of the technology in a real-world setting, the engineering goal of field-testing the technology, and the design goal of inspiring users and designers to think of new kinds of technology to support their needs and desires."

Both RoomWizard and SPAM acted as forms of technology probes which provided a simple fully functional prototype, flexible in use, deployed in order to collect usage data in-situ.

2.3.6 Summary

This section has discussed a range of design approach based around the approaches used in the related work described earlier. Is clear that user-centred design is a broad term which necessitates including the user in the design process to meet their needs. One technique used to meet these needs is iterative prototyping where a user can easily see what the designed envisioned and provide feedback. Participatory design was described as one heavily user-centred design approach which has been used successfully in Scandinavia, but which is less appropriate (in its original form) elsewhere. Ethnography was described as method to understand a domain and users needs through observation within the workplace. Cultural probes were described as a technique to help gather ethnographic information and inspire design, which inspired the concept of technology probes. The two 'probe' approaches have similarities, such as the use of packs containing materials allowing participants to record information, however technology probes are based around the deployment of a simple functional prototype.

2.4 Chapter Summary

This chapter has discussed a selection of relevant researched based on digital display-based systems and applications. The related work has been categorised using Weiser's ideas of tab, pad and board-sized ubiquitous display systems. In many cases, aspects of related work were similar to the aims of the work presented in this thesis, for example several systems were based around door displays supporting awareness and coordination. The

summary of related research presented in Table 2-1 highlighted the large number of related systems that utilised design approaches that often included both quantitative and qualitative techniques to analyse use. In addition, several systems were designed around the notion of providing an information appliance. This chapter also briefly introduced relevant design methodologies, such as those used in the related systems, including user-centred design, prototyping techniques, participatory design, ethnography, cultural and technology probes.

The body of related work discussed in this chapter has demonstrated where the majority of existing related work differs with the aims of the work presented in this thesis (the aims of this work are presented in section 1.5). The majority of related systems have not been deployed for regular use outside of the typical ‘lab’ scenario (apart from short user trials). In addition, none of the related work discussed in this chapter has begun to explore, specially, the affordances a digital display system can provide over traditional paper-based systems.

Chapter 3

The Initial Hermes Prototype

3.1 Introduction

This chapter details the initial phase of the design, development and deployment of the Hermes system. The prototype was intended to explore the aims of this thesis and acted as a starting point in order to gather requirements on a range of levels. Terminology used in this chapter is defined in Appendix F.1.

3.2 Background

The office door and surrounding area provide a very rich place to study interaction. This kind of location can be categorised as 'semi-private' because it includes both private elements (as it 'belongs' to the occupant of the office) and public (as it is part of the corridor and visible to all passers-by). The office door represents the boundary between public and private spaces, often used as an indication of the interruptibility of the occupant (for further discussion of the office door as an 'interruption gateway' see section 1.1 of this thesis and [Jeffrey '02]). For example, an open office door generally means that the occupant is open to accepting visitors and a closed door the opposite (with various states in between). Additionally, many office occupants personalise doors by adding cartoons, photographs or pictures.

A very common occurrence in the Computing Department at Lancaster University is that of colleagues, postgraduate and undergraduate students calling at the office of a member of staff unannounced in the hope of an ad-hoc meeting. This makes the office door an interesting place to explore issues such as messaging, awareness (primarily of the type 'who is there'), coordination and context-sharing as it is often the location where a visitor to an office finds that they can or cannot see the person they seek. Inevitably, a member of the department might be unable to attend a scheduled meeting leading to visitors calling at his or her empty office. In addition to the ad-hoc calling at an office, of course, scheduled meetings also take place in offices. Often if a staff member is unable to attend a prearranged meeting and has no

way of contacting the visitor in time, he or she will leave a paper message on his or her door specifically for the visitor or telephone a secretary or colleague to do this for them. This demonstrates how members of the department take the social obligation of arranging a meeting seriously, though clearly this may depend on the perceived importance of the meeting and the relationship between the people involved.

An additional method for an office occupant to display a message for visitors to his or her office is by using some form of message 'whirler' attached to his or her door, for examples see Figure 3-1. Message 'whirlers' tend to have a predefined set of messages with some form of pointer that can be changed as appropriate.

Figure 3-1: Examples of Message 'whirlers' and Post-it Notes.

Paper notes and 'whirlers' are obviously inexpensive to manufacture, have a low cost in terms of effort and it is inherently clear whether or not they are operational. However, some potentially undesirable physical properties can be observed:

i) lack of security - it is easy for someone to maliciously remove a paper note or change a message 'whirler' displaying a publicly accessible message, also any passer-by could attach a paper note to an office door (or move a message 'whirler') which would be assumed to have been the actions of the office occupant,

ii) no remote accessibility - it is necessary to contact a secretary or colleague physically inside the Computing Department to author and place a paper note or change a message 'whirler' remotely while off-site.

For a visitor arriving at an empty office, at that location and time he or she is unlikely to have many ways of leaving a message for the absent occupant (unless, for example, the visitor had the occupant's mobile telephone number). Consequently, some members of staff even place paper pads outside offices for visitors to leave messages on and a visitor is, of

course, free to place a paper note on an office door should he or she wish to. However, a message left on an office door is visible to all passers-by which, in some cases, may not be desirable. One possible solution might be to provide the mobile telephone number of the occupant on the office door (perhaps inviting the visitor to call or send them an SMS). However, an office occupant is perhaps unlikely to want to make his or her personal mobile telephone number publicly accessible.

3.3 Development Approach

A phased development approach was used when designing Hermes where each phase began with specific objectives in line with the aims of this thesis. The development effort of the Hermes system focussed primarily on owners of door displays. This was because supporting adoption and use by owners was central to exploring these aims, and with limited resources visitors received comparatively little attention. Each phase started by 'rapidly' prototyping and deploying an entire instance of the Hermes system (starting from the previous code-base prior to the initial phase) including new features and required modifications. The Hermes system effectively acted as a functional prototype and was developed in an evolutionary manner. During the development process potential features and user interface designs were discussed with and demonstrated to other members of the development team, providing a form of expert analysis. Following deployment, prototypes were then iteratively refined using feedback from door display owners [Fitton '05]. The complete history of the technical changes made to Hermes is listed in Appendix A. The phased development approach allowed a simple initial prototype and the gradual addition of functionality (with input from owners) which helped fulfil the aim of providing an information appliance. The use of phases also simplifies discussion of the development of the Hermes system.

The development of Hermes was split into six phases. The objective of the first phase (the initial prototype described in this chapter) was to develop core functionality and perform testing in the traditional 'lab' scenario, and then deploy door displays outside the offices of two of the system's developers. This approach ensured some initial testing outside of the 'lab' but with door display owners where low reliability and initial problems were not likely to affect future use [Fitton '05]. The phase 1 prototype was designed and evaluated inside the development team. While this approach was open to the requirements capture problem, the design team were effectively experts on the domain (having worked in the Computing Department for significant periods of time) and this enabled a prototype to be produced relatively rapidly (without the need for approaches such as ethnography to help understand the domain). Later phases of Hermes (discussed in the following chapter) involved overlapping aims, such as expanding the deployment and supporting adoption from owners by adding

features to lower barriers to use, with each phase involving the addition or modification of major functionality.

In order to explore the aim of this thesis to combine technology driven and user-centred design[8], with limited resources, an eclectic approach was taken. In more detail, continual informal feedback was sought from owners via discussion of potential features, demonstration of existing features, reports of problems, specific suggestions for improvement and general discussion about use of the system. This feedback helped to focus the design on the owners and include their ideas, comments and suggestions in the design process. Collection of feedback in these ways was possible because of the proximity of the developers and door display owners, and allowed valuable feedback to be collected in a low cost manner. This informal qualitative feedback was used both to help evaluate existing features and generate new requirements. In addition to informal channels of qualitative feedback, formal methods such as a questionnaire and a semi-structured interview were also used to investigate specific issues such as owner's use and potential new features. These techniques were chosen to help understand adoption and use over the longer term with limited resources (rather than evaluate a specific user interface design where techniques such as 'think alouds' and observational methods would be more appropriate). Additionally, utilising informal feedback through discussion and techniques such as interview gave flexibility to explore interesting issues as they emerged.

An important part of generating feedback via the formal and informal methods described previously was the deployment of door display prototypes for use in the 'real world', allowing an owner to use a prototype as part of his or her daily routines. All use of the Hermes system was logged and, in conjunction with the simple unrestrictive functionality, allowed the door displays to act as a form of technology probe [Hutchinson '03] to help inform the design. Not only did the deployment in this manner enable the collection of qualitative feedback (described in chapter 6) but logging enabled use to be quantitatively analysed (described in chapter 5). This further enabled the understanding of use and exposed new requirements. The development approach helped support the aims of this thesis of

---

[8] The definition of user-centred design in this thesis means the involvement of users, or in this case the owners of door displays, in this design process to help meet their needs (this definition is discussed further in section 2.3.1).

allowing initial adoption and continued use by using feedback to inform the design of features to lower owners' barriers to use.

3.4 Initial Requirements

This section discusses the initial requirements that the Hermes system was subject to, in terms of implications for the application in general and installation.

3.4.1 Application Requirements

To fulfil the aims described in section 1.5 the intention was to make the initial design of Hermes simple and then to evolve the system gradually as it was adopted and appropriated by owners. This approach was used in order to develop features that were useful to owners without overly restricting the way in which the system could be used. For example, a web-based interface enables interaction via virtually any computing device with a web browser and internet access, while a system utilising entries from a Microsoft Outlook™ calendar relies on the maintenance of an accurate and up-to-date schedule using a specific application.

In order to support asynchronous messaging (discussed in aim 1 in section 1.5) in a simple manner, the decision was made to design a prototype providing simple functionality analogous to a paper note. Therefore, the initial requirement was to develop a prototype allowing an office occupant to share a message associated with his or her door and allow a visitor to leave a message for the office occupant. The Hermes system was intended to augment rather than replace existing paper-based systems (discussed in aim 2 section 1.5). Therefore, in order for owners to adopt Hermes and use it in addition (or in preference) to existing paper-based messaging media an incentive must be perceived [Markus '90]. Even though a the properties of a digital system enable a range of additional functionality which might encourage use, the system may effectively be competing with paper notes on the issues of:

i) ease of use (i.e. the system should not be more complex and time consuming to use than, for example, a Post-it note),

ii) reliability (i.e. the owner should not trust the system significantly less than a Post-it note).

Problems in either of these two areas are likely to affect adoption.

3.4.2 Installation Requirements

The deployment of the Hermes door displays impacted upon the layers (from [Brand '94]) of *space plan* (interior layout) and *services* (communication and electrical wiring). This

meant discussion was required with the appropriate stakeholders in order to ensure that deployment could proceed and to highlight areas of particular concern, primarily:

- compliance with university safety regulations,
- compliance with disabilities legislation.

Two other important installation requirements considered were:

- ease of deployment and development,
- appropriate security.

These requirements are discussed in detail in the following sections.

Compliance with University Safety Regulations

The fact that Hermes door displays were to be situated in a public location and were required to run constantly meant the system had to comply with the Lancaster University's Health and Safety regulations. Previous attempts to experiment with the use of ubiquitous displays within the department (e.g. the Flump system [Finney '96]) had been thwarted by the health and safety regulations that forbade the deployment of constantly 'on' High Voltage equipment within the University's corridors. Effectively this restriction meant that the displays had to be based on a low voltage unit, such as a PDA or laptop.

Compliance with Disabilities Legislation

Current UK disability legislation states that public facilities need to be positioned at a height that does not unduly discriminate against people using a wheelchair [Disability Rights Commission '02]. For this reason the door displays had to be situated at a relatively low height from the floor (approximately 150 cm). In the future, it would be desirable to make the displays more accessible to taller visitors.

Easy to Deploy and Easy to Develop

One important requirement for the Hermes system was that it should be relatively easy to deploy (based on limited resources for carrying out deployment). To meet this requirement the decision was made to design the Hermes door display devices as a self contained unit rather than, for example, deploying a PC (and associated hardware) on the inside of an office and a display on the outside. Another important requirement was that of reducing the cabling required to the Hermes displays (ideally requiring none at all). While a wireless network could be used for communication (eliminating the need for wires

completely) it was likely that any-self contained mobile device would have a relatively short battery life and require (low voltage) power from an external source.

These constraints narrowed the choice of hardware down to a PDA or laptop (or Tablet PC) based device. A PDA-based solution was selected as the relatively low cost per unit would enable the largest number of displays to be deployed and it was anticipated that a small screen area would be adequate for the simple messaging applications intended. Additionally, the use of large devices would have had a significant impact on the building fabric and it would have been more difficult to gain approval for the deployment to take place. The intention was for the display device application to be relatively easy to develop so a Microsoft Pocket PC [Microsoft '05a] PDA based solution was decided upon (over Palm OS [PalmSource Incorporated '05]) owing to the large touch sensitive screen, higher processing power and superior Java support.

Appropriate Security

Although access to the Computing Department was restricted during evenings and weekends, it was unrestricted at all other times. For this reason the Hermes door display devices needed to be mounted in such a way that opportunistic theft of the device would be difficult. Additionally, access to buttons on the PDA device had to be removed in order to prevent malicious or accidental termination of the application etc. This latter modification also helped move the unit in the direction of an information appliance.

3.5 The Chosen Hardware Solution

Having decided to develop a system using an ‘off-the-shelf’ based PDA two candidates were considered, namely the Compaq iPAQ H3600 series and the HP Jornada 568. Both of these devices had a relatively large colour touch sensitive screen, incorporated a 206 MHz 32-bit StrongARM processor, 64MB of RAM, provided expansion (via PCMCIA and compact flash slots) and used the Microsoft Pocket PC operating system. After consideration the HP Jornada was chosen for two main reasons. Firstly, at the time, only the Jornada came equipped with a built-in compact-flash slot and therefore could support wireless 802.11b networking without requiring an additional expansion jacket. Secondly, the unit had a relatively square shape (compared to the rounded back of the Compaq iPAQ with expansion jacket) simplifying case design. The case for holding the unit was made from aluminium and illustrated (together with a Jornada) in Figure 3-2. Note how the case was designed to restrict access to the buttons on the PDA in order to prevent malicious or accidental termination of the Hermes application (and to help move the prototype in the direction of an information appliance).

Figure 3-2: The First Deployed Hermes Door Display.

3.6 The Chosen Software Solution

At an early stage it was decided to use a Java based implementation for the Hermes system. This decision was made primarily due to the cross-platform nature of Java which would potentially enable the Hermes application to run on a wide range of devices. An additional important factor influencing this decision was support for the chosen door display hardware (a PDA device). The main alternatives to Java at the time were Microsoft eMbedded Visual C++ and Microsoft eMbedded Visual Basic. However, initial investigation revealed that neither of these products were equivalent to their desktop counterparts, missing certain software libraries which would be required for implementation of the Hermes system.

Largely due to a lack of available information at the time, finding a Java virtual machine (VM) implementation to run on a PocketPC device meeting the requirements for Hermes was a frustrating process. In particular, it was difficult to find a VM implementation supporting the Java Communications API to enable use of the PDA's serial port. Such support was necessary because from a very early stage in the design process it was thought that the use of iButtons [Maxim '05] could prove to be a useful tool for lowering the cost of authentication to help support adoption for both door display owners and visitors.

The choice of Java VMs fell into two categories, 1) those running under the Microsoft PocketPC operating system and, 2) those supported through the installation of a 3rd party operating system on the PDA device. Examples of this latter category at the time included the SavaJe OS [SavaJe '05] (which provided a native Java operating system for iPAQ PDAs) and the possibility of installing Linux on an iPAQ device and running a Linux Java VM ported to the appropriate architecture. After testing, neither of these two solutions appeared to be practical (for example the SavaJe OS only supported a very small number of network

device drivers and an additional memory card was required to install Linux and Java VM on a PDA) and neither supported the HP Jornada 568 device.

Out of all the possible Java VM solutions CrEme [NSICom '05] was chosen. CrEme provided many advantages over alternatives in the same category such as the ability to hide the Pocket PC ‘menu bar’, built in Java Communications API and support for additional APIs. A web page was published including the information discovered about the various options for supporting Java on PDA devices to help other researchers.

Linux was chosen as the operating system for the supporting server in order to easily provide a secure and stable platform allowing web technologies (i.e. simple web page serving and Sun’s Java Servlets [Sun '05b]) to be configured, deployed and managed easily.

3.7 Phase 1 Initial Design

This section presents the design of phase 1 of the Hermes system, the initial design of Hermes is motivated followed by a description of the functionality provided at the start of phase 1 and the design choices explored. The initial design of Hermes focused primarily on door display owners and provided a starting point to explore the different features and uncover further requirements and usage issues.

3.7.1 Exploring Affordances

One of the primary aims of this thesis was to use a prototype to investigate the potential affordances that could be provided by a digital equivalent to Post-it notes and message ‘whirlers’ to support asynchronous messaging. These affordances can be used as a means to explore the additional possibilities for functionality enabled by the properties of a digital equivalent. Consideration of affordances was used to motivate and evaluate functionality provided in the Hermes prototype, the most pertinent affordances (compared to paper-based systems) considered during the development of the initial Hermes prototype are summarised in Table 3-1.

Affordances enabled by a Digital Approach (compared to typical paper-based approaches)	Description
Security/Authentication	With a digital system is possible to ensure that messages are only accessible by specified parties and also that only certain parties can leave messages publicly visible. With paper-based systems anyone can potentially remove or modify a Post-it note.
Control Over Visibility	In a digital system messages left by visitors at a door do not have to remain visible to all passers-by as they would with a Post-it note or message pad.
Remote Interaction	With a digital system there is much scope for configuring publicly visible messages and accessing messages left by visitors (via the web, e-mail, SMS etc.). With a paper-based system this would require help from a co-worker.
Simplified Replying Process	In a digital system, if the sender of a message is known this can be used to simplify the process of replying, for example, by generating a new e-mail message with the destination field already completed.
Context Awareness	A digital system could, for example, be augmented with a location tracking system for office occupants and generate public messages based on the owner's location, or integrate with an owner's electronic calendar.

Table 3-1: Affordances Enabled by a Digital Approach

Conversely, Table 3-2 presents some pertinent real affordances (in the Gibsonian sense of the term) provided by paper Post-it notes which might be challenging to achieve in a digital system. Paper-based systems provide some interesting properties which are desirable in the Hermes system, some of which could potentially be emulated in a digital equivalent. For example, the yellow colour of a Post-it note might help convey to a visitor that a surface supports interaction in a similar manner.

Affordance of Post-it Note	Description
Expressivity	Post-it notes inherently provide a surface which supports authoring of media with a high level of expressivity (text and drawing using different colours and types of pens etc.) which any person can use without instruction
Placement	Post-it notes can easily be attached to virtually any surface, allowing tacit expressions to be used in messages, without damaging the surface to which they are attached and can be removed and re-placed several.

Table 3-2: Gibsonian Affordances Provided by a Post-it Note

3.7.2 Door Display User Interface

The initial user interface was designed within the development team (who were effectively experts in the deployment domain and Hermes door display owners) in order for a prototype to be developed quickly. However, user-centred design techniques were then used

to refine this initial prototype. The chosen hardware for the door display devices, a PDA, provided a screen approximately six centimetres wide by nine centimetres high (in portrait orientation) and for simplicity the Hermes application was developed to utilise this default configuration. In order to support adoption (one of the main aims of this work), an important goal when designing the user interface was that it should be very simple and easy to use with effectively zero time to learn.

From the various possible design alternatives, the user interface layout selected consisted of a thin menu 'bar' along the bottom edge of the screen, textual information presented along the top edge of the screen (including the office number and name of occupant) and content such as messages displayed in the remaining space in the centre. This layout was selected due to its simplicity in terms of implementation and use, the fact it displayed all necessary information on screen simultaneously (status, content and user options) and because it fit well with the size and orientation of the screen area. The design is also reminiscent of the screen layouts of many mobile phones.

The colours chosen for the text at the top of the user interface were black text on an orange background. Orange was selected, over other eye catching colours such as red, both to stand out to passers-by and because the black text remained easy to read. The menu bar consisted of rectangular grey buttons of similar appearance to those in the Microsoft Windows operating system, used to help convey that the buttons performed an action when pressed. The information displayed at the top of the user interface was included to ensure that a visitor realised a door display was associated with an office occupant (by displaying occupant name and office number). The current date and time were included to assist visitors in the case of owners sharing messages including temporal content.

While different variations on the user interface were possible, such as placing the menu bar at the top of the screen to make it more noticeable to visitors, the design was evaluated and agreed upon by all members of the development team. This evaluation also revealed requirements such as the need for the menu buttons to be large enough to be pressed easily with a finger (as opposed to only by a stylus). Screen shots of the door display user interface during Phase 1 are shown in the following sections (Figure 3-3, Figure 3-4, Figure 3-5 and Figure 3-10).

If the choice of user interface design had not been dictated to a large extent by the hardware used, one appealing alternative would have been to use a screen in landscape orientation. If, for example, the screen had been roughly the same size and orientation as a Post-it note this might have helped convey that the system supported messaging in a similar manner, helping visitors to perceive the affordance of leaving a note (Norman's perceived

affordances are discussed in detail in section 1.5). Additionally, the use of a larger touch sensitive screen would have enabled a whole host of user interface design possibilities, such as displaying additional content or applications in parallel with Hermes. It would also have been interesting to include a webcam, if the door display hardware had been capable of supporting this, allowing visitors to leave pictures of themselves to 'sign' notes they left or simply as evidence that they had called at an office. The design of the Hermes 2 system, discussed in Appendix J, addressed these limitations of the original Hermes door display hardware.

3.7.3 Owner Functionality

From discussion between members of the development team five main functions to be provided by the phase 1 prototype were agreed upon:

i) ability to display a public message,

ii) ability to display a private message,

iii) ability to set public and private messages via the web portal,

iv) ability to set a public message via a SMS message,

v) ability to read messages left by visitors.

These features are discussed in more detail in the following sections and were deliberately chosen to be simple in order to maintain an uncomplicated user interface and high reliability.

Ability to Display a Public Message

The primary feature of this phase of the Hermes system was the ability to set a public message visible to all passers-by (analogous to a Post-it note). A public message could be textual or an image, an owner was allowed to set an image in order to support a higher degree of expressivity than with plain text. The door display user interface remained in the 'main' mode (as shown in Figure 3-3) when no office owner or visitor was interacting with it. In this mode the current public message set by the owner was displayed, along with some additional information such as the name and office number of the owner at the top of the screen. This design was chosen for simplicity: a visitor does not have to interact with a display in order to view the owner's current public message. The buttons at the bottom of the user interface in this mode allow a note to be left for the office occupant ('Note') and allow a visitor to

authenticate themselves (‘Log In’). In phase 1 a door display owner was able to set his or her public message via an SMS message or via the Hermes web portal.

Figure 3-3: Door Display Main Screen (Phase 1).

Ability to Display a Private Message

The possibilities for authentication are where the digital approach used in Hermes begins to contrast with traditional paper notes (see section 7.3.2 for a full discussion of the affordances considered in the design of Hermes). In order to explore the potential authentication affordances a door display owner was able to set a private message. Only visitors registered with the Hermes system (having a username and PIN) were able to authenticate themselves (as shown in Figure 3-4) in order to view a door display owner’s private messages, this effectively meant that a private message could only be viewed by another Hermes door display owner. An example of the user interface showing a private message is shown in Figure 3-5. The design of the authentication screen was intended to be a simple as possible and therefore a PIN number was chosen so only a keypad was required on the screen.

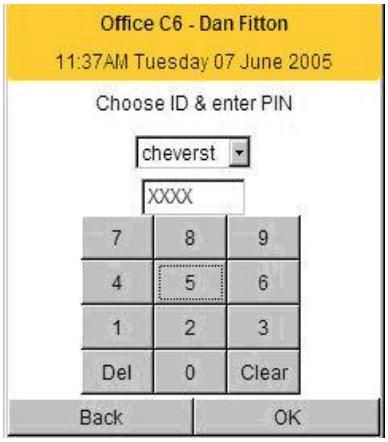

Figure 3-4: Door Display Authentication Screen (Phase 1).

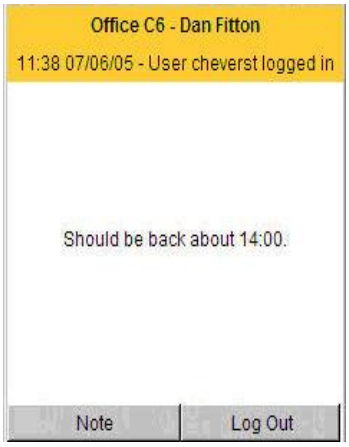

Figure 3-5: Viewing Private Message on Door Display (Phase 1).

Ability to Set Messages via a Web Portal

The primary method provided for door display owners to set public and private messages was a web portal. This method was chosen to support remote interaction from a range of scenarios and could be accessed both on and off the Lancaster University campus using a web browser. The web portal required a door display owner to first complete an authentication process using a username and PIN (as shown in Figure 3-6) before use. After authentication the door display owner was presented with a screen similar to Figure 3-7 which allowed a textual public message to be typed in or chosen from a fixed selection (chosen by the system developers) using a 'drop down' selection box in order to help ease of use. Private messages were set in a similar manner. The design of the web portal was chosen to be a simple as possible and a PIN number was used for authentication as this method was already used at the door displays (as shown in Figure 3-4). Visitor notes were displayed on a separate web page accessible by clicking on an appropriately labelled button, this separation was made to ensure simplicity. In order to encourage owners to view the web page and see their visitor notes, the number of new messages was displayed above the button. Alternative designs would have included displaying the most recent visitor message or all visitor messages on the 'Logged In' page, but these designs would have slightly increased the complexity of the page.

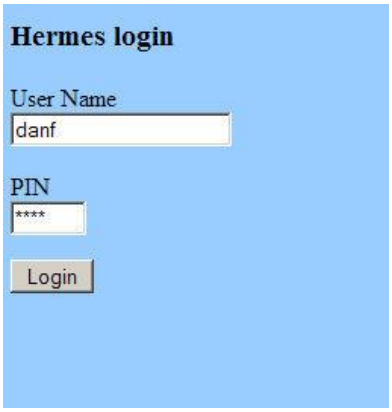

Figure 3-6: Web Portal Login Page (Phase 1).

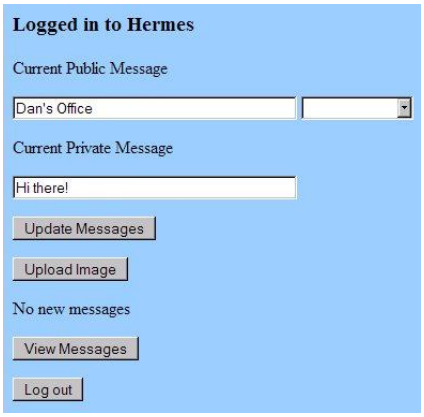

Figure 3-7: Web Portal 'Logged In' Page (Phase 1).

A door display owner could upload an image to be used as a public message by selecting the 'Upload Image' button (see Figure 3-7). The door display owner was then presented with a user interface similar to that shown in Figure 3-8 allowing the desired image to be found in the local file system, then use the 'Upload' button to upload and set it as the current public message. Due to the limited computational resources and storage capacity of the door display hardware (discussed later in 3.5) it was necessary to impose an upper limit on the size of images set (in order to avoid long delays for images to appear on the door display user interface). Figure 3-9 shows how the web portal appeared with a public image set.

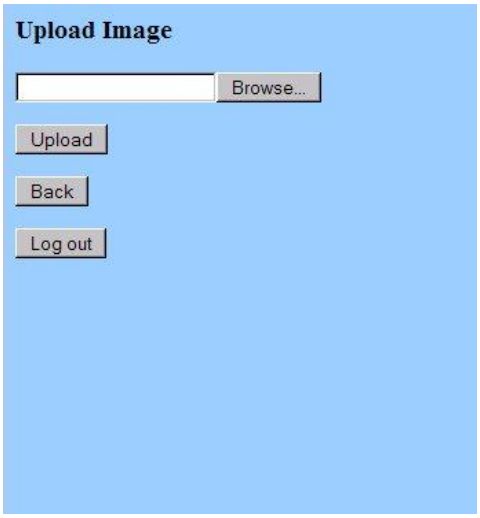

Figure 3-8: Uploading a Public Image Message (Phase 1).

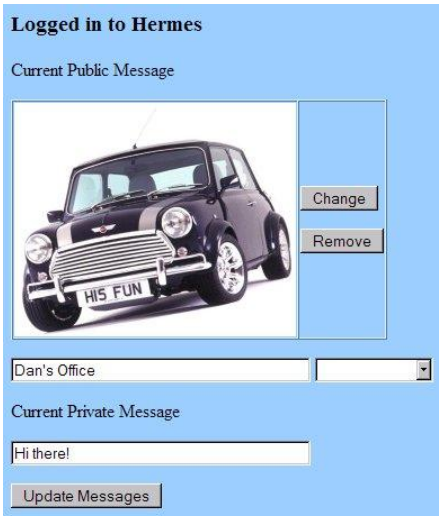

Figure 3-9: A Public Image Message (Phase 1).

Ability to Set Messages via SMS

In addition to using the web portal to set a message, the owner of a Hermes door display could also use GSM's SMS (Short Message Service) in order to set a textual public message, allowing interaction from a mobile device. This feature was motivated by one

system developer (and lecturer) by a fear of being late for meetings, who desired a simple mechanism for informing colleagues in this eventuality (this scenario was discussed in detail in section 1.1). An example of a display showing a typical message received via SMS is shown below in Figure 3-10.

Figure 3-10: Example of a Public Message Sent via SMS (Phase 1).

Reading Messages left by Visitors

Once a door display owner had completed the authentication process on a door display (shown earlier in Figure 3-4), which need not be his or her own, he or she was able to view any visitor notes that have been left for them by visitors (visitor functionality is discussed in detail in the following section).

The web portal also enabled the owner of a door display to read visitor notes. This web page was dynamically generated when accessed and displayed any visitor notes which had been left on the owner's Hermes display (and not yet deleted) in chronological order. In order to make the web page as simple as possible the notes were displayed full size (rather than, for example, using thumbnails and requiring the owner to select the desired note). As can be seen from Figure 3-11, this web page also identified the time and date that each message was left. This aspect of the Hermes system remained relatively unchanged during the deployment.

The identity of the person who left each message was also presented but, as with its traditional paper note counterpart, the Hermes system does not require visitors to authenticate themselves in order to leave a message. However, if the visitor authenticated themselves then the owner's task of replying to the message was simplified. By clicking on the appropriate button positioned alongside the authenticated message (e.g. the bottom message shown in Figure 3-11) the owner was presented with a partially completed e-mail form. This feature provided an additional affordance compared to paper notes, that of simplifying the process of replying to a message from a visitor.

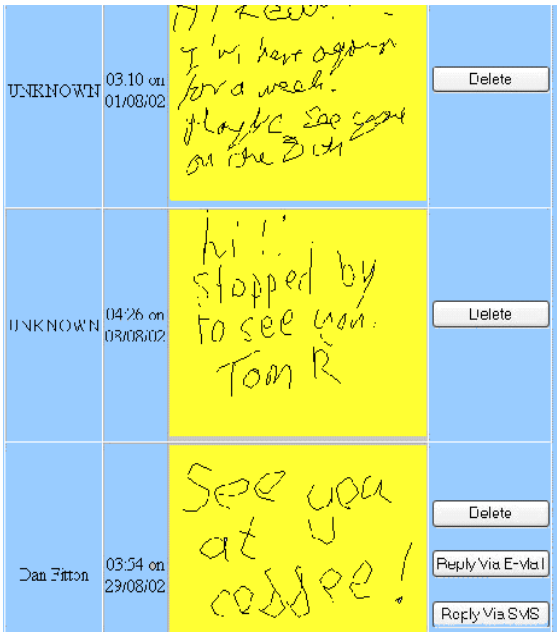

Figure 3-11: Viewing Visitor Notes (Phase 1).

3.7.4 Visitor Functionality

The Hermes system was designed such that a visitor to a door display could not access notes left by other visitors on that display. Hermes was designed in this way to remove the restriction of paper Post-it notes that all messages left by visitors are visible to passers-by. This feature was clearly enabled by this digital equivalent compared to paper notes and it was hoped that the feature would encourage visitors to leave notes. Additionally, if a visitor's note remained visible this would cover any message the owner had left and scheduling the visibility of multiple messages would have increased user interface complexity.

A restriction placed on the functionality available to visitors was that a visitor must be co-located with a Hermes display in order to leave a note; the design of this functionality was of course the same as a paper Post-it note. However, this restriction could easily be removed and potentially visitors could be allowed to leave messages remotely (though the aims of this work were not to replace technologies such as e-mail). This restriction was implemented following discussions with potential door display owners and also based on the preferences of the two owners in phase 1.

In order to leave a visitor note on a Hermes display the visitor simply had to tap on the 'Note' button on the main Hermes interface (as shown in the bottom left of Figure 3-5 and Figure 3-3). Tapping on this button resulted in a change of mode in which a blank area was presented to the visitor on which he or she could 'scribble' a message using the touch sensitive screen with the attached stylus. The background colour of the area for the visitors to draw a note was yellow in colour very similar to that of a Post-it note and the motivation for

this was to help convey to the visitor that a note was left in the same way as a paper Post-it note. An example of a message left by a visitor is shown in Figure 3-12.

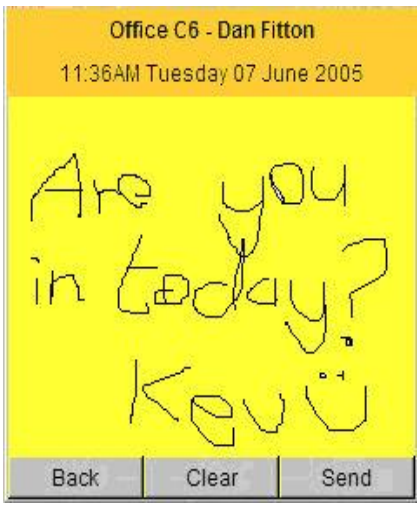

Figure 3-12: A Visitor Composing a Message at a Door Display (Phase 1).

When the visitor had completed the message they simply tapped on the 'Send' button and the display reverted to the main user interface mode. As soon as a visitor note was left at a door display, assuming the door display owner had a valid mobile phone number stored in his or her owner profile (owner profiles are discussed in detail in section 3.7.7), the owner received a notification via an SMS message. Visitors were not given any control over the sending of the SMS message and this additional functionality was hidden. This decision was made in order for the functionality appear analogous to a paper note, to avoid discouraging visitors from leaving messages and to reduce user interface complexity. While visitors to door displays were not the main focus of this work, making visitors aware of this feature may have produced some interesting results (and is an area for future work). For example, a visitor might decide not to leave a message they did not feel important enough warrant bothering the owner with an SMS message, conversely a visitor may leave multiple messages in order to draw attention to themselves.

3.7.5 Early Design Decisions

Several assumptions were made before development began which affected the architecture of the initial prototype. These can be summarised as:

i) *Use of an Experimental Wireless Network*

The location where the Hermes door displays were to be deployed was covered by several experimental wireless networks. It was assumed that these would be suitable for reliable network connectivity and would help ease of deployment.

ii) *Central Storage*

When designing Hermes (in spring 2002), available PDA devices had limited storage and processing resources, for example a Compaq iPAQ H3800 series [Hewlett Packard '05] had 64MB of RAM shared between both programs and storage. This amount of storage would have been too small to store large numbers of image files representing visitor notes and owner messages, in addition to storing log entries generated at regular intervals. Complete power loss also resulted in all data apart from the core operating system being lost. For these reasons a client-server architecture was adopted, with a server providing central storage of information.

3.7.6 Overall System Architecture

The overall system architecture of the Hermes system is illustrated in Figure 3-13, including the main components and the communication between them, colours indicating the different communication protocols (for simplicity the RMI registry running on the Central Server is not shown). In this thesis main software components are referenced in italics (for example: *Central Agent*). This figure is discussed in detail in the following sections. It is important to note the definitions of system components used throughout this thesis:-

Central Server – a single machine on which important software components required by the Hermes system were run (such as the *Central Agent*, *Web Portal Servlets*, and logging facilities).

Door Display – the interactive display hardware component (a PDA) deployed in a specialised housing (see Figure 3-2) outside an office door.

Central Agent – the ‘server’ software application which ran on the Central Server controlled and managed instances of the *Client Agent* application.

Client Agent – the ‘client’ software application which ran on door displays to provide a user interface (etc.).

Web Portal Servlets – a collection of Java Servlets which dynamically generated the HTML pages comprising the web portal .

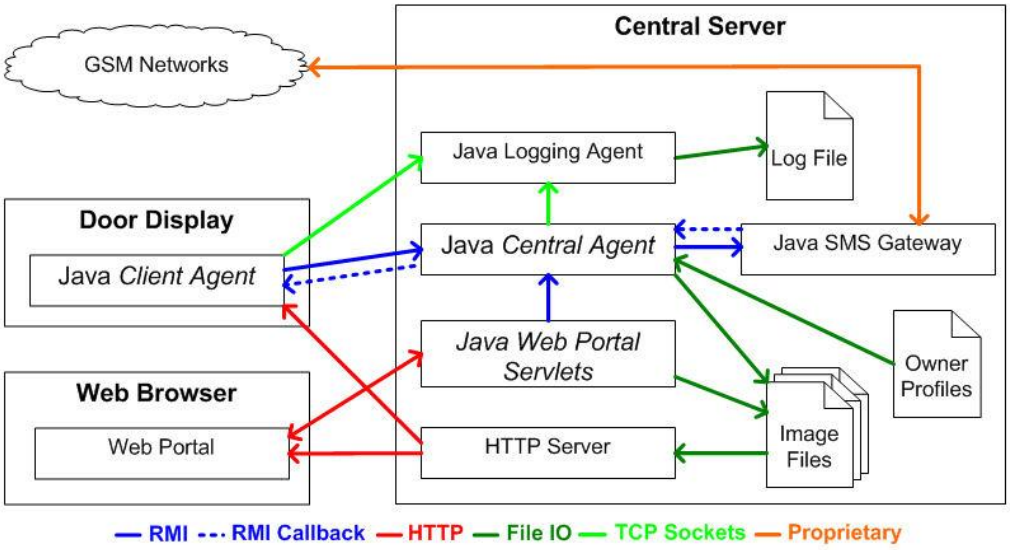

Figure 3-13: Overall System Architecture (Phase 1).

As the choice of programming language was Java (this decision was discussed in detail in section 3.6), the phase 1 architecture was developed using a client-server model with Java RMI for communication (the *Central Agent* being the server component and the *Client Agent* the client). This simple design enabled a functional prototype system to be developed and deployed quickly. The software architecture was not the main focus of this work and other remote procedure call technologies could have been used (such as CORBA [Object Management Group '06] which would have supported interoperability with other programming languages) or other communication models such as peer-to-peer (for example using JXTA [JXTA Project '06]) or web services [W3C Working Group '04]. However, use of these alternative technologies would have increased the development time required to implement a functional prototype. In order to make image files easily accessible throughout the system (to support owner message images and visitor notes) these were stored at the Central Server and made accessible via a HTTP server (as shown in Figure 3-13).

3.7.7 Functionality Provided at the Central Server

At the heart of the system was a single Central Server machine (see Figure 3-13) that provided the following key functions:

i) centralised storage for visitor note images, owner message images and owner profiles,

ii) centralised storage of logs,

iii) communication with the SMS terminal,

iv) the dynamic generation and publication of HTML web pages.

Centralised Storage of Messages and Owner Profiles

Each door display owner had an owner profile that, during phase 1, held the information presented in Table 3-3. For ease of implementation this information was stored in a 'flat' file that was read into Java Objects in memory when the *Central Agent* application started up.

Data	**Purpose**
Unique user ID (iButton ID)	iButton authentication and to address messages
Username	Used to log in on the web portal and on door displays
PIN	Used to log in on the web portal and on door displays
Office Number	Displayed at the top of the door display user interface
Full Name	Displayed at the top of the door display user interface
E-mail address	For developers to contact door display owners
Mobile Phone Number	Identify SMS sender to update public message
Public Textual Message	Current textual public message
Public Image Message	The filename of the current public message image
Private Textual Message	Current textual private message

Table 3-3: Information Stored in an Owner Profile (Phase 1).

Public image messages and visitors notes were stored as individual image files at the Central Server and made accessible via a web server (as shown in Figure 3-13). Providing centralised storage at the *Central Agent* reduced the storage requirement on the limited PDA door display devices and was relatively reliable. However, this approach meant that communication with the Central Server was required in order to access or modify owner messages and visitor notes.

Centralised Storage of Logs

A log was kept of all actions that took place during deployment, this included:

i) setting of public and private messages by owners,

ii) messages left by visitors,

iii) logins/logouts to the web portal and on door displays,

iv) individual user interface component actions (e.g. clicking on buttons on the door display user interface).

Due to the limited storage available at the door displays and continuous streams of information generated by logging, logs were stored at the Central Server via the Logging Agent (as shown in Figure 3-13). Textual information to be logged was sent to the Central Server over TCP sockets and an entry was then appended to the end of a single file. TCP sockets were chosen over, for example, RMI calls in order to introduce as little overhead as possible to the door displays. Each log entry contained three lines, the first containing details

of the sender, the next a timestamp and the third is the actual information received. A sample of a log file is shown in Figure 3-14.

```
dyn196.dhcp.lancs.ac.uk/148.88.241.150
14:22 07/05/02
actionPerformed - source: java.awt.Button[button6,117,0,117x23,label=Log Out]
dyn196.dhcp.lancs.ac.uk/148.88.241.150
14:22 07/05/02
User fittond logged out
dyn196.dhcp.lancs.ac.uk/148.88.241.150
14:22 07/05/02
actionPerformed - source: java.awt.Button[button7,0,0,117x23,label=Note]
dyn196.dhcp.lancs.ac.uk/148.88.241.150
14:22 07/05/02
actionPerformed - source: java.awt.Button[button8,0,0,78x23,label=Back]
dyn196.dhcp.lancs.ac.uk/148.88.241.150
14:22 07/05/02
actionPerformed - source: java.awt.Button[button7,0,0,117x23,label=Note]
dyn196.dhcp.lancs.ac.uk/148.88.241.150
14:22 07/05/02
actionPerformed - source: java.awt.Button[button9,156,0,78x23,label=Send]
dyn196.dhcp.lancs.ac.uk/148.88.241.150
14:22 07/05/02
Anonymous note sent to 764066420633315216067
dyn196.dhcp.lancs.ac.uk/148.88.241.150
14:22 07/05/02
```

Figure 3-14: Extract from a Hermes Log (Phase 1).

Sending and Receiving SMS Messages

In order to support the reception of SMS messages, a Wavecom DB02 GSM terminal was used. The GSM terminal required a SIM card and messages were sent and received using a specialised AT command set sent over a serial connection. A piece of software for Linux called SMSLink [Andersson '05] was used to interface the GSM terminal, appending messages received to a plain text ‘inbox’ file and allowing messages to be sent using a telnet session over TCP. The GSM terminal and SMSLink program are not shown in Figure 3-13 as a Java SMS Gateway application was used abstract over the SMSLink program. This simplified the sending/receiving of SMS messages to/from the *Central Agent* and enabled the underlying implementation of SMS sending and receiving to change (i.e. by modifying the SMS Gateway application) without having to change the *Central Agent*.

The inbox file created by SMSLink was parsed at regular intervals by the SMS Gateway application. New messages were passed to the *Central Agent* via a Java RMI callback [Sun '05a] and if a message received originated from a door display owner (matched using the information stored in owner profiles) the appropriate public textual message was changed to the contents of the SMS.

Dynamic Generation of Web Pages

The primary method for a door display owner to interact with his or her door display during phase 1 was through the Web Portal. This was a collection of web pages generated at the Central Server using Java Servlets hosted using Apache Tomcat [Apache Software

Foundation '05]. This enabled HTML pages to be generated dynamically through integration, using Sun's Java Remote Method Invocation (RMI) [Sun '05a]), with the *Central Agent* application.

Software Architecture

Recall from section 3.3 that a phased development approach was used, this section documents the interaction between components in the software architecture during phase 1. In this thesis interfaces are referenced using a fixed-width font (for example: `Central Agent Interface`) and Objects in a different font (for example: UserData).

Setting a Message at the Web Portal

Figure 3-15 shows how the objects which made up the architecture of Hermes at the start of phase 1 interacted. It shows the four steps involved for a message set at the web portal to update the *Central Agent*, which then updates *Client Agent* (running on a door display). For simplicity, Figure 3-15 does not show the process of the *Web Portal Servlets* or *Client Agent* connecting to an RMI registry in order to lookup the remote `Central Agent Interface` for the *Central Agent* (bound to the RMI Registry running on the Central Server previously).

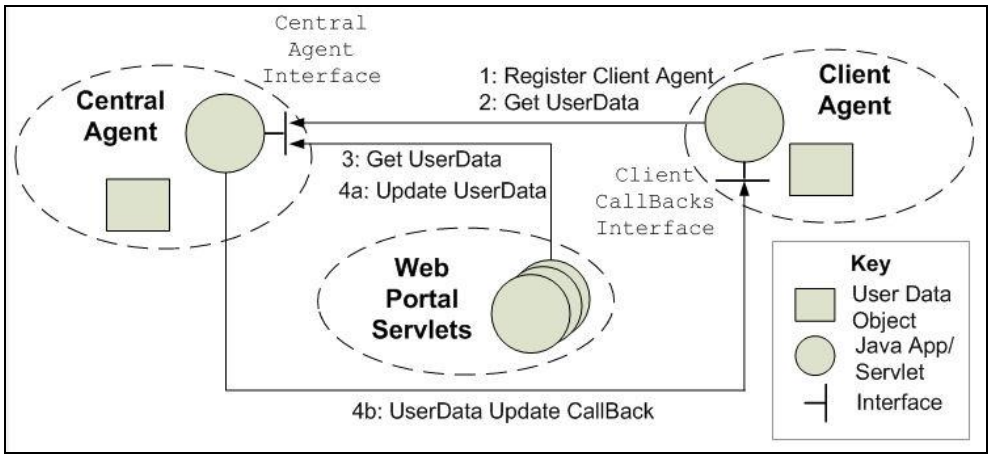

Figure 3-15: Object Interaction Diagram Showing 4 Steps (Phase 1).

Step 1. Register *Client Agent* - This remote method call was performed as soon as the *Client Agent* application on a door display started, and again at regular intervals of 5 minutes. A copy of the *Client Agent*'s remote interface (`Client CallBacks Interface`) was passed to the *Central Agent* during this method call, allowing the *Central Agent* to perform Java RMI CallBacks on the *Client Agent*.

Step 2. Get UserData - A door display owner's profile (containing public and private messages etc.) was stored in a UserData object at the *Central Agent*. A *Client Agent* retrieved of copy of its owner's UserData object as soon as it started in order to display the owner's name, office number (etc.) on the *Client Agent's* user interface.

Additionally, at regular intervals a *Client Agent* checked with the *Central Agent* to see if the owner's public and private messages had changed.

Step 3. Get UserData Object - After a door display owner had successfully authenticated with the web portal's 'Login' Servlet (see Figure 3-6 for a screen shot) a cookie was generated by the 'Login' Servlet and stored at the door display owner's web browser. This cookie was then used to verify and identify the owner interacting with the *Web Portal Servlets*. Once the authentication step was complete, the owner's web browser was forwarded to the 'LoggedIn' Servlet (see Figure 3-7 for a screen shot). The self-contained 'LoggedIn' Servlet, invoked and managed by the Tomcat Servlet runner, used the 'Get UserData Object' method to retrieve the appropriate door display owner's UserData object from the *Central Agent* in order to generate a HTML page displaying the door display owner's current public and private messages (see Figure 3-7).

Step 4a. Update UserData Object - This remote method call was used by a Servlet to update a door display owner's UserData object stored at the *Central Agent*. When this remote method was called the Servlet passed the web browser's Cookie (as described previously) along with the new information to the *Central Agent*. For example, this call was used when an authenticated door display owner using the 'LoggedIn' Servlet changed his or her public message and clicked 'update' (see Figure 3-7). In this case, the 'LoggedIn' Servlet received the HTML post operation from the owner's web browser, detected which piece of information had changed and called the 'Update UserData Object' method as appropriate.

Step 4b. UserData Object Update Callback - When the *Central Agent* received an 'Update UserData Object' call it firstly checked to see if it had previously received a 'Register *Client Agent*' remote call from the appropriate door display owner's *Client Agent*. If a 'Register *Client Agent*' call had been received, the *Central Agent* used the copy of the *Client Agent*'s remote interface (`Client Callbacks Interface`) to perform a CallBack in order to notify the *Client Agent* that its owner's public or private message had changed. This allowed, for example, a new public message set at the *Web Portal*, to be reflected on the user interface of the appropriate door display within several seconds.

Setting a Message Using SMS

In addition to using the Web Portal, during phase 1 owners of Hermes door displays were able to set public messages using GSM SMS messages. Figure 3-16 shows the steps required for this to take place. For simplicity Figure 3-16 does not show the process of the

Central Agent connecting to an RMI registry in order to look up the remote `SMS Generator Interface` for the Java SMS Gateway (bound to the RMI Registry previously). The architecture of the Java SMS Gateway was event driven using Java RMI callbacks. When an SMS was received at the Java SMS Gateway an event was then received at the *Central Agent* via a remote method call.

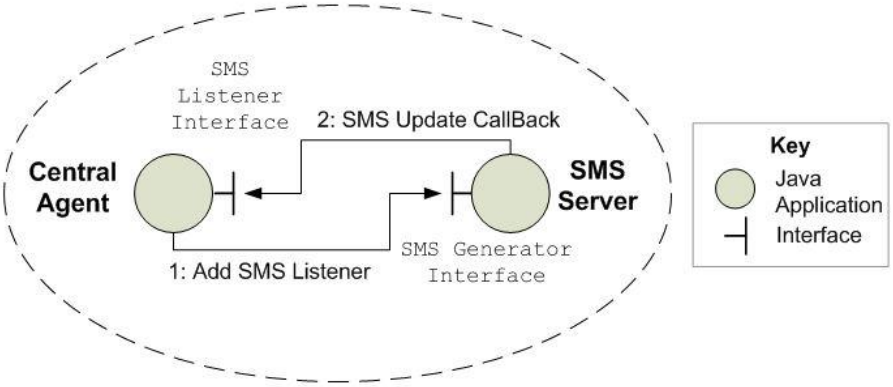

Figure 3-16: Object Interaction Diagram Showing 2 Steps (Phase 1).

Step 1. Add SMS Listener - When the *Central Agent* started it immediately looked up the Java SMS Gateway's `SMS Generator Interface` using a local RMI registry. Next it called the 'Add SMS Listener' method on the SMS Gateway's remote interface, passing it a copy of its own `SMS Listener Interface` remote interface. The SMS Gateway could now perform CallBacks on the remote `SMS Listener Interface` of the *Central Agent*.

Step 2. SMS Update CallBack - The SMS Gateway monitored a plain text 'inbox' file to which all new SMS messages received are appended along with the associated information (time, sender, etc). When a new SMS message was received and appended to the inbox file the SMS Gateway decoded the entry and constructs a SMSMessage object. This object was then passed to the *Central Agent* via a CallBack using the remote `SMS Listener Interface`. This enabled the SMS Gateway to notify the *Central Agent* that a new SMS message had arrived immediately. Once the *Central Agent* had received an SMS Update CallBack remote method call, it compared the phone number stored in the SMSMessage object with those stored in owners' UserData objects, in order to determine which Hermes door display owner sent the message. Once the number of the sender had been matched to an owner's UserData object his or her public message was updated. The *Central Agent* then attempted to notify the appropriate *Client Agent* instance in the same way as described in step 4b of Figure 3-15.

3.8 Deployment

After development and rudimentary testing of the initial prototype, two door displays were deployed. One was deployed for a lecturer, the other for a research student (myself), both in the Computing Department at Lancaster University with offices on the same floor (Owners A and B in Figure 4-3 of chapter 5). Both of these initial door display owners were involved in the development of the Hermes system and as such were considered tolerant of failure (which is likely to be a common occurrence in an early experimental prototype [Fitton '05]). Their proximity to the development process allowed these owners to informally evaluate the deployed system through regular use and feed information back into the design process quickly and easily. The disadvantage of this approach was that it was susceptible to the requirements capture problem of computer scientists developing systems purely for use by themselves and not taking into account other (perhaps less technical) users.

The two door displays received use from both owners and visitors directly after deployment and the following section recounts an analysis of the first weeks of use.

3.9 Emerging Issues

This section firstly describes the salient low and high level issues that emerged from deployment of the phase 1 prototype, focussing on door display owners, these were:

i) unreliability of the wireless network,

ii) unreliability of the door display platform,

iii) accidental/malicious overwriting of owner messages by visitors,

iv) trust/dependability,

v) ease of use,

vi) point of realisation.

This information was used to inform the new requirements discussed in section 3.10 and used in future prototyping phases (described in chapter 4).

3.9.1 Unreliability of the Wireless Network

One interesting problem, that only became apparent when the door display units were deployed, was that of severe 802.11 wireless network signal degradation when multiple people stood in front of a Hermes display. In such circumstances visitors essentially acted as 'large bags of water' and absorbed sufficient 802.11 signal to break network connectivity between a door display and the Central Server. This had a severe impact on functionality with the affected Hermes display, preventing messages set by owners appearing and the delivery of

notes left by visitors. This problem could clearly damage trust and negatively impact adoption. The severity of this situation was exacerbated by the fact that no appropriate visual feedback was displayed to indicate the reduced functionality.

Figure 3-17: Informing the User of a Delay (Phase 1).

In order to help address this problem the *Client Agent* was modified so that when an Java RMI call over the wireless network to the *Central Agent* failed (likely caused by temporary degradation in wireless network signal) after a short delay the operation was attempted again up to a maximum of three times. Due to the relatively long amount of time each RMI call could potentially take to fail, and the fact that the user interface would not respond during this time, a 'please wait' screen (see Figure 3-17) was introduced to help provide feedback to the user that the application was 'busy'. This design was chosen primarily for simplicity in terms of implementation and in terms conveying the state of the application to the user.

3.9.2 Unreliability of the Door Display Platform

An additional problem that only became apparent after deployment of the prototype door display was unreliability of the door display platform. Many crashes and associated problems encountered after deployment were caused by the Java VM, drivers for the wireless network cards and the PocketPC operating system. Individually or together, running continually, these elements have proved a source of instability. Much of this instability was attributed to the unusual use of this platform, perhaps not having been designed or tested under circumstances running continually for long periods. A common problem which caused door displays to crash was attributed to a faulty garbage collection mechanism in the Java VM leading to memory problems.

3.9.3 Overwriting of Owner Message by Visitors

This early version of the system enabled visitors to walk away from a door display with the screen still showing a visitor note by simply not pressing the 'Finish' button. This situation posed significant problems. The fact that visitor notes could remain on the screen went against the decision that notes left by visitors should not be public (this design decision was discussed earlier in section 3.7.4). Another consequence of this situation was that the owner's message would not be publicly visible while the visitor's note remained on the screen. However, the most important consequence of this situation was the adverse effect on the owner's trust in the security of the system which could potentially have a negative impact on adoption.

This problem raised the issue of owner vs. visitor authorship when displaying information publicly. This issue was especially interesting as a door display 'belongs' to the office occupant so occluding a message left by the door display owner seems analogous to graffiti (the shortcoming described here certainly enabled that behaviour). However, it is possible to construct scenarios where this type of functionality (allowing a visitor to appropriate a display) may not be a shortcoming, for example if a member of staff were away ill and unable to update his or her doorplate another member of staff would be able do this for them (as is the case with Post-it notes: see section 3.2 for further discussion of the use of Post-it notes within the Computing Department at Lancaster). From the content and frequency of the messages, this problem of malicious overwriting of owner messages appeared to be a single or small minority of pranksters attempting to play a joke on the door display owners or system developers, in which case this was perhaps unlikely to be a long-term problem.

3.9.4 Trust/Dependability

One key issue which seemed to be linked directly to dependability was that of trust: a door display owner or visitor would only bother to adopt a new system as part of his or her daily routines if they trusted that it worked correctly (i.e. they perceived it to be dependable). This seems a logical requirement from a door display owner's point of view but in order to ensure that the owner does not encounter failure, which may in turn damage trust, very high levels of reliability are required (additionally, feedback on system status might help prevent encounters of failure). The two factors of dependability and trust appeared to have a large impact on use for both the door display owners and visitors.

Initially, the two door display owners (despite being developers) were quite sceptical about trusting that a message set would actually appear outside their respective office doors. This scepticism was justified given that during this early development phase system reliability

was poor (as discussed in the previous sections) and in one case a paper note was placed next to a working door display.

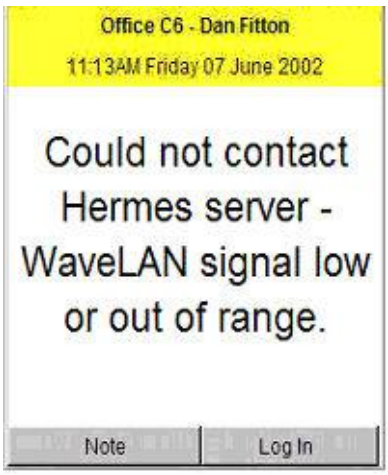

Figure 3-18: Informing the User of Failure (Phase 1).

Two properties paper notes and message 'whirlers' have, which are different to those provided by a system such as Hermes, are that it is clear when they are working and there is no hidden complexity. If the *Client Agent* Application could not contact the *Central Agent* upon start up, an error message was displayed (see Figure 3-18). However, no other indication of lost connectivity was given to owners or visitors. For example, if a *Client Agent* failed to send a visitor's note to the *Central Agent*, after 'Send' had been pressed, the user interface would return to the 'main' mode. Conversely, if a visitor's note was successfully delivered to the *Central Agent* the user interface would also return to the 'main' mode.

Providing system state information to users such as visitors to Hermes door displays is an interesting issue. For example, a visitor may not want to wait at a door display for some form of notification that his or her visitor note had been delivered. However, some form of simple status information might be helpful to both visitors and owners attempting to use a Hermes door display and highlights an issue for investigation in the future.

3.9.5 Ease of Use

In order to encourage initial adoption and maintain use of the prototype door displays, ease of use was an important issue to consider. Features that were time consuming or difficult to use and appeared to provide little benefit were likely to be rejected by owners, one example being the private messages function which required the visitor to authenticate themselves. The ability to set messages and read visitor notes from remote locations using the web portal, for example when attending foreign conferences, was clearly useful. The only problem that arose was that initially it was awkward for owners to remember the appropriate web address (which was long and included an additional port number). A visitor to a door display needed to be

able to leave a message without any prior knowledge of the system and investigation of logs collected during this initial deployment indicated that visitors with no prior knowledge of Hermes had left visitor notes.

When an owner chose to view visitor notes at a door display in phase 1 (the design of this feature was discussed earlier in section 3.7.3) the most recent note was displayed along with ‘Previous’ and ‘Next’ buttons for navigation. One owner commented that this was a poor design and far better implementation would be a table listing all visitor notes ordered by date along with some form of indication on whether a note was new, therefore improving ease of use.

3.9.6 Point of Realisation

One problem associated with the use of the web interface for setting messages was that unless the web page happened to be a foreground window on an owner's desktop then no visual prompting was provided to remind the owner to set a message. Consequently, the early Hermes owners found that they would leave their offices without setting a message, see the door display, realise that they had not set a message and then be forced to return to the office to leave a message via the web interface (or not leave a message at all). Therefore, in order to encourage initial adoption and maintain use, a range of appropriate methods for door display owners were necessary.

3.10 New Requirements

This section presents new requirements derived from analysis of the lessons learned and emerging issues from the deployment of the phase 1 prototype.

3.10.1 High Dependability

It was clear from the initial phase that owners perceptions of dependability were a very important issue when deploying the door display prototypes for regular everyday use. Tightly coupled with this was the notion of trust: if door display owners did not trust that messages set on their door displays would appear, they were unlikely to expend effort to use the system. If regular use was not maintained door display owners were likely to discard the system and not adopt it into their daily routines: which was one of the main aims of this work (the aims of this work are presented in section 1.5).

A second issue tightly coupled with dependability was reliability (i.e. the failure rate). From the deployment of the phase 1 prototype, it became clear that reliability of the software platform and of the network infrastructure required improvements in order to encourage and

maintain use. Improvements to reliability and providing feedback on failure are some of the primary aims for following phases (see Chapter 4).

3.10.2 Appropriate Interaction Methods

Feedback from the two door display owners during phase 1 indicated that the web portal was perhaps not suitable as a primary means of interaction. From this early stage of deployment it became clear that appropriate methods of interaction to lower barriers to use were essential to encourage adoption, and the design of these should be a goal of later phases. Appropriate methods of interaction can be considered in terms of two factors, existing daily routines and ease of use.

If the system does not fit easily into door display owners' existing daily routines too much effort may be required on the part of the owner to change them. Use of Hermes was not mandated, so a door display owner altering daily routines (a potentially time and effort intensive task) was optional and therefore unlikely to take place unless a benefit was perceived [Markus '90]. Consistent with the aim of using user-centred design approach (section 1.5 chapter 1) interaction methods, enabled by this digital equivalent to the traditional Post-it note, needed be explored in conjunction with feedback from door display owners. For example, enabling interaction with Hermes from technologies which door display owners already used on a regular basis (for example e-mail, instant messaging technologies etc.).

An important aspect of supporting adoption was the provision of interaction methods which were simple to use and accessible from a range of locations. During phase 1 the two display owners found that use of the web portal was very time consuming (opening a web browser, entering to the correct URL, entering username and PIN etc.) and a method of interaction when co-located with a door display was required. This was because the action of closing an office door when leaving an office often acted as a trigger to remind the door display owner to leave a message (highlighting the issue of point of realisation/opportunity discussed further in section 6.9.6). The frustration caused to an owner by having to re-enter the office (in order to set a message) suggested the need to extend the ways in which a message could be set to include the door display user interface.

3.10.3 Door Display User Interface Timeout

From the deployment of the phase 1 prototype it was clear that some mechanism was required to return the door display user interface to the 'main' mode (see Figure 3-3), if it was left in any other mode, after a period of inactivity. As discovered, this was necessary to prevent a door display owner's public message being hidden by a visitor note and breaking the

policy of visitor messages being private. Additionally the user interface could potentially be left in the ‘login’ or ‘logged in’ modes with similar consequences.

3.11 Summary

This chapter has presented the initial requirements, design, implementation and deployment of phase 1 of the Hermes system. The door displays themselves were based around a PDA device housed in a custom-made case and a Java application designed to support a limited range of functionality (in order to help support the aim of providing an information appliance).

The deployment in phase 1 for two ‘friendly’ door display owners (members of the development team) was successful in terms of exposing important issues and new requirements. While these owners may not have been entirely representative of a range of typical owners within the Computing Department at Lancaster University, they provided an excellent environment where the prototypes could receive approximate ‘real world’ use but where problems such as failure would not affect future use and feedback was received quickly [Fitton ‘05].

The issues which emerged from this initial deployment, such as unforeseen hardware problems, user interface and usability issues did not surface during testing and use in the lab; this demonstrated the value of deployment and use in the ‘real world’.

The issues that emerged during phase 1 were used to generate new requirements for additional deployment phases, some applying to specific features and functionality (for example the need to improve the current interaction model) and others being more general in the context of the system (for example the need for high dependability and appropriate interaction methods for door display owners in order to encourage adoption). In the following chapter the next phases of the development of Hermes are discussed.

Chapter 4

The Evolution of Hermes

4.1 Introduction

This chapter details the evolution of the Hermes system following on from the initial phase 1 deployment. The development of Hermes focussed primarily on door display owners (designing functionality in order to lower their barriers to use) in order to explore the aims of this thesis to investigate adoption and use. Firstly, background information about the owners of door displays during deployment is provided. Next, each of the five remaining phases of Hermes are presented, including an explanation of each major modification and an analysis. Following this, the issue of reliability is examined though a discussion of the primary reliability problems encountered during deployment and solutions. Finally, a discussion of the user-centred design approach used during development is given.

4.2 The Later Development Phases of Hermes

The development phases of Hermes are shown in Figure 4-1 with bars representing development and deployment in each phase. In the following sections phases 2-6 of development are described individually each with a summary of the major changes and an analysis. A detailed log of all changes made to the Hermes system is provided in appendix A.

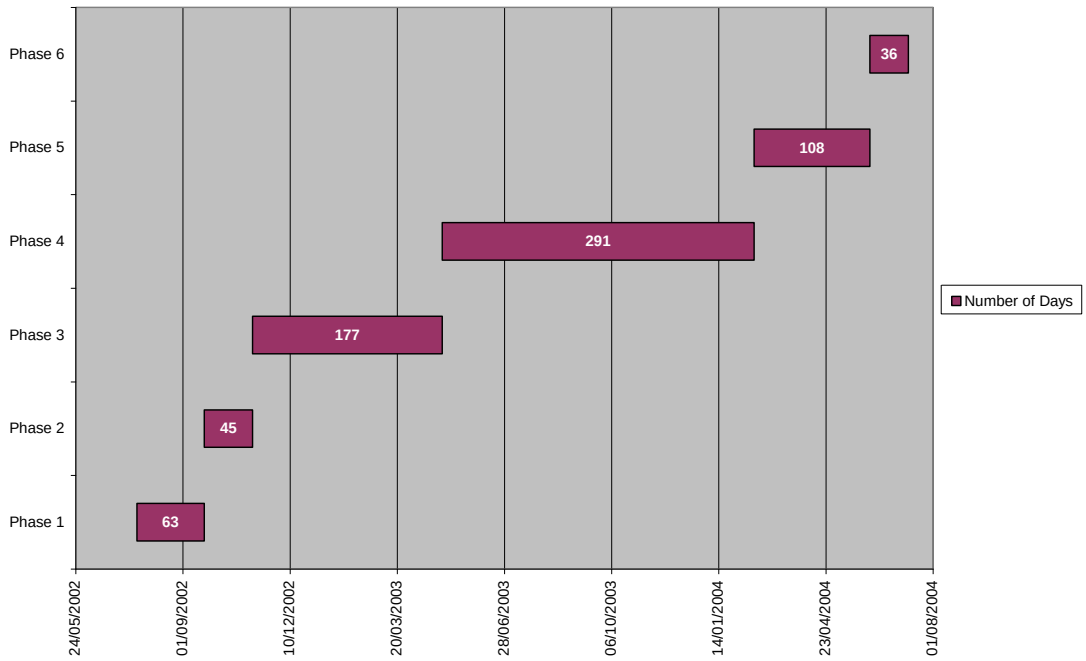

Figure 4-1: The Development Phases of Hermes.

The deployment of Hermes reached a maximum of ten door displays and lasted approximately twenty-seven months, with twelve different door display owners during that time. These owners have included a head of department, a professor, two lecturers, three senior lecturers, four secretaries, one research student and a research fellow. Figure 4-2 summarises the twelve Hermes owners along with the length of time that they had a door display, this information is also shown in Figure 4-3 as a Gantt chart.

ID	Description	Start Date	End Date	Deployment/ Days
A	Senior Lecturer	26/03/2002	16/07/2004	843
B	Research Student	06/05/2002	16/07/2004	802
C	Secretary	20/07/2002	26/05/2004	676
D	Lecturer	14/08/2002	19/07/2004	705
E	Professor	23/08/2002	30/07/2004	707
F	Senior Lecturer	03/11/2002	16/07/2004	621
G	Head of Department	03/11/2002	30/07/2003	269
H	Senior Lecturer	03/11/2002	30/07/2004	635
I	Sociologist	08/11/2002	05/05/2004	544
J	Secretary	23/05/2003	17/07/2004	421
K	Lecturer (part time)	05/10/2003	19/07/2004	288
L	Departmental Officer	03/06/2004	16/07/2004	43
M	Secretary	03/06/2004	19/07/2004	46

Figure 4-2: Hermes Door Display Owners.

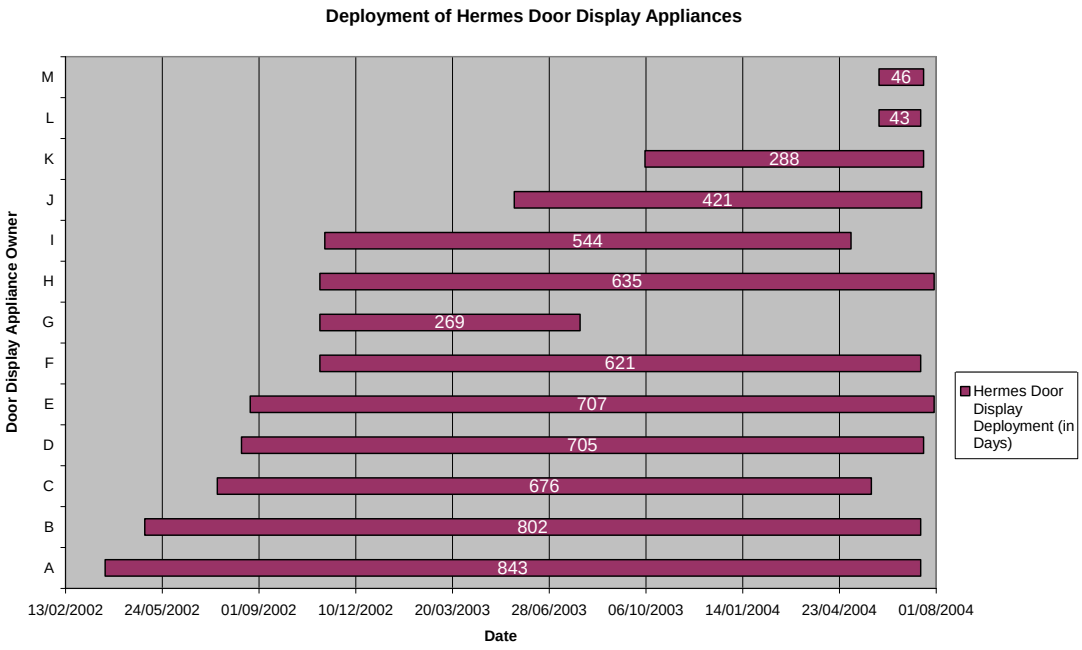

Figure 4-3: Deployment of Hermes Door Displays.

The main motivation for the aims of the phase 2 – 6 of Hermes were driven by the aims of this thesis (to investigate adoption and use of Hermes from door display owners) and included:

- addition or refinement of functionality in order to lower barriers to use from owners (for example, to help Hermes fit with owner's existing routines) to help support adoption,
- improvements to reliability in order to help maintain owner trust and support adoption,
- expansion of the door display deployment.

4.3 Phase 2

During this phase the number of deployed units was increased from two to five (owners C, D and E from Figure 4-2). The primary objective of phase 2 was to improve owners' perceptions of the dependability of Hermes in order to encourage use, as this was identified as a key requirement in the previous phase. This was done by improving system reliability (see section 4.3.1) and addressing usability problems reported by the two door display owners in phase 1 that affected trust (see section 4.3.2). Informal feedback from door display owners was also used to design new features in order to help support adoption. For example, one comment that a door display did not allow the expressivity provided by a paper note resulted in the feature described in section 4.3.3. Comments from owners that it was too

difficult to authenticate and view visitor notes at a door display resulted in the implementation of features described in sections 4.3.4 and 4.3.5.

Prior to deployment of a door display each new owner was asked to 'register' via a web page, where he or she input information such as name, a username, a PIN, a 'default' public and private message in order to create and populate an owner profile. When deploying a door display the new owner was given an induction that consisted of an explanation of each aspect of the Hermes system and a demonstration of all the interaction methods. Figure 4-4 shows the deployment of three Hermes displays in close proximity along one corridor.

Figure 4-4: Deployed Hermes Door Displays (Phase 2).

4.3.1 Improving Reliability

In addition to code analysis (discovery of memory leaks, etc.) the problem of poor wireless network signal (as discussed in detail in section 3.9.1) was tackled by modifying the door display case design. In phase 1 the case was an enclosed aluminium box and the shielding effect caused by this design reduced the wireless network signal. After experimentation it was found that providing a window in the top of the case reduced this shielding effect (Figure 4-5) and all door display cases were modified (this modification is discussed in detail later in section 4.8.1).

Figure 4-5: Modified Case Top with iButton Reader (Phase 2).

4.3.2 Improving Trust

In phase1 it was found that pranksters would overwrite an owner's public message by simple not selecting 'finish' after drawing a note and a requirement emerged to solve this problem (this is discussed in detail in section 3.10.3). An upper time limit was placed on the period that the 'visitor note composition' mode could be displayed. When this time limit was reached the *Client Agent* user interface would return to its 'main' mode and discard the visitor note. The decision was made to discard rather than deliver visitor note after the timeout so that notes left by the prankster (containing offensive material) were not be delivered to owners. The time limit was also imposed on other aspects of the user interface, for example, if an owner did not 'log out' after authentication this was automatically done after a short period of inactivity.

4.3.3 Creating a Freehand Message

After a request from one owner (E in Figure 4-2, who was also involved in work on the Hermes project) that the current functionality did not provide the same expressiveness as his previous paper notes (see section 6.9.8 of this thesis for more discussion of the issue of expressivity) the *Client Agent* was modified to allow an owner to create a freehand message at his or her door display (in order to help support adoption from this owner). This option was available once an owner had successfully completed the authentication process. Figure 4-6 shows an example of a freehand message composed by the owner who requested this feature.

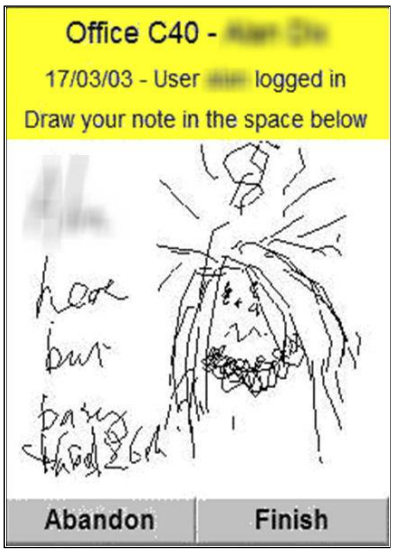

Figure 4-6: Enabling the Hermes Owner to Compose a Freehand Message (Phase 2).

4.3.4 iButton based Authentication

The first door displays to be deployed were equipped with iButton readers (and the hardware and software platforms were chosen to support this technology, see sections 3.5 and 3.6 for further discussion), the motivation for this feature was to help lower the cost of authentication and therefore lower the barriers to use. However, the appropriate software support was only completed during phase 2. Immediately after an owner (or potentially a visitor) docked his or her iButton with a reader the authentication process was automatically completed.

4.3.5 Viewing Visitor Notes

In response to comments from one owner during phase 1 they found the method for viewing visitor notes at a door display difficult to use, the interface shown in Figure 4-7 was designed which included a table displaying the sender, a timestamp of when the note was left and an indication (an asterisk in the far right column) of whether the note had been viewed previously. Owners then used the stylus (or a fingernail) in order to select the desired visitor note by pressing anywhere in the desired row. The use of a table was suggested by a door display owner but equally appropriate designs might have included a collection thumbnails allowing an owners to select a thumbnail to see the full size note and further information.

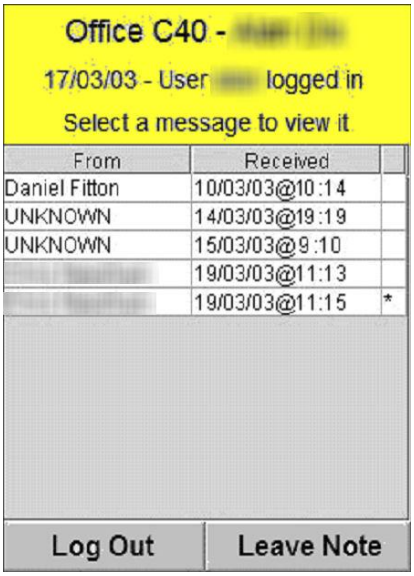

Figure 4-7: Viewing Messages Left by Visitors (Phase 2).

4.3.6 Analysis of Phase 2

Only one of the five Hermes display owners made use of the freehand message drawing facility described in section 4.3.3 (the owner who requested the feature) but this increased his use of Hermes and helped him adopt the system as part of his daily routines. His reason for using this facility was largely due to the extra freedom for creativity that freehand drawing permitted and, in part, due to the previous use he made of a selection of hand drawn paper notes. This owner used the freehand message drawing facility almost exclusively and it was his default method for setting a message.

During this phase it was found that the introduction of iButtons did not prove an acceptable tool to lower the barriers to authentication or increase the extent to which authentication took place. However, it should be noted that only enough hardware was available to equip three door displays with iButton readers (the first three deployed) and only four owners had iButtons. Additionally, there were only three reasons for an owner to authenticate with a door display: to view a private message, to view notes left by visitors and to leave a freehand public message. Out of all three functions, only the latter was regularly used and this was by a single owner. However, early unreliability problems meant that he completely rejected the use of his iButton as an authentication method. Additionally, this owner experienced several failures when attempting to use the SMS interaction method (the design of the SMS interaction method is described in detail in section 3.7.3) and rejected SMS as an interaction method too. A different owner commented that he found the overall experience of using his iButton for authentication (requiring him to remove and replace the bunch of keys in his pocket to which the iButton was attached) simply too awkward to use on

a regular basis. These examples highlight the impact of trust-damaging experiences of failure on adoption.

The use of iButtons for authentication also proved unsuitable as two technical problems emerged during development. Firstly, due to the low processing power available on the door display devices, an owner had to wait several seconds after docking his or her iButton for the authentication process to complete. Secondly, the introduction of additional software libraries to support the iButton reader significantly reduced the reliability of iButton equipped door displays.

During this phase, a number of owners commented that they disliked the interaction model for setting a public message. An owner would set a public message that effectively acted as a 'default' message, e.g. a 'cute' picture or a simple text message such as "X's Office". As necessary, the owner would change this message to something more transient, such as "Gone for coffee". Clearly, the owner would only want this latter kind of message to be displayed *temporarily* before he or she would wish to revert back to the 'default' public message. However, in order to remove a 'temporary' message an owner had to *re*-set his or her public message back to the preferred 'default' message (as shown in Figure 4-8). This meant that the same 'default' message was set repeatedly, frustrating owners. This issue highlighted the importance of lower barriers to use to enable adoption from owners.

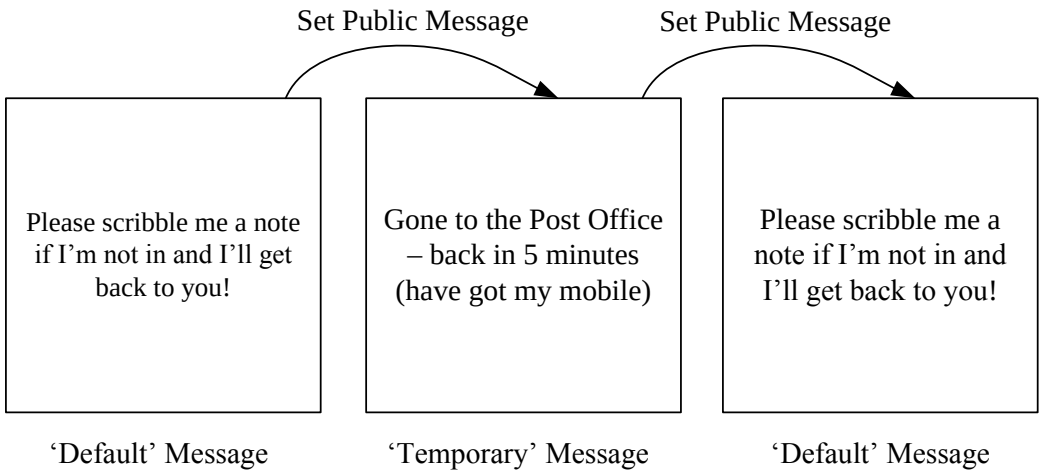

Figure 4-8: The Problem of 'temporary' and 'default' Messages (Phase 2).

Two owners in particular criticised the system for only enabling the reading of notes left by visitors via a web page or a Hermes display. These owners commented that this approach was not always appropriate and simply required too much effort if the corresponding web page was not already open. It was suggested that an alternative mechanism for reading messages should also be available that would not require significant additional effort on the part of the owner.

4.4 Phase 3

During this phase, the number of deployed door displays was increased from five to ten (owners F, G, H, I, and J from Figure 4-2). As discussed in the analysis of phase 2 (section 4.3.6), several owners found the interaction model for setting public messages frustrating and in order to address this, the notion of 'temporary' messages was introduced (section 4.4.1).

In response to criticism from a number of owners that the web portal had to be used in order to read visitor notes (section 4.4.1), and requests from two owners in particular, e-mail integration was added allowing visitor notes to be e-mailed to owners (section 4.4.2). The e-mail integration also enabled owners to set temporary messages remotely in order to support adoption from staff who notified others of absence by e-mailing the departmental mailing list (a common practice among secretaries in the Computing Department, as discussed in section 6.6.3) and to further assist adoption by owners.

A technical change was made to improve the logging functionality (section 4.4.3) and door display owners were allowed to view and change their owner profile via the web portal (section 4.4.4).

4.4.1 Supporting Temporary Messages

The notion of *temporary* and *default* messages was introduced in an attempt to create a simple procedure for enabling an owner to revert back to a 'default' public message when his or her 'temporary' was no longer appropriate. The way in which this aspect of the system worked was quite simple: when an owner chose to remove his or her temporary message the previously set default message was displayed. This is analogous to physically removing a Post-it note to reveal a message or picture which has been hidden behind it. The intention was to help encourage adoption from door displays owner by providing a sufficiently low effort method of sharing a message (the issue of control vs. effort is discussed in detail in section 6.9.10).

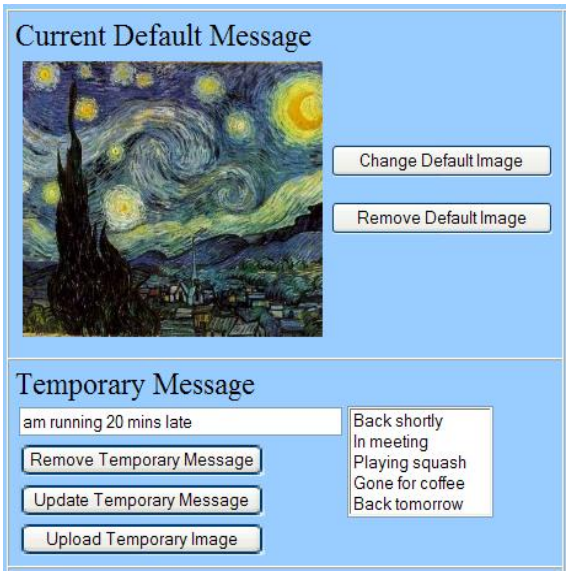

Figure 4-9: The Modified Hermes Web Interface (Phase 3).

As can be seen from Figure 4-9, the modified interface enabled the owner to specify a default message. Typically, this took the form of a picture (as in the example shown) or a textual message such as "John's Office – Please leave a message". Beneath this section of the interface the owner was able to specify a temporary message. The door display owner still had the choice of selecting a message from a list of preset messages or entering free text. In the example shown in Figure 4-9 the temporary message field reflected a temporary message that the owner had entered remotely via SMS but had not yet been removed. A temporary image had the highest visibility precedence, followed by temporary textual, followed by default image and finally default textual. Image messages were given a higher precedence that textual messages in order to help simplify the web portal user interface (i.e. an owner cannot see the options to configure a textual message when an image is configured).

Given the existing functionality this modification seemed logical and discussion with door display owners revealed a positive response to the design. One alternative design possibility would have been to force owners to use an image as a default message and only allow textual temporary messages, however this would have reduced expressivity.

Having removed the private message feature implemented during the development of phase 1, the intention was to return to exploring the notion of private messages when a suitably low effort (for the owner) and timely authentication method (for the visitor) became available.

4.4.2 E-mail Interaction

In order to address the comments of owners described earlier in this section, the system was modified such that every time a new visitor note was left on an owner's display a

HTML based e-mail would be sent to the owner containing an image of the message. A screen shot example of a Hermes email message viewed with a typical email client is shown in Figure 4-10. Additionally, the e-mail interaction method enabled a door display owner to update his or her current temporary textual message by sending an e-mail (either textual or with an image file attached) to a predefined e-mail address. Enabling images attached to e-mail messages to be set as a temporary message also meant that an owner could update his or her door display using a mobile phone via MMS (Multimedia Messaging System) as an e-mail address can be entered as a MMS message destination. These two remote interaction mechanisms demonstrated affordances provided by a digital approach (compared to the traditional paper based approach). See section 7.3.2 for a full discussion of the affordances provided by Hermes.

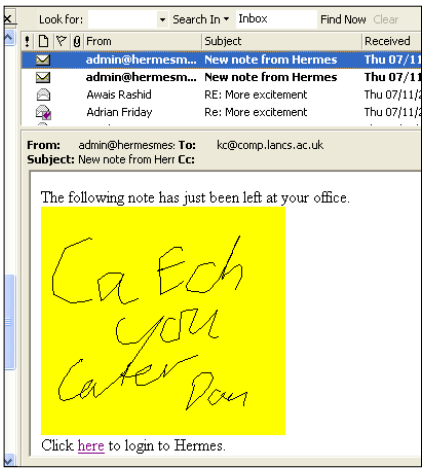

Figure 4-10: Receiving Hermes Messages via E-mail (Phase 3).

4.4.3 Improvement to the Logging System

During this phase an oversight in the design of the logging system was discovered whereby log messages sent from door displays were intended to be identified using the originating IP address. However, problems with the wireless network led to the IP addresses of door displays (assigned via DHCP) changing on a regular basis which made it impossible to identify the door displays from which log messages originated. During phase 3 the opportunity was taken to carefully redesign the format of the logs to include more information and to improve the way in which information was appended to the log file in order to aid later analysis (see Appendix B for an example of a generated log file).

4.4.4 Access to Owner Profiles

During phase 3 the web portal was modified in order to allow an owner to modify his or her owner profile. The main motivation for this was to allow owners to tailor the functionality of Hermes primarily by enabling or disabling notification of new visitor notes

via SMS and e-mail. One additional advantage of this was that owners could now alter personal information (such as e-mail address, mobile phone number etc.) without needing to contact the system administrator. It should be noted that for simplicity of implementation changes to owner profiles were stored in the *Central Agent* application using Java objects (residing in main memory); the configuration file was not updated.

4.4.5 Analysis of Phase 3

After deployment, informal feedback from owners demonstrated a positive attitude towards the notion of default and temporary messages (section 4.4.1) and the delivery of visitors' notes via e-mail (section 4.4.2). However, five of the ten owners commented, informally, that the effort required to set and remove messages (primarily the latter) was still too great, implying that to encourage owners to adopt the Hermes system and use it to share context the barriers to use must be lowered further.

Unfortunately, the general reliability of the system during this phase was still of insufficient quality. When a door display failed, it was up to the owner of the display to notice that it was not functioning correctly and provide feedback to the system administrator. This was entirely the wrong approach. Firstly, it was not always apparent to an owner when his or her display stopped functioning correctly. Secondly, staff in the department tended to be extremely busy and (quite rightly) would not always give priority to notifying the system administrator. Thirdly, such reliability problems can greatly reduce the perceived dependability of the system and, consequently, have a detrimental effect on adoption and use.

The redesign of the logging system, especially the logging format, was an important step as the majority of the logs generated previously were of very little use, the originating door display (and hence owner) effectively not being attached to log entries. The design considerations for the logging system are discussed further in section 5.3 of chapter 5.

4.5 Phase 4

The main goals of this phase were two-fold, firstly to use owners' comments to help enable adoption by lowering barriers to use. This was done by providing a feature to allow temporary messages to be quickly and simply set and removed (section 4.5.1) at a door display. Secondly, to tackle some of the reliability problems that harmed owners' trust (section 4.5.2). Additionally, the web portal was modified in order to encourage owners to personalise door displays (section 4.5.3) and, in order to fulfil his specific requirements, one enterprising door display owner built his own tangible user interface (section 4.5.4). During this phase, a PDA unit from a door display was stolen and, consequently, steps were taken to improve the physical security of the displays (section 4.5.5). A questionnaire was given to

door display owners at the start of this phase in order to investigate potential new features, this is discussed in more detail in section 4.10.1.

4.5.1 Removing and Setting Messages via a Door Display

When the notion of temporary messages was first introduced in phase 3, owners commented that the effort required to remove a temporary message was still too great. Several door display owners (five out of ten) commented, informally, that the door displays were ideally placed to allow a message to be configured when entering or leaving an office but that they were forced to use other interaction methods (for example the web portal or e-mail). Prior to phase 4, the procedure to set a temporary message at a door display was relatively cumbersome (given the need to carry out an authentication process and draw a message by hand) and was only used by a single owner in order to gain the level of expressivity he desired (see section 4.3.3 for further discussion of this owner). The comments highlight some key problems that needed to be addressed to encourage adoption.

The chosen solution was to enable owners to set temporary messages using the interface shown in Figure 4-11. If the middle part of the screen was touched for a short period of time, the interface shown in Figure 4-11 was displayed, an owner could then touch the desired temporary message to set it (or 'Abandon'). The system was modified to enable owners to remove temporary messages by touching the screen for a short period of time. The 'screen touch' period for setting and removing messages was preset at one second but which could be set by a door display owner via his or her owner profile.

Figure 4-11: Temporary Messages Door Display Interface (Phase 4).

The labelling of buttons depicted in Figure 4-11 illustrates how a door display owner could select from a choice of prescribed temporary messages. The prescribed temporary messages were stored in the door display owner's profile and, as such, could be personalised

using the web portal (as shown in Figure 4-12). In order to make the buttons tall enough to be easily pressed with a finger only five could be displayed on the screen at once, if the owner had configured more than five messages a scroll bar had to be used.

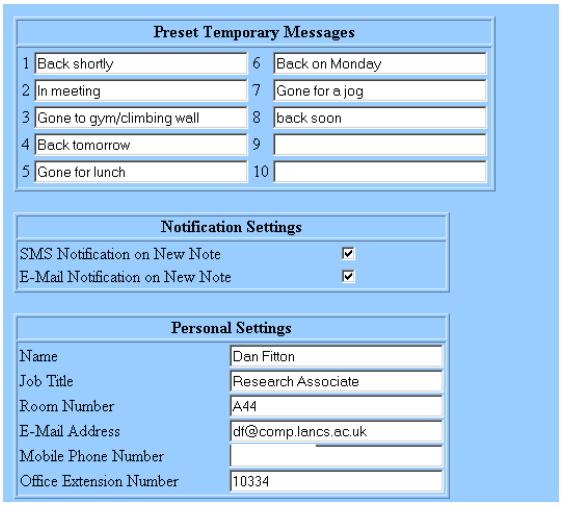

Figure 4-12: Configuring a Predefined Temporary Message List (Phase 4).

When designing this solution an interesting conundrum involving a security vs. ease of use trade-off was encountered. To make the task of setting a temporary message as simple as possible it was decided not to force an owner to authenticate themselves. This decision simplified the owner's task of setting a temporary message. However, an obvious implication of this was that the security of the door display was compromised as any visitor to a door display with knowledge of this feature could remove or set a temporary message. By prescribing the temporary messages that could potentially be set by an unauthenticated visitor/owner (i.e. by not allowing an unauthenticated visitor to enter a freehand message) this removes the potential danger for 'prank' or 'inappropriate' content being left publicly visible (as described in section 3.9.3 of chapter 3). It was found that this feature allayed owners' fears of unauthenticated visitors changing the current temporary message (as only messages chosen by owners could be set) especially when owners realised that this trading-off of security for ease of use enabled a temporary message to be set at a door display with such little effort (the issue of control vs. effort is discussed later in section 6.9.10).

These features were designed to provide a simple means for an owner to configure messages using his or her door display with a very small amount of effort in order to encourage regular context sharing using Hermes (the issue of control vs. effort is discussed in detail in section 6.9.10). A questionnaire given to Hermes owners during this phase (the results of which are shown in Appendix C and discussed later in section 4.10.1) was used to gain owner feedback before implementation. However, one possible low effort alternative would have been to use some form of location awareness technology (for example active

badges [Harper '92]) to monitor when an owner has left his or her office and automatically set a message (e.g. to set ‘Out to Lunch’ if an office is left between 12:00-13:00). While this design would have required little or no effort on the part of the owner and increased security, many owners were not keen to have their location tracked (as discussed in the results to the owner questionnaire in section 4.10.1) and this would have been very costly to develop and deploy. Alternatives to the user interface used to set a message (shown in Figure 4-11) would have included thumbnails allowing images to be set or even allowing more descriptive messages to be constructed by selecting the appropriate words from a list (e.g. “Gone for {lunch, coffee, meeting} back in {5 minutes, 10 minutes, 15 minutes}” etc.). While alternatives such as these may have increased expressivity they were discarded as a key aim was to maintain simple functionality and user interfaces.

4.5.2 Increasing System Dependability

In order to help improve system dependability an additional *Management Agent* component was added (discussed in detail in section 4.9) which included functionality to detect and provide feedback on the failure of door displays. The motivation for providing this feedback to owners was to help avoid potentially trust damaging scenarios where an owner might attempt to interact with a non-working door display.

4.5.3 Encouraging Personalisation

The majority of door display owners did not set informative text or an image for a default message. Consequently, door displays not having a temporary message set appeared to always display the same message (for example “Leave me a message” or “X’s office”) which was unlikely to attract an owners attention and help remind them to use Hermes. In an attempt to address this issue owners were encouraged to set a visually attractive picture as a default message, also effectively promoting personalisation. Ten thumbnail images were included on the main ‘Logged In’ page of the web portal (Figure 4-13) and clicking on these set the full-size image as the owner’s current default image message. This design was chosen as a simple and low cost method to support personalisation in this way. The right had side of the main web portal page was chosen to ensure it did not demand an owners attention but was still easily visible. Alternatives would have included automatically changing all owners default image (for example to the Lancaster University logo) or prompting the owner to ask if they would like to set a default image, both of these options were discarded as they may have irritated owners.

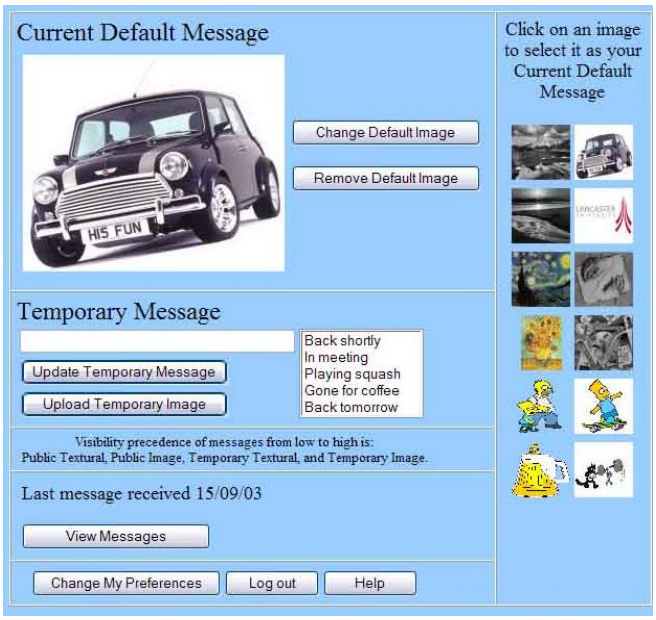

Figure 4-13: Encouraging Owners to Use Pictorial Default Messages (Phase 4).

4.5.4 A Tangible User Interface

Interestingly, some owners commented that the Hermes display itself did not provide an appropriate/sufficient visual prompt for setting a message. Indeed, one owner in particular commented that although he was a strong advocate of the Hermes concept he found that he frequently forgot to set a message because he tended not to notice his door display when leaving his office. This particular owner solved this problem through the development of an additional tangible user interface. This allowed him to set predefined messages extremely quickly and the tangible interface could be placed in an appropriate location (for example highly visible location to act as reminder) to fit in with his existing daily routines. This can be seen as an extreme case of domestication: adapting technology to particular features of a domain and developing new forms of use [Fleck '88].

The hardware component (shown in Figure 4-14) provided an additional set of physical buttons (each with associated LEDs to provide feedback to the owner when a button was pressed) each of which allowed a specific, tailorable, state to be selected. This device was constructed using a PIC 16F628 microcontroller and RS232 serial driver. Key presses were conveyed to the owner's desktop PC via a serial line, where they were read by a custom built Windows .NET service. Key presses were subsequently interpreted and automatically used to configure the Hermes system via the web portal.

Several different physical positions were possible for the keypad device, but the owner in question found that his favourite was alongside his monitor (so that he saw the keypad when getting up from his desk) as illustrated in Figure 4-14. Although the owner

mentioned that locating the device on the *inside* of his door frame also had the desired visual prompt effect. This issue of point of realisation/opportunity for owners setting messages using Hermes is discussed further in section 6.9.6.

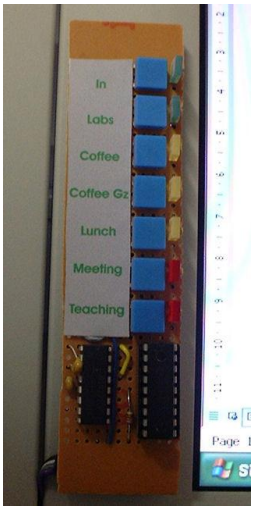

Figure 4-14: An 'Owner Developed' Prototype Tangible Interface (Phase 4).

4.5.5 Improving the Security of Door Displays

The housings for the door displays were manufactured in two parts, a main body housing the PDA device and a removable top cover enabling the PDA device to be removed. Prior to this phase, when door displays were deployed the top covers were simply screwed on to enable the PDA devices to be removed easily in the event that they needed to be reset (the reset switch being on the rear of the PDA device). The original intention was to secure the top covers with metal rivets (as opposed to screws). However, using screws made it very easy for the administrator to remove the PDA devices which seemed an acceptable trade-off for security (from the administrator's point of view).

During this phase a PDA device was actually stolen from its housing, the thief only needing to remove the screws to steal the device. This clearly demonstrated the need to use the more secure method of fastening the housing tops with metal rivets. However, the PDA devices still crashed occasionally and needed to be reset (requiring the device to be removed from its housing). The solution to this problem was to attach wires to the reset switch inside the PDA device and run them to the interior of the office to which it was attached. Door display owners were then shown how to reset the PDA devices and re-start the Hermes application, effectively enabling them to reboot the system.

4.5.6 Analysis of Phase 4

Door display owners responded positively to the functionality that enabled temporary messages to be removed and set by touching the screen of a door display. The interaction

method was provided in an ideal location for the task of setting a message when leaving an office and completing the task only required two presses of the door display screen (typically taking a few seconds). Additionally, an owner could change his or her list of predefined messages to ones used regularly. Many owners seemed to favour this interaction method over all others, the primary advantage being its speed and ease of use (see section 6.9.2 for further discussion of appropriate methods of interaction). From the increase in use after the addition of this interaction method (discussed later in section 5.5) it is clear that this lowered the barriers to use sufficiently to help enable adoption from door display owners. The fact that owners were prepared to give visitors the potential to remove a temporary message because it simplified the process of removing messages for themselves demonstrated an interesting instance of the security vs. ease of use trade-off. This new feature also had some interesting impacts on context sharing as it enabled owners to share relatively unspecific messages from their predefined lists but the trade-off was that owner set more messages (the issues of appropriate interaction methods, context sharing and control vs. ease of use are discussed further in sections 6.9.2, 6.9.4 and 6.9.10 respectively). As owners were able to set temporary messages more quickly the temporary granularity of messages set changed. In more detail, as the cost of interaction was small owners would now set messages such as “Back in 5 minutes” and “Gone for coffee” on a regular basis (the issue of temporal granularity in messages set is discussed in detail in section 6.9.5)

The addition of thumbnail images to the web portal ‘Logged In’ page represented a move towards encouraging door display owners to personalise door displays (by lowering the effort to set a default image). The small selection of images were chosen to appeal to a range of owners and all door display owners (apart from one) were quick to use this new feature.

Since deploying the tangible interface the owner in question found that he set messages much more regularly. The interaction method has some striking similarities with the other interaction methods added during this phase (indeed it was developed after the deployment of the feature described in section 4.5.1) and it is interesting to note that the association of setting a temporary message with the pressing of a ‘button’ was helpful for this owner. In the future this tangible interface should be a requirement for a system such as Hermes (see Appendix H) as this low effort mechanism for sharing context which can be position to encourage use could clearly encourage adoption (the issues of control vs. effort and point or realisation/opportunity are discussed in detail in sections 6.9.6 and 6.9.10 respectively).

In addition to improving the physical security of door displays in this phase, a mechanism was provided allowing door display devices to be reset more easily. This change

potentially meant that owners could help rectify some reliability problems, however, only a single owner made use of this facility on a regular basis.

4.6 Phase 5

During phase 5, two main technical modifications were made to the Hermes system in response to owner feedback. Firstly, one owner had commented that Microsoft's MSN Messenger would make an ideal remote and local interaction method for Hermes. In response to this owner's comment, and because it was likely to assist adoption of Hermes by door display owners, this interaction method was added (section 4.6.1). Secondly, persistent storage for owner profiles was implemented in order to avoid the changes owners made to profiles being lost when the *Central Agent* was restarted (for updates etc.). Nine out of the ten door display owners personalised their owner profiles and commented that they found it irritating when changes to profiles were lost (and the personalisation process had to be repeated).

4.6.1 MSN Messenger Integration

Several door display owners were regular users of the MSN messenger application and, as instant messaging applications are fast becoming a regular part of working routines [Lovejoy '03] to support lightweight textual communication, they provide an ideal way for an owners to set messages. Additionally, most instant messaging applications enable users to share some notion of state with a closed user group (commonly called a contacts list, 'buddy' list etc.) a common example being 'At lunch'. Users often have to configure this state explicitly through a user interface and several applications allow a user's state to be changed automatically (a common example being a change to an 'Away' state if the user does not interact with his or her computer in a predefined amount of time). This notation of state also fits well with the Hermes system, as a door display message could automatically be updated to reflect the state of an owner's instant messaging application.

To enable MSN messenger integration[9] the door display owner firstly had to configure a MSN Messenger e-mail address in his or her profile using the web portal then add

[9] Initial investigation into the technical feasibility of this interaction method was carried out by Edward Hannay as part of an undergraduate project for a Computer Science degree course at Lancaster University.

the Hermes server to their MSN Messenger contact list. Once these steps were complete, if an owner sent a textual message to the 'Hermes Server' contact the message was set as the owner's current temporary message. Once the new message had successfully been set, the owner received a confirmation message (see Figure 4-15). If the owner prefixed the textual message with '!default' the textual message was set as the current default message, the message '!notify' toggled functionality enabling the *Central Agent* to respond to changes to the owner's MSN Messenger state and update the current temporary message as appropriate. Additionally, if a visitor note was left at an owner's door display and the owner was logged in to MSN Messenger, the Hermes *Central Agent* would send the owner a message to this effect along with a URL which will take the owner to an image representing that message (this functionality could be disabled in the owner profile).

Figure 4-15: Setting a Temporary Message via MSN Messenger (Phase 5).

4.6.2 Persistent Storage of Owner Profiles

Prior to this phase, changes made to owner profiles were stored in memory and not reflected in the appropriate file (therefore every time the *Central Agent* was restarted changes to owner profiles were lost). In the early phases of Hermes, a *Central Agent* restart primarily meant that owner's default and temporary messages would revert to values input during registration (the owner registration process is discussed in section 4.3). If an owner had set a picture for his or her default message (especially common after the changes discussed in section 4.5.3) he or she would often infer that the *Central Agent* had been restarted upon noticing that his or her default message had changed. After phase 4, when owner profiles included a carefully chosen set of personalised temporary messages, door display owners were (quite rightly) annoyed at losing changes to profiles and this reduced trust in the reliability of the Hermes system. Additionally, much more information was now being stored in owner profiles (as shown in Table 4-1) than in phase 1 (as shown in Table 3-3).

Data	Purpose
Unique user ID (iButton ID)	iButton authentication.
Username	Used to log in on the web portal and on door displays.
PIN	Used to log in on the web portal and on door displays.
Office Number	Displayed at the top of the door display user interface.
Full Name	Displayed at the top of the door display user interface.
E-mail Address	For developers to contact door display owners.
Mobile Phone Number	Identify SMS sender to update public message.
SMS Notify on New Note Option	Whether to alert the owner via SMS if a visitor has left a note at his or her door display.
Default Textual Message	Current default textual message.
Default Image Message	The filename of the current default message image.
Temporary Textual Message	Current temporary textual message.
Temporary Image Message	The filename of the current temporary message image.
Ten predefined Temporary Textual Messages	The predefined list of ten textual temporary messages.
'Screen Press' Action timeout	The length of time the screen has to be pressed before a temporary message can be set/removed.
MSN Messenger E-mail address	The owner's e-mail address used for MSN.
MSN Notice State Option	Whether to update the owner's temporary message based on MSN Messenger state.
MSN Send New Note Option	Whether to send owners notification of new notes left by visitors via MSN.

Table 4-1: Information Stored in an Owner Profile (Phase 5).

The decision was taken to store door display owner profiles in a persistent database table to avoid the loss of owner profile information. A database was chosen due to the flexibility and potential for replication it provided. The *Central Agent* was modified in order to maintain a copy of the information from the database in memory and ensure that both copies were consistent (this approach enabled much existing code to be re-used and enabled the *Central Agent* to function in the event of database problems). The use of a separate database enabled the web portal to be decoupled from the *Central Agent* (see Figure 4-16) allowing it to function without any dependence on the *Central Agent* (simplifying the architecture and potentially improving the reliability of the web portal). In order for the *Web Portal Servlets* to inform the *Central Agent* of changes made to the database, a simple message passing mechanism using TCP sockets was implemented. TCP sockets were chosen over more flexible language independent technologies such as SOAP (Simple Object Access Protocol) [The World Wide Web Consortium '03] for simplicity and ease of implementation (recall from chapter 1 that the aims of Hermes focussed more on areas such as adoption from door display owners that software architecture). This revised communication mechanism for the web portal is shown in Figure 4-16 (where the 'database is abbreviated to 'DB').

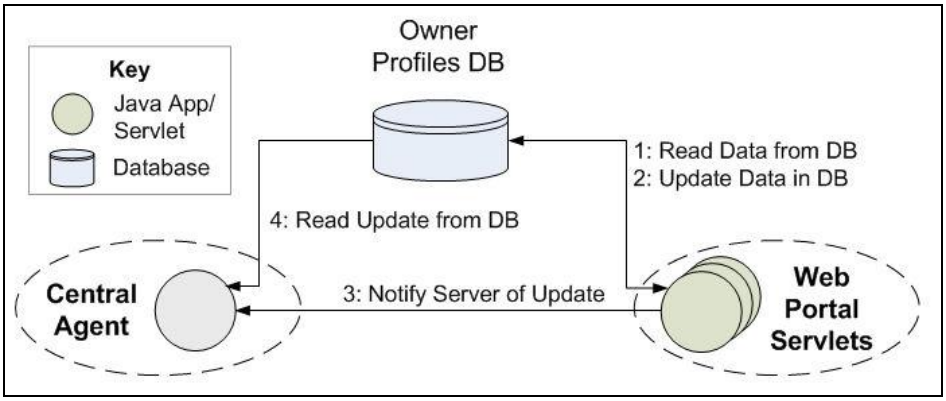

Figure 4-16: Communication mechanism for the web portal (Phase 5).

4.6.3 Analysis of Phase 5

The MSN messenger integration was an immediate success with those door display owners that previously used MSN messenger on a daily basis and help encourage adoption (as can be seen from the increased use in section 5.5). For these owners the interaction method fitted in well with existing routines and required very little additional effort for adoption (the issue of control vs. effort is discussed in detail in section 6.9.10). It is interesting to note how owners enjoyed the level of detail that could be included in messages with relatively little effort with this interaction method (the issues of appropriate methods of interaction and context sharing are discussed in detail in sections 6.9.2 and 6.9.4 respectively). The additional feedback given to owners when a message was successfully set using this method helped build up trust, the additional feedback was something which was lacking with other interaction methods. Once owners had successfully set a message using MSN Messenger several times (by physically checking his or her door display) they appeared to associate the confirmation message (i.e. feedback) with the action of successfully setting a new message. This was a good illustration of the importance of providing appropriate feedback, which is discussed later in sections 4.9.4 and 6.9.3. The mechanism that updated an owner's temporary message using his or her MSN Messenger state appeared to be ideal for automatically sharing awareness information with Hermes. However, owners did not make use of this mechanism. This might simply have been because they did not use the state feature of MSN Messenger, although qualitative analysis is required to explore this issue further.

The initial MSN Messenger integration component proved far less reliable than other interaction methods and when the connection to the MSN Messenger server was interrupted in various ways this left the Hermes contact 'off-line'. Fortunately, it was straightforward for door display owners to see when the MSN Messenger component was not working (the Hermes server being 'off-line' on an owner's contact list) and owners did not associate failure of the MSN Messenger component with failure of the Hermes system as a whole (and

additionally owners had a variety of alternative interaction methods). This key advantage, of owners easily being able to see when the interaction method was not working, was not available with any other interaction methods and helped enable adoption in the face of poor reliability (this issue is discussed later in sections 4.9.4 and 6.9.3). This issue of trust for different interaction methods is an interesting one that is discussed further in section 6.9.3.

The persistent storage of owner profiles was a necessary step after the expansion of the amount of information stored in them (and the high chance of this increasing in the future) and the advent of an owner carefully personalising his or her owner profile. This change was effectively hidden from door display owners but removed the burden of owners having to reconfigure owner profiles (default message, predefined temporary messages etc.) every time the *Central Agent* was restarted (to apply updates etc.). The use of a well established database technology was clearly an important step for reliability, for example the web portal was now dependent on this reliable database technology (which could be easily be replicated for even stronger reliability), rather than the potentially unreliable *Central Agent* Java application.

It is interesting to note that personalisation was clearly an important issue for door display owners, the ability to modify the list of temporary messages which could be set from the door display clearly gave the interaction method much additional value. Previously, when owner profiles were lost (during a *Central Agent* restart or update) door display owners were modestly annoyed at 'losing' the default image used to personalise a door display and damage caused to owner trust was likely to have impacted adoption.

4.7 Phase 6

Phase 6 was the shortest and final phase of Hermes as the move to a new Computing building meant that the system had to be dismantled. Unfortunately, the impending move meant that changes made during this phase had to be designed and implemented in a relatively short space of time. A key aim of development was still to help enable adoption from door display owners and during this phase the comments from owners resulted in the implementation of three new features. Firstly, the majority of owners (seven out of ten) commented that occasionally they found that the temporary message they had set had changed unexpectedly. One owner in particular found that when she set a temporary message that was intended to be visible for several days (for example when she was on leave or away ill) she would often find on her return that the message had been removed. She attributed this to visitors accidentally removing the message (by tapping the screen) while leaving her a visitor note but this demonstrated how the security vs. ease of use trade-off was clearly not appropriate in this scenario and owner trust was likely to be negatively affected. In order to

address this problem a mechanism was implemented in order to prevent temporary messages being set and removed at a door display at the discretion of the owner (section 4.7.1).

A single owner requested some form of 'tick-box' that he could use to make important messages stand out. He also commented (together with another owner) that visitors to his door display might find his messages more useful if the time and date on which the message had been set was visible. In response to these requests the features described in section 4.7.2 and 4.7.3 were implemented. A key technical change was also made during this phase (see section 4.7.4) to help improve reliability and remove the need for wireless network connectivity at the *Central Agent*. In this section the overall architecture at this end of this final phase is illustrated.

4.7.1 Enabling 'Secure' Temporary Messages

While door display owners found the ability to set (from a predefined list) and remove temporary messages at a door display without authentication very useful features, which encouraged adoption, there were certain circumstances where this security vs. ease of use trade-off was not appropriate (this trade off is discussed in detail in section 6.9.10). For example, when setting an important message valid for a long period (e.g. "Away at MobileHCI but checking e-mail, back next week") the mechanism for setting messages had several shortcomings:

i) if the owner used a default textual message this could not be changed by others but it could be 'covered' by setting a temporary message,

ii) if the owner used a temporary message this could be removed or changed.

In response to comments from owners highlighting these shortcomings, a feature was added to help improve security (security in the context of public situated display systems is discussed further in [Dix '04]). The main criteria when designing this feature was that it should be easy to use and require very little effort on the part of the owner. Therefore the initial design of a solution to this problem was a checkbox when setting a temporary message to disable its removal at a door display. A checkbox was chosen in order to add a small amount of additional complexity. This facility was provided (on a per message basis) on both the web portal with the addition of the 'Disable Display Press Action' checkbox shown in Figure 4-17 and on the door display user interface with the addition of the 'Prevent Removal With Screen Press' checkbox as shown in Figure 4-18.

Due to the small amount of time before the move of Computing buildings there was little opportunity to discuss this feature with door display owners and other solutions may

have been equally suitable. Alternative would have included an 'away' mode (configurable in the owner preferences of the web portal) which only allowed a textual message to be configured via the remote interaction methods, or perhaps some form of prefix for a textual message that prevented their removal via a door display.

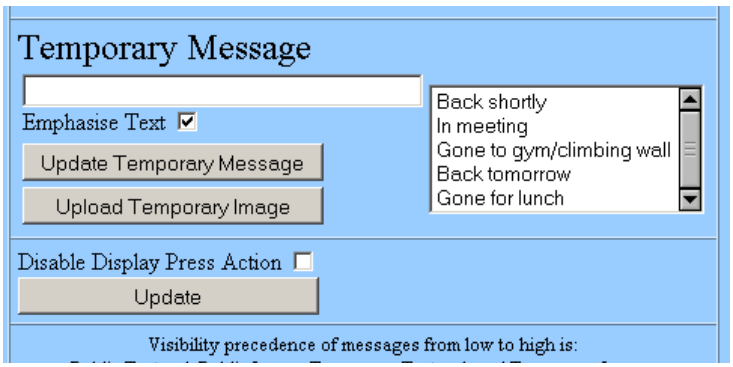

Figure 4-17: Changes to the Web Portal (Phase 6).

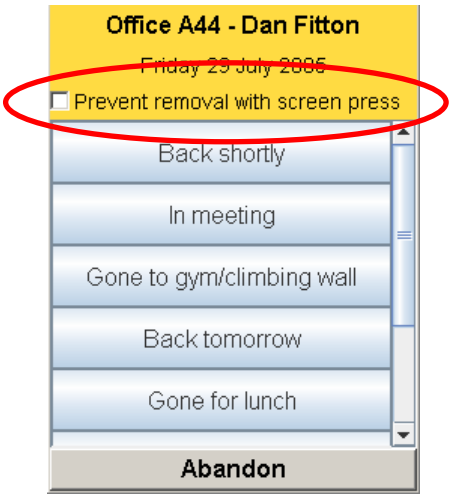

Figure 4-18: Changes to the Door Display Interface (Phase 6).

4.7.2 Changing the Salience of a Textual Message

An interesting issue that emerged through discussion with owners was the lack of ways to increase the salience of textual messages (the issue of salience is discussed in more detail in section 6.9.7). For example, to a passer-by, a temporary textual message was displayed in exactly the same way as a default textual message, even though a temporary message may convey important information and a default message may not convey any important information per se. When using a paper note to display a message, the author could use different colours and different sized text to help signify importance (e.g. large red text would help attract a visitor's attention more than smaller black text). Earlier phases of the system clearly did not provide this level of expressivity supported by paper notes. The issue of

expressivity generated some important requirements for the Hermes system and is discussed later in section 6.9.8 of this thesis, and is listed in appendix H.

In order to help rectify this problem (and address a direct request from one owner) the notion of 'normal' and 'emphasised' messages was introduced, each with different textual formatting options configured via the web portal and stored in owner profiles. For each type of message the colour of the text and background could be configured, along with an option to make the text bold. The user interface to configure these options is shown in Figure 4-19 and the effects of these options are shown in Figure 4-20. Emphasised textual messages could only be set using the web portal, the additional 'Emphasise Text' tick-box to do this is shown in Figure 4-17. A tick box was used both because it was requested from an owner and it added minimal complexity to the user interface. Owners were only given a limited amount of control over the formatting options in order maintain simple user interfaces and functionality. While this simple design enabled rapid implementation and deployment, one extremely flexible alternative to allow changes in salience would have been to support HTML tags in the messages. This option was not explored due to limited development resources.

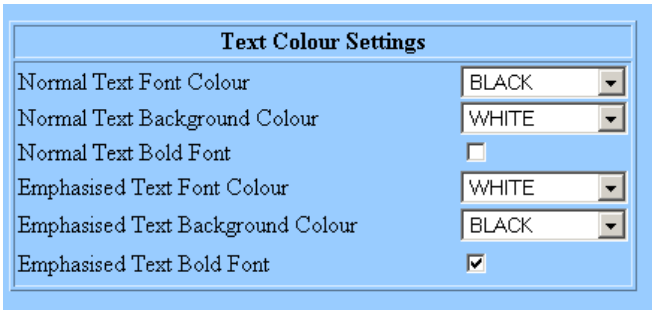

Figure 4-19: Configuring the Formatting of Textual Messages (Phase 6).

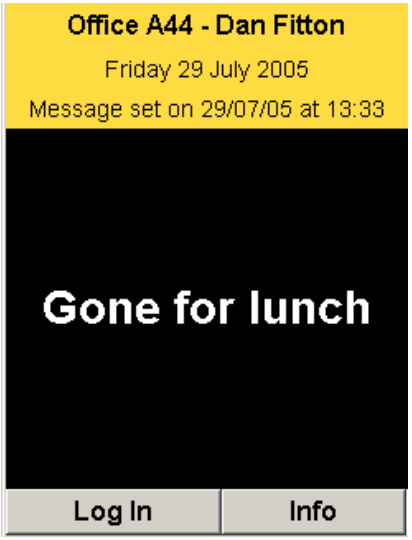

Figure 4-20: An Example of Formatting a Textual Message (Phase 6).

This feature enabled a level of expressivity comparable to the use of different coloured pens on traditional Post-it notes (and the use of different coloured Post-it notes).

4.7.3 Adding a 'timestamp' to Messages

Two owners in particular asked for the time and date of messages they set to appear on the door display user interface. They reasoned that this extra piece of context would make messages set more useful to visitors. For example, if a message read 'Gone to X' (X referring to a different part of campus) and it was clear to a visitor that the message has been set several minutes ago, they would be able to infer that the owner might still be in the Computing Building and be able to find him or her if they hurried. This feature highlighted another interesting affordance compared to paper-based messaging systems, that of automatically including additional context in messages (the affordances explored by Hermes are discussed further in section 7.3.2). This extra information is shown on the top part of the user interface as shown in Figure 4-20 and a door display owner was able to disable this feature using his or her owner profile. This feature can clearly have an impact on the issue of accuracy and ambiguity (discussed further in section 6.9.9) in messages as, for example, if a message set over twenty minutes ago read "back in fives minutes" it might be of little help to a visitor.

4.7.4 Removal of RMI Callbacks to the Client Agent

In order for the *Central Agent* to perform Java RMI CallBacks on a *Client Agent* (used to update the door display when the owner has set a new message remotely) the *Central Agent* required wireless and wired connectivity. Wireless connectivity was necessary at the *Central Agent* in order to remove the need to alter the configuration of the routing mechanism between the wired and wireless networks (administered at a departmental level).

These issues were addressed through the use of message passing over TCP sockets (as used to decouple the *Central Agent* and Web Portal, discussed in section 4.6.2) instead of Java RMI CallBacks. Every *Client Agent* contacted the *Central Agent* on a regular basis (as described previously), when this process occurred the current IP address of the *Client Agent* was stored. When an owner changed his or her list of predefined temporary textual messages (or certain parts of the owner profile) a serializable Java object was created containing an array of string objects containing this new information, the object was then sent to the owner's *Client Agent* using a predefined TCP port. The *Client Agent would then* continually listen on the predefined port and any information it received it would attempt to cast to the serializable Java object containing an array of strings (representing the various default and temporary messages etc.) which were then used to update the current message etc. This approach was

used (over other appropriate technologies such as SOAP etc.) due to simplicity and ease of implementation.

4.7.5 Overall Architecture

The overall architecture at the end of the final phase of Hermes is shown in Figure 4-21 where different colours are used to indicate the different communication protocols used. There are several key differences between the architecture at the end of phase 6 and the initial phase 1 architecture (as shown in Figure 3-13), such as additional sub-components for MSN Messenger and E-mail support at the *Central Agent*. Other key changes include the use of a database to store owner profiles and the removal of RMI Callbacks from the *Central Agent* to the *Client Agent*. All the key architectural changes since phase 1 are discussed in the preceding sections 4.3 to 4.7.

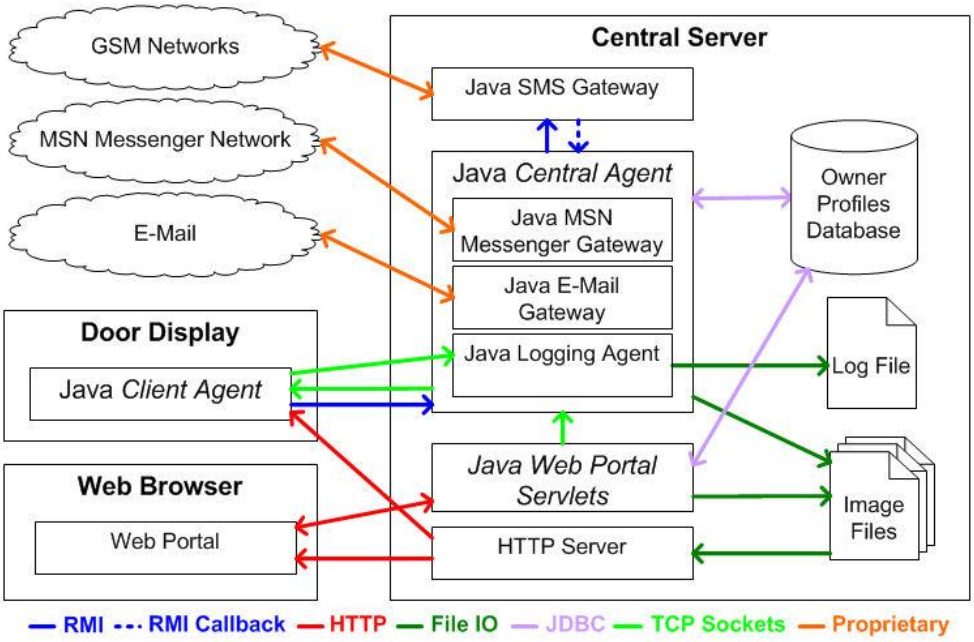

Figure 4-21: The Overall System Architecture of Hermes (Phase 6).

4.7.6 Analysis of Phase 6

Unfortunately, phase 6 of Hermes was only deployed for a short period of time (approximately a month) due to the move to a new Computing building. All door display owners received notification and an explanation of the new features via an e-mail, but the majority did not change the default text formatting setting (though several owners made positive comments about its presence). Many owners commented that they had experimented with the 'Disable Screen Press' option, but did not fully understanding how to use it. For example, one owner did not realise that the option was only associated with a single message, not permanently enabled or disabled. Such preliminary findings showed that this required

further investigation. However, in this phase the iterative refinement of features [Fitton '05] (which took place in earlier phases) was not possible due to the limited time available before the move.

4.8 The Challenge of Managing Reliability

One of the largest problems and greatest challenges during the development and deployment of the Hermes system was the issue of reliability. Deployment of multiple prototypes outside of the 'lab' for a range of users is relatively uncommon for experimental systems, and raised a whole host of unexpected additional challenges [Fitton '05]. One door display owner highlighted this importance of reliability when discussing her experiences of Hermes (see section 6.9.3 for further discussion of this owner):

"…it wasn't reliable, and reliability is the absolute key."

Conversely, another door display owner commented on the poor reliability of paper notes and found Hermes more reliable (see section 6.6.4 for further discussion of this owner):

"They're not reliable are Post-its, because they just don't stay up you always end up having to stick sellotape."

4.8.1 Technical Problems Encountered

Many of the reliability problems, which caused door displays to crash, were attributed to the PDA device and associated software (see section 5.4.1 for a quantitative analysis of failure). These crashes were reduced with updated versions of the Java VM, device drivers for the wireless network cards and operating system updates.

A second source of problems was the experimental wireless network used by the Hermes system. The major problem was caused by weak signal strength. The displays can be thought of as 'thin' clients and the majority of information was stored at the *Central Agent*. Because of this, most user interface actions (such as 'logging in', leaving a message etc.) on the Hermes door displays required communication, via Java RMI, with the *Central Agent*. The RMI calls using the Java VM on the Hermes displays were very sensitive to network quality and consumed large amounts of CPU time. This meant that if a door display owner/visitor attempted to perform an action requiring communication with the *Central Agent* and there was a temporary degradation in wireless signal strength (for example due to owners/visitors standing in front of a Hermes display) the application could halt temporarily. During this time the application would not respond to input, giving the impression that the application or the system had crashed. Unsurprisingly, this led door display owners/visitors to think that Hermes was unreliable, damaging trust and discouraging future use.

The scenario described previously highlights the importance of providing feedback on failure to help maintain trust. For example, notifying the user (owner or visitor) that a door display was temporarily ‘out of order’, perhaps by using a visual indication on the user interface, would prevent the user attempting to interact with the display and avoid a frustrating experience of attempting to interact with a non-functional display

Initially, the display housings were completely enclosed aluminium boxes, this design worked well for areas with good signal strength, but in low strength areas the signal was significantly reduced or seemed to be blocked for periods. Recall from section 3.9.1 (chapter 3) that the wireless network signal is absorbed by humans, exacerbating the problem. Initially it was assumed that the wireless base stations used by the devices were located in the false ceilings of the corridors, though after investigation it was found that all but one of the wireless access points (WAPs) were actually located in the false ceilings of the floor below (this is shown in Figure 4-22, where Hermes displays are shown in red and wireless base stations in green).

Figure 4-22: Hermes Displays (red) and Wireless Access Points (green).

This deployment of base stations led to wireless signal ‘hot spots’ above the access points, though further away the signal strength appeared to be dictated by the structural anomalies of the building (e.g. expansion joints between walls significantly reduced signal).

Solutions

One potential solution to the problem of poor wireless network signal would have been to use a different design of software architecture for Hermes. For example, in the Rover

toolkit [Joseph '95] non-blocking remote procedure calls can be queued during periods of disconnection and are executed on reconnection. Alternatively a caching approach such as that used in the Coda file system [Kistler '92] could have been used to transparently manage disconnections when accessing a shared data repository. Either of these approaches could have been used to redesign the Hermes architecture to help enabled the *Client Agent* to function independently of the *Central Agent* (an idea proposed by one of the more technical owners, discussed in section 6.3.4). The focus of this was on areas such as supporting adoption and use and not the software architecture, therefore the approach taken primarily focussed on making minor alterations to hardware as described in the following sections.

After experimentation it was found that removing sections from the top part of the case at the front and back near the protruding part of the wireless network card significantly increased the signal strength. This small modification was so successful the decision was taken to modify all the currently deployed units (as shown in Figure 4-5 – Phase 2). In one particular location the wireless network signal proved so weak that the case modification did not prove effective, for this location a new type of a prototype door display was developed using a wired Ethernet card. This proved challenging due to hardware constraints, the PDA in use, a HP Jornada 568, only accepted type 1 compact flash cards and type 1 Ethernet cards proved relatively scarce. For various reasons, including the need to utilise existing hardware, the solution was to use a modified Compaq IPAQ and compact flash expansion jacket with a type 2 wired Ethernet card.

Figure 4-23: Modified Compaq iPAQ with Wired Ethernet.

After experimentation it was discovered that an iPAQ without the rear casing (but including battery) along with a Compact Flash jacket without any of the casing (see Figure 4-23- left) would fit inside the original housing. The housing did require slight modifications

(as can be seen in Figure 4-23 - right) to accommodate the slight 'bulge' at the top of the iPAQ case. Also, removing the housing from the connector 'dongle' of the Ethernet card allowed it to fit in the space designed for the protruding section of a compact flash wireless network card (this can be seen in Figure 4-23 - right). It should be noted that all of the exposed circuit boards and electronic components were entirely insulated before the device was placed in the housing.

Unfortunately there was no viable method to improve all the existing hardware and software platforms to provide the high levels of reliability needed. However, in the forthcoming Hermes 2 system (discussed in Appendix J) reliability has been a crucial requirement at many levels. Additionally, it was not always the hardware at fault; several pieces of third party software (among other things) have proved themselves unreliable. The key to improving dependability and owners' perception of dependability may not lie solely in preventing faults. One solution to improving this situation is through accepting that faults may occur, and providing measures to minimise downtime and provide feedback to door display owners of the system status, this point is revisited in chapter 7 (conclusion).

Previously owners were relied upon to notify the system administrators when door displays had crashed, or through the chance encounter of an administrator noticing when a display was not working. In an attempt to solve this problem a *Management Agent* was developed to monitor all the displays and provide (among other features) automated notification of display failure (the feature is discussed in section 4.8.2).

4.8.2 Supporting and Managing Hermes

As one might expect, supporting and managing Hermes was a non-trivial task. This section firstly outlines the roles of the system administrator in Hermes and then presents the *Management Agent*. The main motivation for the *Management Agent* was to provide a system to monitor the Hermes displays, so both system administrators and door display owners could be alerted to display failure. While designing this new system the opportunity was taken to include desirable features intended to be useful for system administrators.

The Role of the Administrator

In Hermes the system administrator (myself) was responsible for all duties involved in deployment, management and maintenance. These can be summarised as:

i) installation and configuration of door display hardware,

ii) management of door display devices (updating drivers etc.),

iii) installation, configuration and deployment of *Central Agent*, *Client Agent* and *Web Portal* software,

iv) configuration and management of the server machine hosting the *Central Agent* and associated services (e.g. web server and servlet runner),

v) induction of new owners and demonstration of new features to existing owners,

vi) responding to reports of failure from owners,

vii) notifying owners of failure and scheduled downtime,

Performing all these duties for a system of ten door displays proved very time consuming, especially with features being regularly added (or modified) requiring new software to be installed on all door displays. This provided one of the motivations for the development of the *Management Agent* described in the following section, scalability is listed in appendix H as a specific requirement.

4.9 The Management Agent

This section provides an overview of the *Management Agent* developed during phase 4.

4.9.1 Notification

One of the key methods to help increase a door display owner's trust of Hermes, identified earlier (in section 4.6.3), was by providing automated notification of system failure in order to avoid owners attempting to interact with a non-functioning part of the system (and damaging trust). This kind of feature is clearly an affordance enabled by a digital approach (to paper-based messaging systems) as, for example, a person away from his or her office would have to rely on a colleague noticing that a Post-it note was missing and contacting them. Initially an e-mail list was set up containing the addresses of all door display owners, this was used to notify owners of scheduled system downtime for upgrade work etc. This idea was extended in the *Management Agent* to provide e-mail notification on failure to individual door display owners and the system administrator. E-mail was chosen over, for example, SMS as it was free and widely used by door display owners, easy to organise and asynchronous. A similarly important feature was of notifying a door display owner when his or her Hermes door display was working again. There was also the added advantage that the system administrator learned of door display failure at the earliest opportunity. Enabling any problems to be resolved quickly and so improving overall dependability.

Detection of door display failure relied on an existing regular 'heartbeat' sent from each C*lient Agent* (the design of the 'heartbeat' feature was discussed in 4.5.2). This design was chosen for simplicity in order to explore the idea at minimal cost (a more suitable alternative might have been, for example, to use a regular request-response mechanism involving sequence numbers to ensure integrity). If a heartbeat was not received in a specified period of time then failure was assumed. Initially this time was set to five minutes but after occasional 'false alarm' notifications of failed displays this period was increased to fifteen minutes. After deployment, the new interval still proved too short, especially in one area of very low wireless network signal where the door display could lose signal for around twenty minutes then start working again normally (generating numerous false alarm e-mails during a day). Increasing the time interval seemed to be the wrong strategy in this case, and the problematic door display was modified to use the wired network (as discussed earlier in section 4.8.1).

4.9.2 Management Agent Web Portal

The *Management Agent* included a Management (or 'Admin') Web Portal, accessible by door display owners with correct privileges (i.e. administrators). This allowed easy access to management features both locally and remotely. There was only a single access level implemented allowing access to all management features. However, it was the intention to extend this in the future, making subsets of features accessible to door display owners who may need them (for example allowing secretaries to set important messages on multiple door displays).

Monitoring

The main management web portal screen (shown in Figure 4-24) included the status of all door displays in a table with one row for each owner to make the information easily visible. The table showed owner username, real name (an e-mail link), office number and the last date and time the associated display was known to be alive. If an owner's door display was assumed to have failed (see sections 4.5.2 and 4.9.1 for a discussion of door display failure) then the corresponding entry was highlighted in red. Each row in the table also provided a 'View' button to access the message currently displayed on the owner's door display Figure 4-25.

Figure 4-24: Management Web Portal Main Screen.

Figure 4-25: Viewing the Message on a Door Display.

A button was also provided to view and edit owner profiles. Another important feature included was that of ‘pinging’ a door display, this feature initiated a sequence of remote calls to and from a door display to verify that the *Client Agent* application and wireless network were functioning correctly. If a ‘ping’ was successful this was reflected in the management web portal through updated ‘last alive’ time. To initiate a ‘ping’ on a door display the administrator ticked the check box on the appropriate row in the table, then selected the ‘Ping Selected’ button. This design provided a simple interface and allowed multiple door displays to be ‘pinged’ simultaneously.

These features allowed a system administrator to monitor all door displays from a single point. This was useful for many reasons such as to check if a door display was functioning correctly, to check if a message update has been successful or to monitor the Hermes system remotely.

Additional Management Features

When designing the *Management Agent*, functionality was included to allow an administrator to change the temporary message for one or more door display owners. This feature was implemented in order to enable some initial investigation into the use of door displays for sharing information of public interest to support awareness (for example a reminder for an important meeting etc.). When selecting the owners to change the temporary message for, this feature was similar in use to pinging door displays (selection using check boxes). It allowed the administrator to set a textual message or upload an image file. Once the temporary message has been changed the administrator could use the 'view' feature (as shown in Figure 4-24) to ensure that door displays had been updated successfully. When a door display owner's temporary message had been changed using the *Management Agent* he or she was informed via an e-mail also including reassurance that they could change or remove the message at any time. One alternative design for this feature would have been to cycle between multiple messages at predefined time intervals, however this was discarded as it would have added additional complexity to the user interface. Another novel alternative would have been to use semi-transparent text to superimpose one messages onto another while allowing both to be visible, this idea was also discarded on the grounds of complexity (both for the user interface and implementation).

Initial feedback from owners about the use of door displays as part of a navigation system proved very positive (see section 4.10.1 for a discussion of an owner interview where this issue was investigated), which might indicate that owners would be similarly enthusiastic the use of door displays for sharing information of public interest. For example, departmental secretaries could use multiple door displays to display pertinent messages and reminders.

4.9.3 Analysis of the Management Agent

The *Management Agent* was operational for approximately ten weeks and, although during that short time it enabled the failure of door displays to be detected more quickly, it is difficult to speculate whether it had increased door display owners' trust of the system. Unfortunately the implementation of the e-mail notification on failure feature proved unreliable and unpopular with door display owners, the primary problem being 'false alarms'. A false alarm occurred when a door display owner would be notified via e-mail that his or her door display had failed then after a short period of time another e-mail would be received saying that the door display was functioning correctly again. This problem was caused in areas of low wireless networking signal where a passer-by could easily block the wireless signal, for example one owner received upwards of thirty of these e-mails per day.

Modifications were made to the system in order to solve this problem, but due to the initial negative reaction to the false alarm emails from owners the functionality sending notification of failure was disabled completely. Unfortunately, this hindered investigation into the other feature of the *Management Agent*.

Problems with the notification of failure aspect of the *Management Agent* should be attributed to poor design and implementation rather than the actual idea, as notifying owners of failure proved valuable in other aspects of the Hermes system (see section 4.5.6 for further discussion of this issue). The granularity of the system could also be changed to the component level in order to notify owners when, for example, the SMS component was not working. Using this granularity of notification would prevent potentially trust damaging scenarios where, for example, an owner would attempt to set a message via SMS and later find that the operation had been unsuccessful (the issues of reliability and trust are discussed in section 6.9.3). Providing owners with knowledge of which parts of Hermes were not working correctly would also be extremely valuable in terms of allowing owners to select alternative interaction methods if appropriate.

The ability to view the messages on door displays remotely proved useful for the administrators of the Hermes system. For example, it was used on occasion by owners with administration status to effectively check if someone was in his or her office before making the trip in person.

4.9.4 Analysis: The Challenge of Providing Feedback

From discussion in the previous sections is clear that failure, especially in an experimental prototype such as Hermes, is likely to occur. One of the key solutions to this problem, as discussed earlier in sections 4.6.3 and 4.9.1, was providing feedback in order to help prevent an owner attempting to use a non-functional part of Hermes. A negative experience of failure was likely to undermine an owner's trust of the system and could discourage future use. For example, one owner rejected the SMS and iButton interaction methods after experiencing failure with each, the owner later commented *"early bad experiences put me off!"* (the issues of reliability and trust are discussed in detail in section 6.9.3).

The value of providing feedback in order reduce the impact of failure on trust (and therefore adoption) was clearly demonstrated after the implementation of the MSN Messenger interaction method (discussed in section 4.6.3). The MSN Messenger integration initially proved unreliable and would regularly fail to reconnect to the MSN Messenger network after connectivity problems (with the local network or MSN Messenger network). However,

owners could easily see if the Hermes MSN Messenger component was ‘on-line’ (i.e. working) via the MSN Messenger user interface and could only set messages if this was the case. Despite the early unreliability problems MSN Messenger proved a popular way to interact with Hermes (this popularity is shown in Table 6-1 and discussed in analysis of owner interviews in sections 6.3 - 6.7). Additionally, as described in section 4.6.3, feedback allowed owners to cope with failure by utilising alternative interaction methods if appropriate. Feedback on remote interaction is another interesting affordance which is enabled by a digital equivalent to paper based messaging systems (the affordances explored by Hermes are discussed further in section 7.3.2).

MSN Messenger was the only interaction method which provided confirmation when a message had been successfully set (see section 4.6.1 for a discussion of the design of this feature) which three out of the four owners analysed in detail found encouraged trust (this is discussed in detail in sections 6.3.4, 6.4.4 and 6.5.4). This highlights another key use for feedback, to reassure an owner that his or her use of an interaction method has succeeded.

The use of feedback on a range of levels appears crucial to encourage trust. The important levels identified in Hermes were:

i) system – whether the system as a whole is functioning correctly,

ii) component - a system component which, for example, provides an interaction method such as MSN Messenger or SMS,

iii) interaction - an interaction that an owner carries out such as setting a message.

While the implementation of the *Management Agent* feature to provide e-mail feedback on complete system failure was unsuccessful, this is potentially an important level on which to provide feedback to owners. For example, a multitude of e-mails to inform an owner that every individual component in a system has failed is potentially analogous to the problematic ‘false alarm’ e-mail scenario discussed earlier.

The MSN Messenger component inherently included component level feedback in a way that was unobtrusive to the owner and this contrasted with the unsuccessful ‘pushing’ [Cheverst '01] of e-mails used by the *Management Agent*. Interaction level feedback was only explicitly provided by the MSN Messenger interaction method and when setting a temporary message at a door display, in this latter case many owners waited for the new message to appear (as described by owners in sections 6.3.4, 6.4.4 and 6.5.4). Providing feedback on individual interactions for remote interaction methods would generate additional ‘traffic’ for owners (e.g. an additional confirmation SMS message sent back to owner when using the SMS interaction method). However, owners should be allowed to personalise the behaviour of

the feedback mechanisms in their owner preferences depending on their need to build trust during adoption. Additionally, a mechanism for system administrators that enabled the currently visible message on a door display to be viewed remotely (see section 4.9.2 for further discussion of this feature) proved successful. This kind of mechanism might provide an additional tool to help owners build up and main trust without the need for (potentially irritating) feedback messages.

4.10 Fostering a User-Centred Design Approach

One of the primary aims of this work was to use user-centred design approach (aim 1 in section 1.5). This approach has been crucial in helping to support adoption by display owners through adding and modifying functionality to, for example, fit in with owners existing daily routines and lower barriers to use. For example, in phase 2 one owner requested a feature providing the expressivity provided by the paper notes he used previously (see section 4.3.3 for further discussion of this feature). During phase 3 feedback from owners in relation to problems with the mechanism for setting and removing messages resulted in the introduction of temporary and default messages (see section 4.4.1 for further discussion of this feature). In phase 4 a feature was introduced allowing security to be traded-off for ease of use when setting temporary messages from a door display (see section 4.5.1 for further discussion of this feature) after feedback indicating that this trade-off was desirable. It was only when owners were involved in the design of this aspect of the system that approaches which fitted in well with owner's existing patterns of work were developed.

Functionality was added and refined in conjunction with feedback (both formal and informal) from door display owners and, as such, the inspiration for new features often came from owners attempting to adopt Hermes as part of their daily routines. A questionnaire was given to door display owners during phase 4 of deployment that was used as the basis for future features, an overview of the results of which are discussed in the following section.

4.10.1 Owner Questionnaire Results

The door display owner questionnaire (see Appendix C) was carried out in May 2003 and completed by ten owners. A questionnaire was selected as a low cost method to investigate specific issues, it asked for owner's opinions on a variety of questions, some based on current functionality and some based on hypothetical changes. The questions were divided into three main categories and a five-point Likert scale was used to obtain owner opinion to questions such as:

"I would be like to have a link from my home page to the contents of my Hermes display (given the currently supported set of features)."

The most pertinent responses that affected the design of Hermes are discussed in the following sections.

Sharing Personal Context

Questions in this section related to remote accessibility of messages on door displays and potential features providing automatic context sharing. When door display owners were asked if they would like the facility to display currently visible door display messages via homepages (Appendix C, question 1.1) eight owners agreed (one strongly). However, comments from several owners seemed to reflect a desire for some form of privacy (for example *"only for people here"* and *"with control"*) potentially making a simple feature complex to design and implement.

When asked if owners would like public calendar entries displayed on door displays six agreed (two strongly) and seven owners agreed that they would like their (sensed) location automatically displayed. However, feelings towards making this latter information accessible via the web were less positive. Although owners' responses when asked about these two features were moderately positive there were simply not enough resources available for implementation during the Hermes project. However, the ability to share public calendar entries should be a requirement for future work (see appendix H).

Control

When owners were asked if they would be prepared to let visitors use door displays to browse the web or play simple games (Appendix C question 2.1) the responses ranged from strongly disagree to strongly agree (with a majority of four agreeing), with a variety of comments reflecting this. However, when asked if they would allow door displays to be used as part of a department wide navigation system (Appendix C, question 2.2) owner responses where overwhelmingly positive (one agree, nine strongly agree).

Potential Features

The questionnaire investigated owners' opinions of potential functionality allowing temporary messages to be set and removed on door displays without authentication (the implementation of this feature is presented in section 4.5.1). The opening question (Appendix C, question 3.1) asked if this feature would increase the likelihood of owners setting a temporary message, the majority of owners (seven) strongly agreed with three agreeing and one not sure. When asked about concerns that visitors would potentially be able to set messages that appeared to be from them, only two owners agreed while four disagreed and four were not sure. One of the owners who was not sure made an interesting point that this is same situation as with paper Post-it notes, anyone can put a message on a door which would

appear to been have been authored by the office owner. The final question in this section (Appendix C question 3.4) asked if owners were concerned that visitors could potentially remove temporary messages. Responses to this ranged from disagree (the most popular with five responses) to strongly agree (the least popular with one response). The positive feelings towards this feature led to its implementation, and its effects on owner's use of the Hermes system are discussed in section 5.5 in chapter 5.

4.10.2 Analysis of User-Centred Design Approach

From the results of the door display owner questionnaire it was apparent that when it comes to developing new features for Hermes in a user-centred manner there is no 'one size fits all' approach. Preferences and feelings differed between owners, sometimes conflicting: this attributed to personal preference, technical knowledge and different usage patterns (quantitative analysis of use demonstrating different usage pattern between owners is discussed later sections 5.5, 5.6 and 5.7).

Trade-offs have to be made at the design stage: this may be in terms of siding with the majority opinion (as was the case with the implementation of the interaction method described in section 4.10.1) or increasing user interface complexity to accommodate new features (as demonstrated by the new features described in section 4.7.1). A key feature during the evolution of Hermes has been owner profiles to support personalisation which became increasingly more important as new features were added. This gave door display owners the opportunity to personalise system behaviour as they wished, for example disabling undesirable features (as shown in Figure 4-12 where an owner has the facility to disable SMS notification on new visitor notes).

Another trade-off encountered during the development of Hermes was between the development of new features and the management and maintenance of the deployed system. More specifically, the limited available resources (primarily time) impacted the development of new features and required the implementation of new features to be prioritised according to which were most likely to encourage use or enable adoption. Primary examples of this were the lack of context-aware [Schmidt '02], [Dey '99] technologies used in Hermes and lack of integration with owner's electronic calendars. However, owners' feelings towards these two features were explored further in the post-deployment interview described in section 6.2.

The use of a user-centred design approach seemed to pay dividends in helping to support initial adoption and continued use by door display owners (further qualitative analysis of use is provided in chapter 6). This chapter has primarily focussed on the design of interaction methods, through qualitative feedback received during deployment it has emerged

that the two interlinked issues of reliability and owner trust are equally important. While a remote interaction method may appear to be appropriate, it is important that it is backed up with feedback [Dix '95] or failure might be severely damaging to trust and future use. For example, the use of an iButton for authentication (as discussed in section 4.3.4) appeared to be an ideal interaction method for one owner, but after several experiences of failure the owner discarded the feature completely (see section 4.3.6 for further discussion of this owner). Conversely, interaction via MSN Messenger (the design of this features is discussed in detail in section 4.6.1) proved popular with owners despite low initial reliability as it was clearly visible to an owner whether the MSN Messenger component of Hermes was working (see section 4.6.3 for further analysis of this feature).

4.11 Summary

This chapter has discussed five phases in the evolution of the Hermes system after the initial phase 1 (described in chapter 3). Every phase was presented (in section 4.2) along with a description of the addition or modification of features and followed by an analysis. Many of the requirements for new features were unlikely to have emerged without the longitudinal deployment and use of this prototype system outside of the ‘lab’ and use of user-centred design. In section 4.8, the challenge of providing reliability in the Hermes deployed experimental prototype was discussed, and approaches used to manage this important issue. Finally, section 4.10 discussed the use of a user-centred design approach in the development of Hermes and presented the results from an owner questionnaire carried out during phase 4 and used to investigate owner’s feelings towards new features.

Chapter 5

Quantitative Analysis of Use

5.1 Introduction

Firstly, the processes used to extract information from the log files collected during the deployment of Hermes are described (section 5.2) along with a set of requirements for a logging system (section 5.3) validated in the context of Hermes. This chapter then utilises the information extracted from log files in order to quantitatively analyse the following four aspects of the Hermes deployment chosen to help illustrate the failure and use discussed in the previous chapter:

i) analysis of 'heartbeat' entries in order to quantify failure (section 5.4),

ii) analysis of daily use from owners (section 5.5),

iii) analysis of the different types of messages set by door display owners (section 5.6),

iv) analysis of context sharing in a sample of messages set by door display owners (section 5.7).

The analysis discussed in this chapter focuses primarily on owners of door displays, rather than visitors to door displays, as owners were central to exploring the aims of this thesis (to investigate adoption and use) with limited resources.

5.2 Extraction of Data from Log Files

The logging system used during Hermes appended log entries onto a single flat file (for an example see Appendix B) and several large files had been generated during the six phases of deployment. Prior to analysis the different log files had to be combined and converted into the same format to aid analysis. The logs collected during the deployment of Hermes contained five main types of information:

i) ‘heartbeats’ (sent at a regular interval) from every door display,

ii) all messages set by door display owners (public, temporary and private),

iii) visitor notes authored by visitors to door displays (in the form of filenames),

iv) logins/logouts at the door displays and on the web,

v) user interface actions that occurred at door displays.

It should be noted that log entries only consisted of textual strings and image files were stored separately. The analysis described in this chapter required investigation of the first two types of information (i and ii).

Early log analysis performed deployment had involved manipulation of the flat files using UNIX text processing commands such as ‘grep’ and the writing of simple programs to perform functions such as filtering and counting entries. In order to allow efficient and flexible analysis of all aspects of the Hermes system, all entries were extracted from the log files and stored in a MySQL [MySQL '05] database table (using a program written specifically for this purpose).

The single table of all log entries held some six million records (largely owing to the regular heartbeat sent by each door display). However, the information was separated out into many smaller tables (e.g. a tables for messages set by each owner) in order to make the data easier to manipulate. This highlights the issue of producing ‘manageable’ sized log files that can easily be manipulated, this is particularly important when deploying over the longer term where a large amount of logging information is generated. This issue potentially has impacts for the storage of logs, the design of the logging system and the amount of information which is logged, see section 5.3 for further discussion of this.

Programs were then written to query the tables to produce CSV (Comma Separated Value) files for each door display owner, allowing them to be imported into a spreadsheet application for further analysis. A program was also written to produce a human readable HTML file showing the messages set on a door display. HTML was chosen as it allowed any pictures to be easily included (for an examples see Figure 5-11 and Figure 5-11). The requirements for a logging system gained through experiences of log collection and analysis in Hermes are presented in the following section.

5.3 Requirements for a Logging System

Several errors were discovered in the early implementation of the logging system used in Hermes which resulted in early parts of the logs being unusable (see section 4.4.3 for further discussion of this problem). Additionally, some parts of the logs were lost due to hard disk failure at the Central Server (as described in section 5.4). This section details the requirements for a logging system in the context of Hermes (many of these requirements emerged during deployment):-

i) Replicated Storage – reliable storage providing replication (or at least an appropriate backup strategy) is crucial in any long term deployment where logs are collected.

ii) Use of a Storage Method to Aid Analysis – it is important to use a storage method which will simplify the task of analysis. For example, the flat files used in Hermes made analysis time consuming and complex but the use of a database greatly simplified analysis (as discussed in section 5.2).

iii) Logging Detail – careful consideration should be made of what events to log and on which levels. A trade-off here is between the granularity of information logged and the size of the log files produced. An important issue is how much of the context to record when logging an event in order to support analysis (as discussed in section 4.4.3).

iv) Monitoring of the Logging System – in the early phases of Hermes the logging system was a separate component to the *Central Agent*. A lack of visibility led to failure of the logging system going unnoticed (see section 5.4). Potential solutions to this problem were a monitor to 'watch' the logging system and provide notification to administrators on failure or a method to make logging more visible to administrators (perhaps providing weekly statistics of use).

v) Automated Analysis – a potentially useful advantage of logging use in a system such as Hermes would have been the ability to perform automated quantitative analysis of use as necessary. In more detail, with hindsight it would have been possible to design a logging system enabling an administrator (or even an owner) to view usage over any period for which logs had been collected. For example, after deploying a new feature it would have been possible to see if use had

increased immediately after deployment, how use increased after the deployment of previous features etc.

The problems with storage and collection of logs which emerged in Hermes were largely unanticipated and demonstrated that the issue of reliability was equally important for the more 'mundane' aspects of the Hermes system. Additionally, automated analysis of the logs, allowing recent use of the system to be visualised, might have yielded many benefits in terms of identifying usage patterns during deployment which could then have been used to help inform the design process.

5.4 Quantitative Analysis of Failure

Failure of door displays in Hermes was quantitatively investigated through analysis of 'heartbeats' sent from a door display to the Central Server on a regular basis. Logging of a 'heartbeat' relied on two factors, the logging system operating correctly and the door display operating correctly. In early phases of Hermes the heartbeat interval was set to five minutes, giving a maximum of 288 recorded heartbeats a day from each door display. In later phases this interval was reduced to forty-five seconds in order to help detect failure more quickly (see section 4.9.1 for further discussion of this change) giving a maximum of 1920 recorded heartbeats a day. However, the actual numbers of heartbeats recorded for door displays were less than these maximums. This was because once the heartbeat timer at the *Client Agent* fired it did not restart until the sending of a heartbeat completed successfully or failed (through a timeout). Due to the low processing power of the PDA devices on which the *Client Agent* application ran, the sending of a heartbeat message would typically take several seconds and longer if the wireless network signal was weak.

By collectively analysing the heartbeats received each day for each door display, an overall picture could be built up of when the logging system and door displays were functioning correctly. This was required due to the unfortunate loss of parts of the log owing to hard disk failure and periods during deployment where the malfunction of the logging system had gone unnoticed. If multiple 'heartbeats' were received from a door display owner's *Client Agent* during a day, it could be inferred that the owner's door display was functioning correctly. This reasoning could be used to determine how many door displays were functioning correctly for each day of the Hermes deployment and to identify periods of failure for individual door displays.

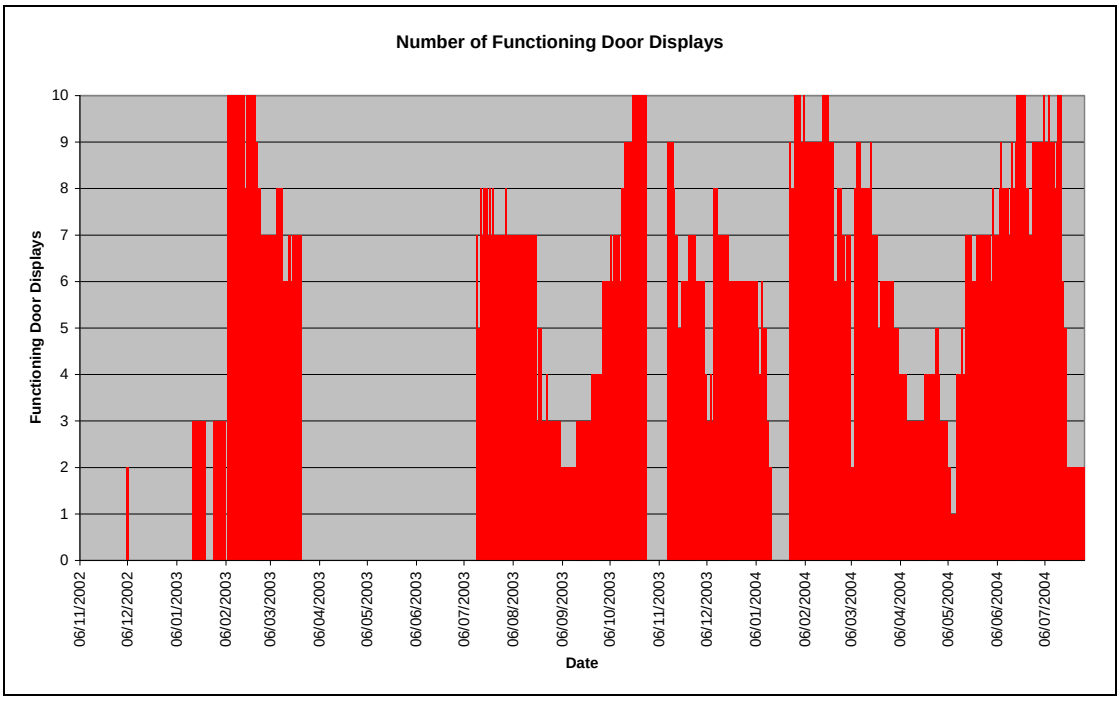

Figure 5-1: Door Displays Functioning Per Day.

Figure 5-1 shows the number of functioning door displays for each day of deployment, each vertical line represents a single day. The gaps along the x-axis in Figure 5-1 are breaks in the logs where no heartbeats were recorded from any door displays due to failure of the logging system. During the period of deployment covered in the graph there were a minimum of nine door displays deployed. The 'spikes' in the graph are where multiple door displays were functioning correctly and the troughs were caused by failure. From the data used to generate Figure 5-1 it is possible to precisely detail when one or more door displays were functioning correctly *and* the logging system was working (Table 5-1).

Start Date	**End Date**	**Number of Days Uptime**
5/12/2002	6/12/2002	2
16/01/2003	23/01/2003	8
29/1/2003	5/2/2003	8
7/2/2003	25/3/2003	46
14/7/2003	28/10/2003	106
11/11/2003	15/1/2004	65
27/1/2004	30/07/2004	185

Table 5-1: Hermes System 'Uptime'.

The smaller breaks in the logs (up to approximately seven days in length) were periods where the *Central Agent* and *Client Agent* software were in the process of being updated. In more detail, this process could take several days due to the time taken to configure the Central Server and solve any last minute problems or bugs which may not have been

identified during smaller scale testing. For example, applying an update on Thursday or Friday and running into problems would sometimes mean that the system was ‘down’ over the weekend and these problems were not rectified till the following week.

The large break shown in Figure 5-1 (between 26/3/2003 and 13/7/2003) was caused by a hardware failure at the Central Server (hosting the *Central Agent*). A hard disk failure caused the contents of the current log file to be corrupted and lost, unfortunately the most recent backup of the log file was done on 25/3/2003. After this failure the Hermes system was still not functional for several weeks due to the time taken to order replacement hardware, re-install and re-configure the server. The break early in the graph (between 7/12/2002 and 15/1/2002) was due to a fault in the early logging system causing it to malfunction which went unnoticed and caused loss of logs (this fault is discussed in detail in section 4.4.3).

The y-axis of Figure 5-1 shows the number of *Client Agents* sending heartbeats to the logging system each day of deployment and should reflect the number of door displays which have been deployed. From Figure 5-1 it is easy to see that this is not the case and this is due to failure of the *Client Agent* application or door display PDA devices.

5.4.1 Quantifying Door Display Failure

By comparing when an individual door display was functioning to whether one or more *other* door displays were functioning, periods of failure for that single door display can be identified. In this section two door display owners have been selected for analysis (owner *F* and *B*) as they represent the two extremes of reliability. Recall from section 4.4.3 in chapter 4 that several aspects of the logs prior to phase 3 could not be analysed, therefore analysis was only performed on logs generated from this phase onwards. After logging began there have been long periods where the entire system (and of course door displays) appear not to be working (corresponding with Figure 5-1). Also, there were short periods where owners’ door displays were not functioning but the rest of the Hermes system (i.e. as indicated by one or more other functioning door displays) was.

Owner F

This owner encountered seven periods of failure giving a total of twenty-nine days where the door display was known not to be functioning correctly. During the total 589 days of deployment in which the logging system was in place the door display was known to be working correctly for 381 days (the remaining 165 days being unknown). The door display shown here (for owner *F*) was the one *least* affected by failure during deployment, with a known failure rate of approximately 7%.

Owner B

This owner encountered many more periods of failure than owner F and out of a total of 589 days of deployment in which the logging system was in place the door display was not functioning correctly for 246 days and only functioned correctly for 178 days (the remaining 165 being unknown). The door display shown here was the one *most* affected by failure during deployment, with a known failure rate of approximately 58%.

5.4.2 Summary

While large breaks were evident in the Hermes logs (see Figure 5-1), large portions of the Hermes logs were intact and enabled analysis of the reliability of the Hermes system and of individual door displays. The failure rate for owner *F*'s door display was 7% and qualitative analysis of failure for this owner is discussed in section 6.3.4. However, the failure rate for owner *B*'s door display was a far larger 58%. These two door displays represent the two extremes of failure, with the majority of door displays falling in between.

5.5 Quantitative Analysis of Daily Use

This section discusses use in terms of the number of temporary *and* default messages set by door display owners per day. In

Figure 5-2 the average number of messages set by owners per day is shown, along with a moving average with a period of fourteen days to help show trends. As several aspects of the logs prior to phase 3 could not be analysed (the reasons for this are discussed in section 4.4.3) analysis was only performed on logs generated from this phase onwards.

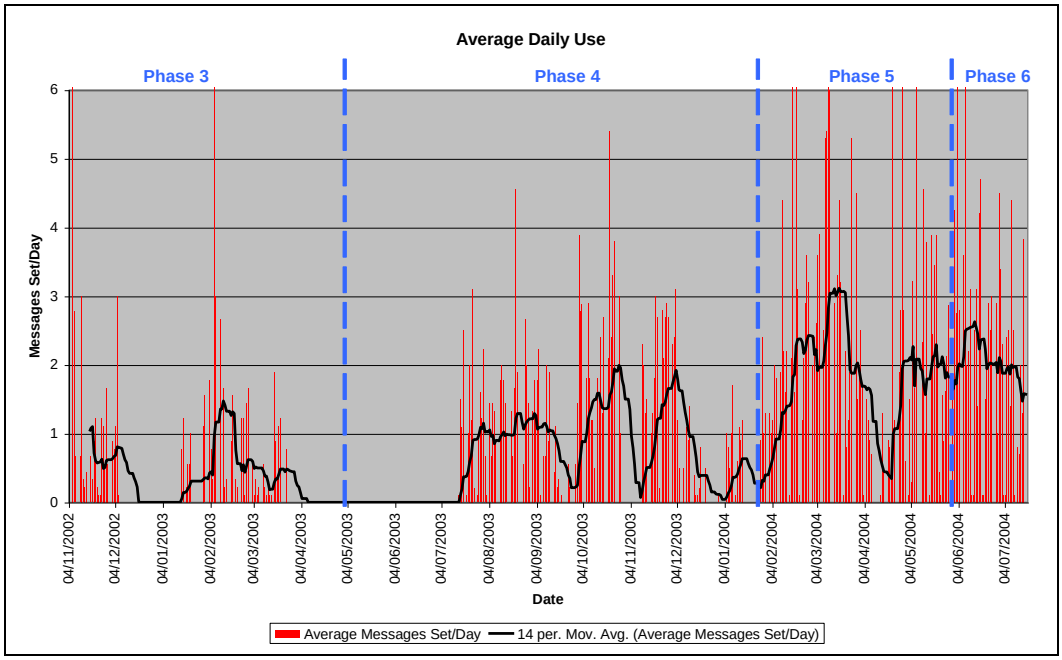

Figure 5-2: Average Number of Messages set per Day.

It appears that use increased with time, with an average daily use of approximately 0.5 messages a day set before April 2003 followed by an average of slightly over 1 message a day between July 2003 and January 2004. After February 2004 the average daily use was approximately 2 messages a day. Average use appears relatively steady until interrupted by failure and other factors such as door display owner's holidays (for example, there are breaks in use in December).

Comparing the increases in average use to the development phases (as shown in Figure 4-1), the first increase (visible in July 2003) is seen after the deployment of phase 4 when an interaction method enabling temporary messages to be set and removed more easily than previously possible (described in section 4.4.1) was introduced. As described in the following chapter, which presents qualitative analysis of use, owners found that this feature increased use of Hermes (owner F highlights this in section 6.3.3). The second large increase in use (starting around February 2004) coincided with the deployment of phase 5, where the main feature was the addition of Microsoft MSN Messenger integration (this feature is discussed in detail in section 4.6.1). This feature proved popular with owners that already used MSN Messenger (owner K confirmed this in section 6.5.3 of chapter 6) and was very likely to have caused this increase in use.

The following subsections analyse daily use for four owners in more detail *F*, *J*, *K* and *M*. These have been chosen as they represent a range of different owners that have made use of the Hermes system. These four owners are the focus of the qualitative analysis in chapter 6.

5.5.1 Owner F

Figure 5-3 shows the daily use (temporary and default messages set) by owner *F* (a senior lecturer and researcher) together with a moving average with a period of 14 days. It is clear that this owner's use was approximately double the average (shown in Figure 5-7). *F* set, on average, 2 messages a day until April 2003 followed by a slight increase in use around July 2003 and after February 2004 average use was approximately 4 messages set a day. For this owner, the introduction of MSN Messenger integration seemed to have a larger impact on use than the introduction of functionality enabling messages to be set from a door display without authentication. The following chapter (qualitative analysis) gives clues as to why this could be (section 6.3), *F* preferred to leave 'free text' temporary textual messages to include detail (as opposed to the relatively unspecific ones provided by the predefined list of temporary messages).

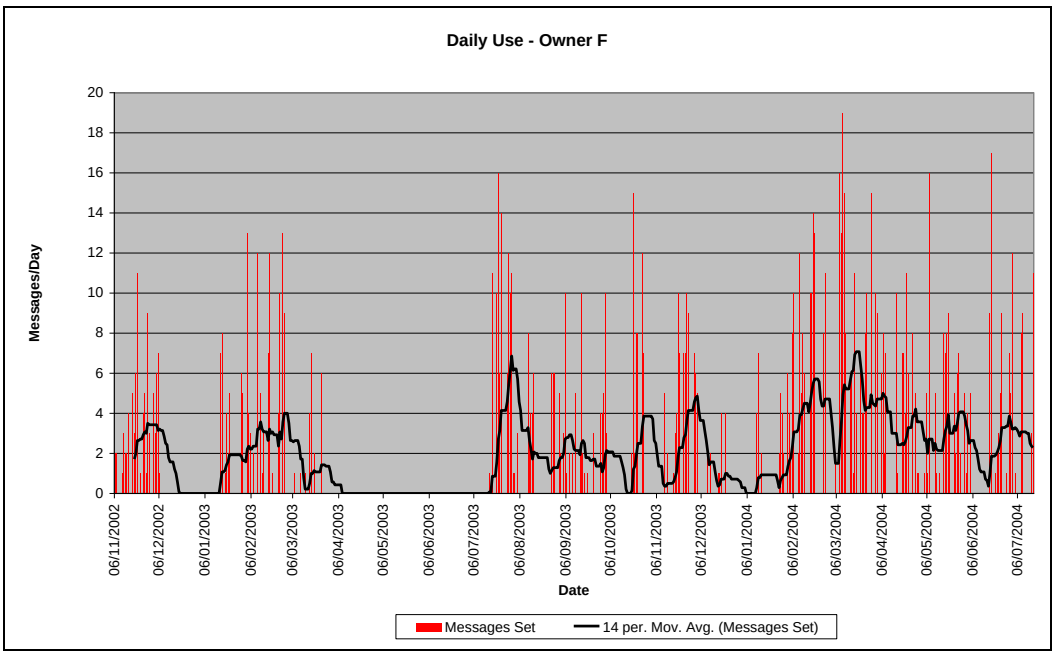

Figure 5-3: Daily Use - Owner F.

5.5.2 Owner J

Figure 5-4 shows the daily use (temporary and default messages set) by owner *J* (a departmental secretary). It is clear that this owner's use was approximately triple the average (shown in Figure 5-7). On average she set approximately 3 messages a day until November 2003, this slowly increased until the end of deployment where approximately 6 messages a day were set. Quantitative analysis of this owner's use (discussed in detial later in section 6.4) seems to provide two main reasons for her sustained and slightly increasing use: firstly, this owner previously had a message 'whirler' on her door which she used on a regular basis and secondly, visitors regularly called at her office without making an appointment. She felt it was

a necessity for her to display some context about where she had gone when leaving her office so visitors to her office could find her.

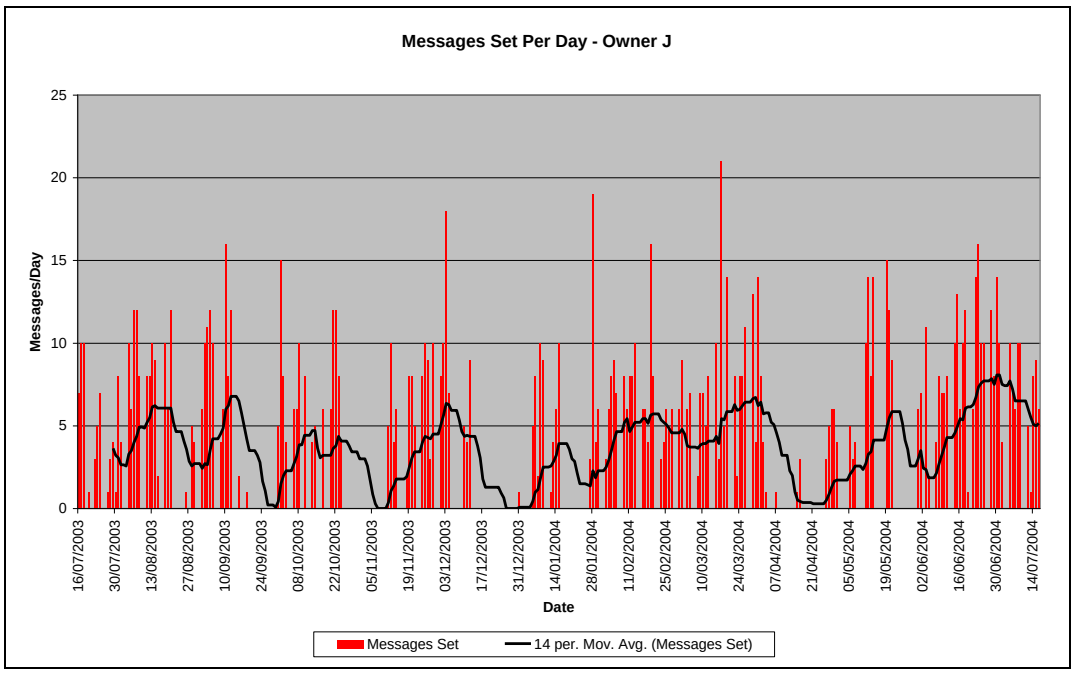

Figure 5-4: Daily Use - Owner J.

5.5.3 Owner K

Figure 5-5 shows the daily use (temporary and default messages set) by owner *K*, a researcher and lecturer working part time in the Computing Department who split his working day evenly between his two jobs in different departments on the Lancaster University campus. On average this owner set less than one message a day until February 2004. After this point the average use increased to approximately two messages set a day, coninciding with the introduction of MSN Messenger as an interaction method (as discussed in 4.6, this owner actually requested this feature). Qualitative analysis confirmed that this increase was linked to the addition of MSN Messenger integration, the owner rating it his 'favourite' interaction method (qualitative analysis of this owner is discussed in detail in section 6.5.3). After February 2004 there appears to be two distinct peaks and troughs in daily use. Even from qualitative analysis it is difficult to see why these occurred, the most likely explanations are changes in the owner's working habits (i.e. working solely away from the Computing Department) or that the owner encountered some form of failure.

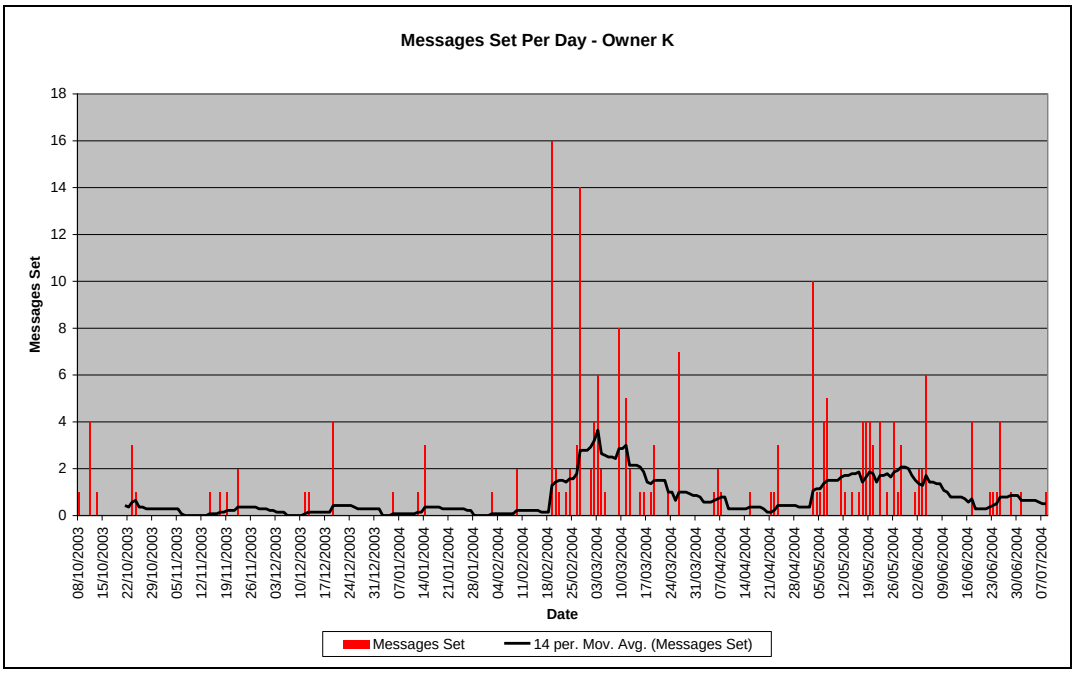

Figure 5-5: Daily Use - Owner K.

5.5.4 Owner M

Figure 5-6 shows the daily use (temporary and default messages set) by owner *M* (a departmental secretary), together with a moving average with a period of seven days. On average this owner set approximately two messages a day over the fourty-six days that she was a door display owner. The owner had used her door display for such a short period of time it is difficult to see any strong pattern emerging. However, it is intesting to note that she used her door display at least once a day when she was in the Computing Department (the breaks are caused by weekend and when she was away from the Computing Department, indicated by messages set on her door display).

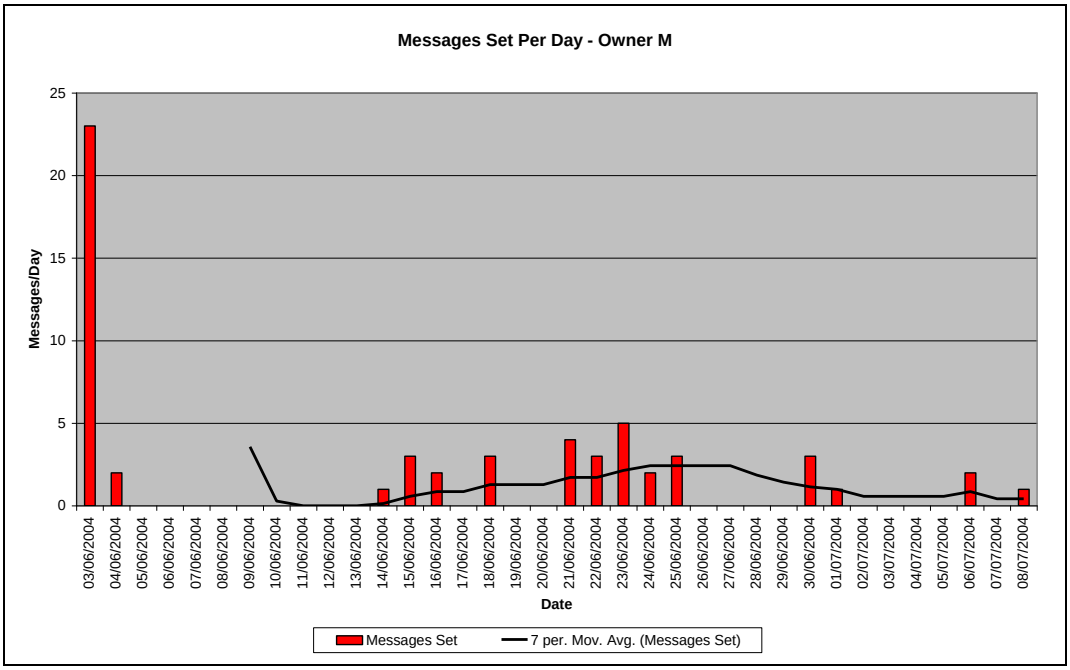

Figure 5-6: Daily Use - Owner M.

5.5.5 Summary

Quantitative analysis has been useful in order to identify usage trends and identify changed in the frequency of daily use. In the case of owners *F* and *K* an increase in daily use was seen after the introduction of the MSN Messenger interaction method. For owners *F*, *J* and *K* it is clear that daily usage of the system (despite occasional drops in usage) gradually increased. However, quantitative analysis alone did not provide an indication of why daily use was, for example, increasing or decreasing and in such cases additional qualitative analysis was necessary.

5.6 Quantitative Analysis of Messages Types

Since deployment began, owners of Hermes displays have set approximately 5500 messages (although a small proportion of these were set for testing purposes). The four different types of message are classified here as default textual, default image, temporary textual and temporary image. From the logs collected during deployment it is possible to see, for each door display owner, the number of each of the four different types of messages set per day. Figure 5-7 shows the total number of messages set broken down by type. It is clear that the most used type of message is temporary textual, making up 90% of the messages set.

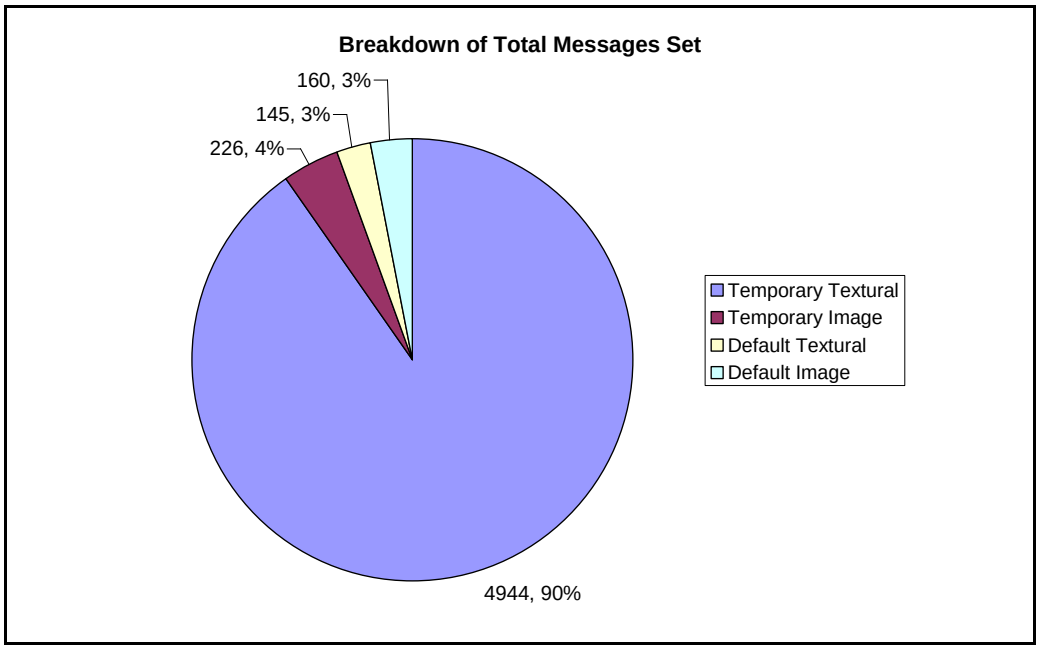

Figure 5-7: Breakdown of Total Types of Messages Set.

The following subsections investigate the different types of messages set for two owners (*E* and *J*), chosen to illustrate two different patterns of use.

5.6.1 Owner E

Figure 5-8 shows a breakdown of messages set by owner *E* (a professor) who has many duties taking them away from the Computing Department at Lancaster University. He used the introduction of Hermes to augment his existing practice of drawing and leaving paper notes outside his office, often with cartoons. For this owner the facility to draw a freehand temporary image message at his door display accounts for the large proportion of temporary image messages set. A typical example of this is shown in Figure 4-6 of chapter 4, where a hand drawn cartoon has been annotated with the message *"here but busy"*.

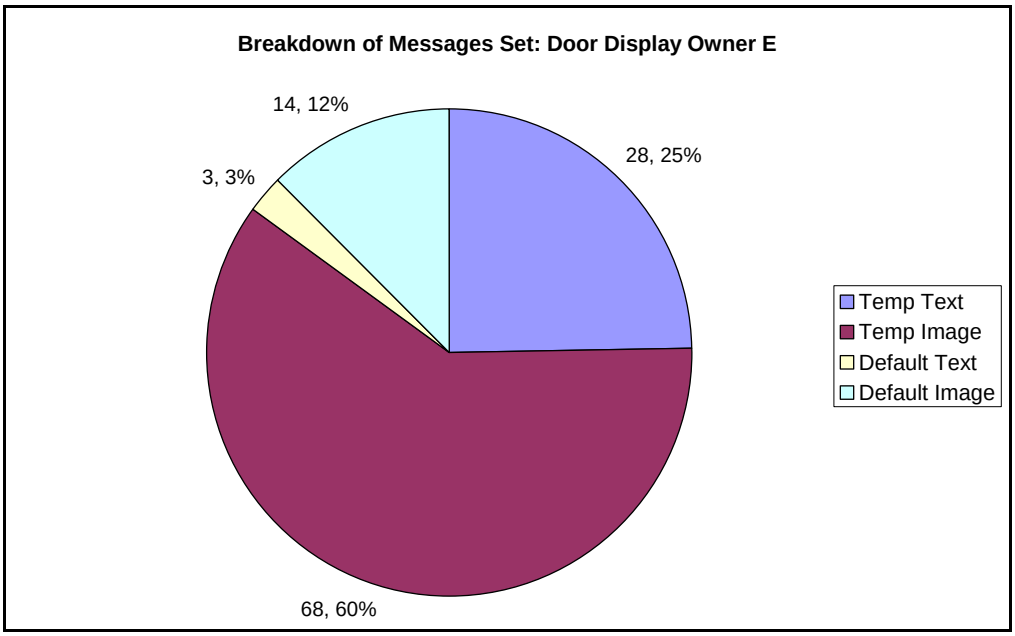

Figure 5-8: Breakdown of Messages Set: Owner E.

5.6.2 Owner J

Figure 5-9 shows a breakdown of messages set by owner *J* (a departmental secretary), this owner set the largest number of messages during the deployment of Hermes. As can be seen from the figure, the owner almost exclusively set temporary textual messages, with the default image messages very likely being used to personalise her door display (see section 4.5.3 for the steps taken to encourage this practise).

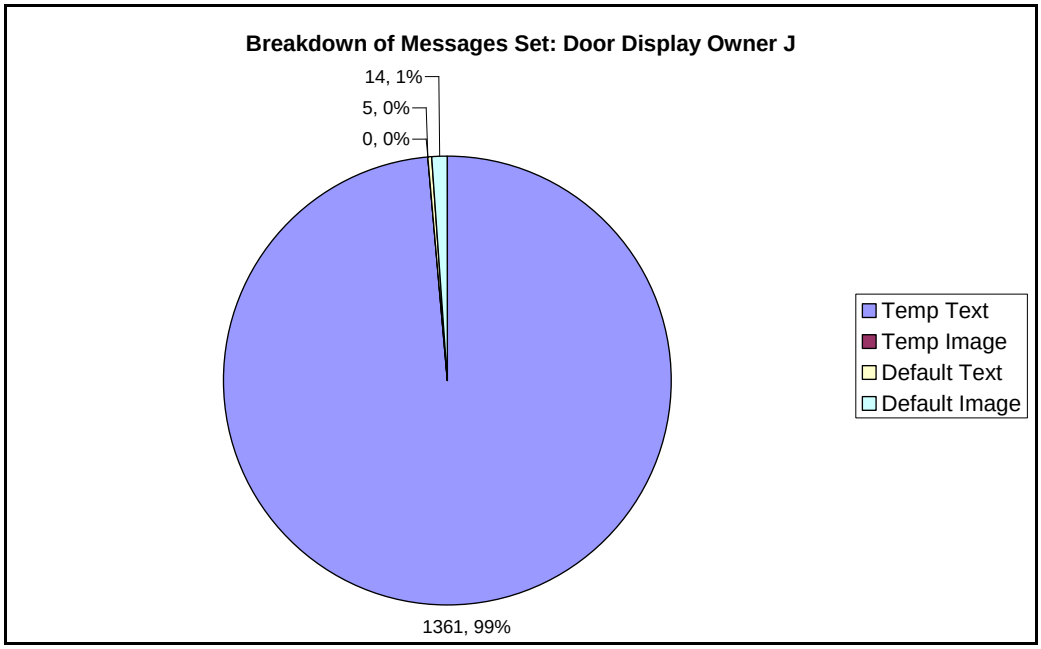

Figure 5-9: Breakdown of Messages Set: Owner J.

5.6.3 Summary

As can be seen from Figure 5-7, the overall most popular way for door display owners to display information was by using a temporary textual message. This is perhaps unsurprising, as the provision of low-cost (in terms of time and effort) methods for setting these types of messages was a recurring theme in chapter 4. However, it is evident from Figure 5-8 and Figure 5-9 that there was a large variance in the different types of messages set. Qualitative analysis provided in the following chapter gives further insights into this issue.

5.7 Quantitative Analysis of Context Sharing

This section presents the results of an initial analysis of 300 messages set by the owners of door displays over a continuous period between November 2002 and March 2003 (this qualitative breakdown of context is also presented in [Cheverst '03c]). The goal of this analysis was to obtain a rough approximation of the proportion of messages which shared personal context in some way and the breakdown of these messages in terms of their containing location, activity or temporal information (this is part of the aims of this research as described in section 1.5 of chapter 1).

Of the 300 messages analysed, 250 (83 %) contained some aspect of sharing context. Furthermore, out of the total 300 messages posted:

93 (31%) referred to location:

110 (37%) referred to temporal:

142 (47%) referred to activity:

41 (14%) referred to location + temporal

38 (13%) referred to location + activity

39 (13%) referred to temporal + activity:

23 (8%) referred to activity + location + temporal:

Figure 5-10, illustrates the breakdown of messages in a Venn diagram representation.

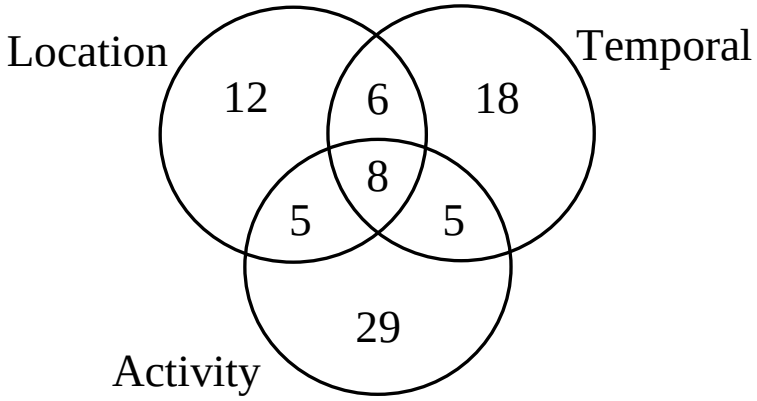

Figure 5-10: Breakdown of Messages by Sharing Context (%).

In order to obtain this statistical breakdown it was necessary to manually tag messages in the message log with tags representing each of the 3 context categories. A sample from the log including tags is shown in Figure 5-11 (the names of the door display owners have been changed).

The exact categorisation of some messages was not always obvious, for example, the message: "At CSCW'02 back Monday 25th Nov" was categorised as containing activity + location + temporal but it could be argued that the message only contained temporal and location attributes. By far the most popular single message to appear in the logs was "Gone for lunch", which in part accounts for the large percentage of activity related messages.

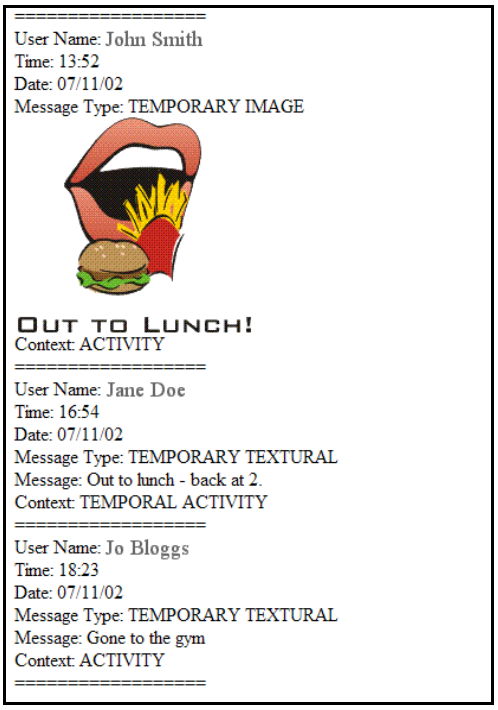

Figure 5-11: Part of the Message Log including Context Tags.

It is important to note that many of the messages categorised as activity only implicitly contained a temporal or location element, “Gone for lunch” and “Lecturing” being prime examples. Nevertheless, visitors (the vast majority being undergraduate and postgraduate students, research staff etc. from Lancaster University) are likely to have some kind of domain knowledge, including the temporal and locational rhythms of everyday lecturing life. For example, that lunch and lecturing typically last for an hour and are usually conducted in particular locations outside of the Computing Department.

5.7.1 Analysis

From the quantitative results presented in this chapter it is clear that, from the messages analysed, the most common contextual information to be included in a message set on a door display related to activity (47%). Sharing an activity seems to be the simplest way to convey general information as to *why* a person is not in his or her office. For example “Gone for lunch” is a very succinct and perfectly acceptable explanation as to why a person is not in his or her office even though it does not convey anything about where a person has gone or when they are likely to be back. For a colleague that might be all the information they need to know (with relative certainty) *where* to find the office occupant or *when* they will return. However, these kinds of short messages might be also used to give a plausible explanation for absence even if they are not strictly true. This analysis of use has demonstrated how the Hermes system was used to support cooperation.

5.8 Summary

This chapter began with a discussion of how information was extracted from logs collected during the deployment of Hermes then presented a set of requirements for a logging system, based around the shortcomings of the logging functionality provided in Hermes. Information from the logs was used to demonstrate and quantify failure for several door displays, also to quantify daily use during deployment and variances in the proportions of the different types of messages set by different door display owners. The logs were also used to quantify context sharing (using a sample of the logs) demonstrating the use of the system to support cooperation.

This chapter has demonstrated how logging and associated quantitative analysis is very useful to measure the reliability and use of a relatively complex and distributed ubicomp systems such as Hermes. However, quantitative analysis of use does not provide a complete picture, for example, the reasons for low or high levels of use, increases or decreases etc. To examine these issues and others pertaining to use qualitative analysis is also required (discussed in the following chapter).

Chapter 6

Qualitative Analysis of Use

6.1 Introduction

This chapter begins with a description of the post-deployment interview given to each door display owner. Following this, the most pertinent responses from the four owners chosen for further investigation (*F*, *J*, *K* and *M*) are discussed along with a summary section. Next, a post-deployment e-mail questionnaire sent to door display visitors is presented and discussed. Finally, drawing on both quantitative and qualitative analysis a discussion of the usability and dependability issues encountered during the deployment of Hermes is presented. The analysis discussed in this chapter focuses primarily on door display owner as lowering the barriers to use in order to support adoption from owners was key to exploring aims of this work, and with limited resources visitors received comparatively little attention

6.2 The Hermes Door Display Owner Interview

In addition to the informal feedback from owners gathered during deployment and owner questionnaire (discussed further in section 3.3), a post-deployment semi-structured interview based around a questionnaire was used to further evaluate the design of Hermes. This query approach was chosen to help understand adoption and use over the long term, additionally it enabled a variety of different areas to be investigated at low cost and provided the flexibility to explore interesting issues if they emerged during discussion. The interview was based around a questionnaire with sixty-two questions, using a five-point Likert scale and multiple choice answers where appropriate (see Appendix D). In addition to finding out about current use and attitudes towards the Hermes system, several new features were presented along with ideas for future work. The sections from the interview were as follows:-

i) Role – this section investigated the owner's role and responsibilities within the Computing Department at Lancaster.

ii) Contactability/Availability – how much time owners spent in the Computing Department and how they arrange and re-schedule meetings.

iii) User Expertise – this section investigated the owner's knowledge of the Hermes system and the extent to which different features were used.

iv) Hermes as an Information Appliance – this section investigated owner's attitudes towards Hermes as an information appliance.

v) Trust/Dependability – this section probed owner's perceptions of the dependability of Hermes and how this affected use.

vi) New Feature - Remote Accessibility – here the owner was presented with the possibility of new functionality allowing messages set by Door Display owners to be visible remotely over the web and asked about how this may affect use.

vii) New Feature - Visitor Feedback – here the owner was presented with the possibility of new functionality allowing visitors to leave feedback on messages set by door display owners, potentially helping to inform owners of how often messages they set were read and how useful visitors found them.

viii) Usability – this section attempted to find out owner's opinions of the usability of Hermes, e.g. how well it fit in with owner's daily routines.

ix) Future Work – this section investigated owners' opinions of new directions for the Hermes system, e.g. the use of multiple displays and additional types of messages.

The interviews were all recorded and transcribed. Four owners chosen for further analysis (*F*, *J*, *K* and *M*) are described in the following sections. The analysis focuses on pertinent responses (or those that demonstrate a strong viewpoint) given to questions in five sections of the Hermes interview (role, contactability/availability, user expertise, trust/dependability and usability). These five sections of the interview were chosen to help provide background on each owner and include the material most relevant to the discussion in this thesis.

6.3 Analysis of Interview Transcription: Owner *F*

This section analyses responses to the Hermes interview from owner *F*, who had a door display for approximately two years.

6.3.1 Role

In addition to duties as a senior lecturer, this technically knowledgeable owner was involved with several research projects in addition to being an MSc course admissions tutor and supervising a range of undergraduate and postgraduate students. This led to regular scheduled and unscheduled meetings with both students and staff. The owner regularly updated his door display when leaving his office (for example when going for lunch), and remotely using SMS as appropriate:

"I've definitely used it when I've had people coming to meet me here and I've been stuck, I was definitely stuck at the post office queuing once, I've been stuck on the bus, all sorts of places, and I've texted in and said I'm going to run late, and I've used that three or four times I guess"

The owner commented that colleagues would update his door display if he forgot to do so, an interesting (and unintentional) feature enabled by the trading-off of security for ease of use:

"I use it to say out to lunch, and it's quite interesting that the guys, if I don't, as I always set it to out to lunch as I walk out the door, if I forget, they set it to out to lunch for me, which I think it quite nice"

6.3.2 Contactability/Availability

This door display owner worked in the Computing Department from approximately 9am to 5pm most days including out of term time, though did spend much time working away. The Hermes system appeared to have been adopted as part of his daily routines, for example when talking about working from home he said:

"I would update Hermes to say I'm working from home – it's part of my working routine"

This owner's primary method for organising meetings was via e-mail for all types of visitors, with MSN messenger being used to a lesser extent (preferred by PhD students and researchers). He mentioned that the most successful method of organising a meeting with him was often to go directly to his office, but apart from his door display he didn't use any other methods to indicate availability (such as leaving his office door ajar). He found that all types of visitors, including those external to the Computing Department, would notice and leave messages on his door display:

"*.. and I've had visitors who have left me a message saying, you know, had to run and get a taxi, or left me a message on Hermes to say they've gone."*

This owner felt that Hermes lent itself to sharing relatively unspecific messages, owing to the ease of setting a temporary message from the predefined list on his door display. However, he would have liked to include more information when setting messages using this method, and often used e-mail or MSN Messenger to set messages that included more detail:

"I only set it to thing that weren't very specific, like in a meeting, out to lunch, and back shortly. What I would have liked to have done is had a hierarchy of frequently used things I could say: in a meeting, and then it would come up, in innovations lab, in X's office. I would have liked to have been more specific, so I actually used to set my message by e-mail and then more latterly by messenger a lot, because I wanted to give people more information."

The owner strongly disagreed with the idea of having his location sensed and shared on his door display (question 2.6 in Appendix D), he wanted control over what information was displayed and disliked the idea of his exact location being continually available. He was unsure about having his activity inferred from his location and displayed, but said he would try it. However, he stated that he would like a system which made accurate contextual suggestions when he went to change his message, but would want overall control:

"... so maybe it would have said: I've inferred that you've been sitting in this thing and your calendar says that you're in a meeting, do you want me to set your doorplate to 'I'm in a meeting', yes or no. I think I would have liked that."

6.3.3 User Expertise

This owner set temporary messages at his door display daily when leaving and entering his office. This was his most heavily used interaction method as it was both convenient for him and he found it easy to associate the physical interaction method with the action of leaving and entering his office:

"... it's at hand, it's something about your setting it on Hermes as well, so the changes you are making are associated with the physical thing right there, the direct interaction metaphor."

He also made much use of e-mail (between weekly and daily) to set messages from both at home and in the department. The door display owner began to use MSN Messenger as an alternative to e-mail, but he found that this method was less reliable than e-mail when initially introduced. He made use of the SMS integration feature approximately on a monthly basis.

The web portal was this owner's least favourite (and least used) interaction method, only being used to delete messages left by visitors and configure his preferences as necessary.

The owner described the facility of remote interaction as his favourite feature of Hermes, it being something he did not have previously. When asked about his least favourite feature of Hermes, he described that because all messages were set via a server if there was a problem with the server or connectivity to it he could not set a message on his door display. He found this frustrating, as even though his door display was functioning correctly, he could not always set a message:

"…it doesn't work in disconnected mode, so that when the network is down, which is frequently outside of your control, it would just hang basically, because it would be trying to set the status on the server, and really I didn't care about the server I wanted to change the message then, and if that change took a long time to propagate back to the server then that's fine, I didn't care, I just want it to change the status on the doorplate there and then, and let the system worry about the reliability problems, and so I think that my least favourite feature has to be the dependence on the network."

6.3.4 Trust/ Dependability

This owner said that he usually set a message on his door display between five and ten times a day, occasionally forgetting to set a message when leaving his office. He set messages in order to help make others aware of what he was doing and how to find him:

"I guess it's public spirited, it's trying to help people to be aware of what I'm doing and being able to find me more easily, or work out whether I'm available, or when I'll be back or something."

When asked if he checked to see if messages he had set appeared, he admitted to *"often"* checking on both messages set from his predefined list at the door display and set using e-mail. The owner went on to explain that there had been periods where the system had been working flawlessly and he came to trust it completely, however, it only took a few failures to begin undermining that trust:

"…there were definitely long periods where it was so reliable you wouldn't have even questioned it. I had a couple of failures with the SMS gateway, where I set the message with my phone and it just never appeared, and that really undermined my confidence..."

He said he found the confirmation given when setting a message via MSN Messenger reassuring and, after experiencing very few failures using this method, rarely checked to see if messages set using this method appeared. When asked what it would take for the owner to completely trust the system (>99%) he responded:

"If every time you set it it appeared then you'd just get to trust it wouldn't you."

He then went to talk about two changes that would help improve his trust, re-designing the client and server to be independently stateful with synchronisation (to solve the problem he described previously) and providing some sort of additional information about synchronisation (i.e. when a message set at the server had propagated to the server). As the owner was very technically savvy, it seemed very important for him to know not just if the system was not working but also why it was not working, having a mental model where he could identify where problems occurred seem to increase his trust:

"…I mean it's helping you answer that question if something has gone wrong where it's gone wrong as well, so if you know you've told the server then you know that the system knows and it's just a matter of time…"

When asked about reliability, this owner described how occasionally there were problems with individual interaction methods, which would effectively prevent him from using Hermes:

"…the SMS stuff I couldn't get to work, then the e-mail stuff failed, we had all the stuff about whether the message was in the subject line or in the body, and it stopped seeming to be able to parse my e-mails, those are my two primary ways of setting the door display. And both of them had gone, and I was like grr! You know this is slowly becoming unusable…"

Typically, this owner noticed that Hermes was not functioning correctly when he attempted to set a message at his door display and the user interface would hang or the message set would not appear. The fact that he was often able to deduce why the failure was occurring enabled him to come up with such technical suggestions for improvements to improve trust, as described previously. When asked if he was aware of the factors that affected reliability, this owner correctly identified all the causes of failure (see question 5.7 in Appendix D). He also recognised the difficulty in providing a prototypical system such as this to run continually.

When talking about his overall impression of reliability, this owner's comments seemed to conflict slightly with earlier statements, saying:

"..and on the whole it was very very resilient."

He also strongly disagreed that failure affected his future use, responding to question 5.8 (Appendix D) with:

"…I carried on using if through all the problems, I strongly disagree with that. That's mainly because it worked really really well at the start, if it had never worked well at the start, maybe I wouldn't have become such a strong advocate of the system."

This response highlighted the crucial importance of the initial trust formation phase [Siau '03] in the staged development and maintenance of trust process [Sillence '04].

This owner's technical knowledge of the system affected the way he coped with failure, for example, if he thought there was a problem with the wireless network connection or a temporary software fault, he would regularly 'test' the system to see if the problem had been solved, a last resort being to e-mail the system administrator. If he perceived the problem to be major, such as hardware failure, he would e-mail the system administrator immediately.

6.3.5 Usability

In addition to previous comments on usability, when asked if the introduction of the ability to set a message at a door display from a predefined list had increased his use the owner strongly agreed, but reiterated that he would have liked to include more information. However, he did agree that the trade-off of level of detail for ease of use was acceptable, and disagreed that the security and ease of use trade-off was unacceptable.

6.3.6 Summary

This owner was clearly an advocate of the Hermes system and was not only keen to use Hermes, but found it useful as part of his working routines. His technical knowledge enabled him to deduce the likely causes of failure and develop appropriate coping strategies. This also enabled him to make very specific suggestions for improvement and to use this knowledge to evaluate proposed new features.

6.4 Analysis of Interview Transcription: Owner *J*

This section analyses responses to the Hermes interview from owner *J*, who had a door display for approximately eighteen months. She is classified as a semi-technical owner, having limited experience in some areas of computing.

6.4.1 Role

This Hermes door display owner was a research secretary, responsible for finance, ordering of equipment and invoicing for approximately fifty research projects. She had all types of members of staff (from PhD students to the HoD) visiting her office on a regular basis, often these visits are important and involve making arrangements including a time constraint, for example arranging travel at the 'last minute'. This owner used Hermes almost every time she left her office and when she would be away for longer periods, primarily to let visitors know when she would be back.

6.4.2 Contactability/Availability

This owner works part-time, with set hours, but regularly starts earlier and finishes earlier than the usual 9am-5pm, she mentioned that others were not usually aware of her hours of work. People called at her office to see if she was free to discuss something immediately, when asked about how others arranged meeting with her, she replied:

"I'm not the type of person you make an appointment to see - my door is open all the time and everyone just turns up…"

Aside from arranging travel, ordering equipment was another of this person's main duties, typically a person would e-mail her with a list of items to be ordered, and receive and e-mail back when the order had arrived, they would then call at her office to collect it.

She propped her office door open when in her office (unless she was taking a lunch break) and prior to using the Hermes system, she used to set a paper message 'whirler' to indicate why she was not in her office from a list of predefined messages (see Figure 3-1). When asked if she found it more acceptable to display information about an activity than location, this owner strongly agreed, and expressed concerns about people coming to see her when at lunch outside of the department, stating:

"…people only need to know that I am not available in my office, not necessarily where I am."

6.4.3 User Expertise

This owner regularly set messages from her predefined list of temporary messages at her door display when leaving her office, this was her favourite method of interaction which she found very quick and easy:

"As I'm pulling my door closed I'm tapping my screen to say…."

She occasionally used the web interface or MSN Messenger to set messages when away from her office or when needing to set a message not catered for by her predefined list, stating that she used the web portal less when MSN Messenger was introduced, and that it provided a backup if the MSN Messenger integration was not working.

6.4.4 Trust/ Dependability

This owner stated that she set a message on her door display more than ten times a day (which from analysis provided in section 5.5 appears accurate), aiming to use it every time she left her office. She explained that this was because people didn't make appointments and simply went to her office, so it was important that people knew where she was. When asked about how often she checked to see if messages set had appeared she said she always

checked to see if messages set using the door display and web portal appeared, but rarely checked when using MSN Messenger: however, she did wait for the confirmation message sent back through MSN Messenger.

When asked how often Hermes was not working, she said approximately monthly, but that there were *"months on end"* where the system did work, punctuated by weeks with lots of problems. This owner had a coping strategy for dealing with failure, realising that if the Hermes server was not 'signed in' on MSN Messenger there might be a problem, but the whole system might not necessarily have failed. She would then attempt to set a message using her door display, if this failed she would then use the reset wires (described in 4.5.5) to reset her door display and then start the Hermes *Client Agent* again. If this did not fix the problem she would contact the system administrator.

6.4.5 Usability

This owner strongly agreed that the ability to set a message at a door display from a predefined list had increased her use (see section 5.5 for quantitative analysis of daily use) as it was simpler and faster compared to the previous methods. When asked if she found she did not include enough detail in messages set from her predefined method, this owner strongly disagreed, because her messages were *"well chosen"*:

"...for example, if someone knew I was at the photocopier they would know where I was and be able to estimate how long I might be."

When asked if the door displays provided enough expressivity, she said she was not sure, stating that she sometimes had difficulty fitting all important points in a small space, but reasoning that it was *"only a note"*. This owner strongly agreed when asked if she found malicious or accidental changing of her messages a problem, describing how she thought that her own temporary message was sometimes accidentally removed when visitors left a note, and that this was a problem when she set messages valid for long periods (e.g. "On holiday till X").

6.4.6 Summary

The Hermes system appeared ideal for this door display owner, providing a digital equivalent to the paper message 'whirler' she used previously. She used her door display on a very regular basis, the functionality allowing messages to be set quickly and easily from a predefined list fitting very easily into her existing daily routines.

6.5 Analysis of Interview Transcription: Owner *K*

This section analyses responses to the Hermes interview from owner *K* (see Appendix D), who had a door display for ten months leading up to the door displays being taken down. He is classified as a technical owner.

6.5.1 Role

This door display owner worked as a lecturer in the Computing Department (where a door display was deployed outside his office) and in another department on a different part of the university campus (where he did not have a door display), dividing his time evenly between the two jobs. Aside from lecturing, when this owner was in the Computing Department his additional duties included supervising undergraduate and PhD students, who often visited his office for scheduled and ad-hoc meetings. Due to this owner working in two different locations, Hermes seemed to have fit particularly well into his daily routine:

"…what I would typically be doing is coming into computing at about 9 am in the morning that's where I'd use Hermes just to change the status for the previous day to say that I'm in here. What I'm doing at the moment is tending to work in computing in the morning, spend a couple of hours here depending on the workload, and then I'll move across to ISS. I'll typically update the status when I'm on my way out. Depending on what the workload is I may come back [to computing] at some time in the afternoon, so that way Hermes is really used for me - I use it as an indicator of when I'm here and when I'm there."

This owner also recounted an example of using SMS to update his door display when he was unexpectedly held up and likely to miss a pre-arranged meeting at his office.

6.5.2 Contactability/Availability

The majority of this owner's meetings were arranged using e-mail, though the other department in which he worked used a calendar sharing and meeting scheduling system, which he seemed to find an effective way to arrange meetings. This owner agreed that he found it more acceptable to display information about his activity rather than his location, primarily to protect his privacy, but was interested in sharing different granularities of information under different circumstances:

"…you don't want them tracking you down while you're down at X or gone for lunch. Whereas if it was someone who had some urgent problem that they wanted sorted out then you might be a little less upset if they turned up at X saying 'I've got this immediate emergency, can you help?'."

6.5.3 User Expertise

When asked when he set messages using the predefined list on his door display, this owner replied:

"The move to ISS every day. Typically the message list setting would be first thing when I come in, 9 o'clock in the morning, and then again probably at 10:30…"

He found this method very easy to use, and described how his *"ultimate"* interaction method to set temporary messages would be a set of tangible buttons, having already seen the tangible interface developed by another door display owner (see Figure 4-14 in chapter 4). He went on to describe the tangible interface as the *"next step"* and analogous to the simplicity of switching off a light. This owner would use the web portal for reading messages left for him by visitors, for setting a message if he forgot to do so when leaving his office, and for configuring his list of predefined messages. He approximated his use of the web portal as weekly, but said he had problems remembering the URL. He also found the MSN Messenger integration a useful alternative to setting messages at his door display:

"I definitely was using that as an alternative really to me setting it on the display itself. That was quite handy."

This owner rated the MSN Messenger integration as his favourite feature of Hermes, when talking about why this was the case, he made it clear that not only was the interaction method very easy and simple for him to use, but it also fitted well with his existing routines:

"It wants to be something you don't have to go out of your way to do."

6.5.4 Trust/ Dependability

This door display owner said he always waited to see if temporary messages set at his door display appeared (the user interface taking several seconds to update after the final selection) and often checked messages set using the web portal. When setting messages using MSN Messenger, this owner found that he checked the first few times he used it, and after that the confirmation message sent back helped to improve his trust. When asked what would help this owner completely trust the system, he remarked that:

"Some confirmation, obviously is good."

He then went on to describe how he would like a method of retrieving the current message display on his door display.

Owner *K* had a broad technical knowledge and as such he had an understanding of all the major factors that affected the reliability of Hermes. He described how, on average, he found that his door display was not functioning correctly once or twice a week but that it had

worked correctly for weeks at a time. He would typically infer that there was a problem with Hermes if a message he attempted to set did not appear, and would periodically 'test' the system to see if it had started working again. When asked if failure was likely to affect his future use (question 5.8 in Appendix D) he explained that if the system was not working one day, he was unlikely to try to use it again that day, but might try it again the next day or next week.

6.5.5 Usability

This owner found that he typically set messages valid for several hours at a time, for example whether he was working in the Computing Department or not. He also set messages for shorter periods of time (e.g. "In Meeting") but only when in the Computing Department. He described how he would need a proportionately easier method of interaction when setting messages valid for very short periods of time:

"…it's almost like you need a proportionately easier way of setting the message, but if you think 'if I'm going away for five minutes and it's a faff to set the message I won't bother… The more effort it is, it seems it's less likely used for the smaller shorter messages: that's my way of thinking about it."

This owner was unsure whether or not how busy he was affected his likelihood of leaving a message on his door display (tending towards agreeing that it did), explaining how he was more likely to set longer term messages when busy:

"It comes back to that sort of fine granularity of messages, so the longer lived messages, I think, you're more likely to set even in a busy environment. Whereas if it's a short term message, I personally would probably not set that proportionately to how busy I was…"

When asked if the ability to set predefined temporary messages from his door display affected his use this owner strongly agreed. He also mentioned that he disagreed with the naming terminology for the different types of messages, as his 'temporary' messages were usually valid for relatively long periods of time. He also explained how he spent time customising his list of predefined temporary messages so that they fitted well with the way he used Hermes, finding that he could include all the detail he required. For example "At ISS (Room A7)" and "In Computing" were this owners two most commonly set messages (from the logs), denoting the two locations where this owner works. When asked if accidental or malicious changing of his messages was a problem (acceptability of security/ease of use trade-off) this owner was unsure, having experienced his temporary message being changed, but not finding it a problem.

6.5.6 Summary

This door display owner demonstrated a usage pattern unlike owners F and J: Hermes being primarily used as an indicator of the location where owner K was working, messages indicating this were valid for several hours at a time. This contrasted with other owners who tended to set messages that were valid for shorter periods of time (e.g. "Gone for lunch", "Back shortly"). This owner's technical knowledge (coupled with his usage pattern) enabled him to take a 'relaxed' approach to the failure of Hermes. While this owner appeared to have adopted Hermes as part of his daily routines failure only had a temporal impact on use.

6.6 Analysis of Interview Transcription: Owner *M*

This section analyses responses to the Hermes interview from owner *M* (see Appendix D), who had a door display for approximately a month in the final phase of deployment and is classified as a non-technical owner, having little computing knowledge.

6.6.1 Role

This door display owner's job title was departmental officer, and her responsibilities include departmental finance, secretarial duties for the HoD and organising exams within the Computing Department. The people that came to see this owner at her office were all from within the university (but not limited to the Computing Department). She used her door display to let people know when she would be away from her office and the reasons why she was away from her office, this was done when leaving her office.

6.6.2 Contactability/Availability

Owner *M* usually worked in the computing department from 9am to 5pm, and commented that meetings with her were usually organised by e-mail and occasionally people called by her office expecting to talk to her, but this was often used as an opportunity to arrange a meeting at a later date (due to her being busy). When asked if she found it more acceptable to display information about her activity than her location the owner agreed, but when asked to elaborate on her answer (given the example of "gone for lunch" vs. "gone for lunch at X") commented that she had never considered the idea of sharing her location in this kind of scenario:

"It's not something that I've even thought of before, just 'gone for lunch' I think is enough information, I've never even considered saying where I'm going for lunch… I don't do it so nobody can find me, it's just gone for lunch, that's it!"

This owner was unsure whether she would tolerate her current location being displayed on her door display, but had no specific concerns about privacy while at work. She

liked the idea of having her activity inferred from her location, as this would remove the likelihood of her forgetting to set a message and require no effort on her part.

6.6.3 User Expertise

This owner set temporary textual messages using the predefined list on her door display on a weekly basis and set temporary textual messages using e-mail on a daily basis. She preferred e-mail due to her familiarity with this technology and because she already sent e-mail messages to the department-wide mailing list to inform others of her absence (a typical message had the subject "Away…", with the body "…from the office on Friday 15th April 2005. Back Monday 18th"). When asked about her favourite feature of Hermes, she seemed to like that fact that it helped other people to find her when she was away from her office:

"I liked leaving my office, or leaving wherever I was going and people knowing where I was and when they could expect to catch me if they needed something, it's traceability I suppose, I liked that."

6.6.4 Trust/Dependability

This owner estimated that she set a message less than five times a day, occasionally not setting a message when leaving her office as she knew she would only be away for a few minutes or because she was in a rush, but taking care to set a message when leaving her office for *"any length of time"*. She described how initially she physically checked her door display after setting every message, but began to trust the system and checked less often. When asked what it would take to completely trust the system (question 5.4 Appendix D) she replied that she already had a very high level of trust through experiencing it working correctly over a period of time:

"…it's just a habit that you get into, a habit of leaving a message."

This owner only experienced a single very short period of failure and disagreed that failure reduced her likelihood of using Hermes again. Clearly, failure is likely to break any habit, however, this owner had not experienced more than one minor failure (during the relatively short forty-six days she was a door display owner) and so her comments were understandable.

6.6.5 Usability

This owner agreed that messages set from the predefined list did not include enough detail, speculating that this was why her preference was for e-mail, but conceded that the interaction method was useful when in a hurry:

"..because perhaps that's why I tend to use e-mail… so you can be more specific if you do your own message, but [the predefined message list is] a useful feature in a hurry isn't it?"

This door display owner experienced no visitors accidentally or maliciously changing her temporary message and saw Hermes as an improvement over her previous use of Post-it notes:

"[Post-it notes] did tend to fall down, or you'd leave them on your door when you're in [laughs] you forget to take them off. They're not reliable are Post-its, because they just don't stay up you always end up having to stick sellotape."

When asked if she though Hermes was more reliable than a Post-it note the owner replied *"Oh yeah – definitely"*, however this comment may have been influenced by the Hawthorne effect [Franke '78].

6.6.6 Summary

This owner had only used the Hermes system for a short amount of time and appeared to have used her door display regularly (see section 5.5.4 for quantitative analysis of this owner's use). Her existing routines of notifying other of her absence may have assisted this regular use. This owner made some very positive comments towards the Hermes system, however this was only based on a small period of use where failure was largely not encountered.

6.7 Analysis of Owner Interview Transcriptions

The four owners chosen included two very technical owners (*F* and *K*) and two far less technical owners (*J* and *M*). Additionally, the owners had been using Hermes for different periods of time and different job responsibilities lead to different groups of people visiting each owner for different purposes. Interestingly, one owner (*J*) had actually used a paper message 'whirler' previous to Hermes and another (owner K) split his working day between the Computing Department and another department on campus.

Analysis of door display owner interviews provided some fascinating insights into use and owners' opinions of the Hermes system. It is interesting to note that every owner used Hermes in a different way to fit in with his or her working patters, with differing approaches to failure (coping strategies) and use. The technical owners were far more verbose when asked about, for example, their approaches to failure and opinions of new features. It seems that owner *F* was perhaps the most passionate about Hermes using the opportunity of the interview

to talk about his regular use of Hermes, problems he had encountered and ideas for new features.

6.8 Visitor's Use of Hermes

One aspect of use in the Hermes system that was not explored in detail was use from visitors to door displays. In order to explore the aims of the thesis the design and analysis focussed on owners and with limited resources meant that visitors received comparatively little attention. This is perhaps reflected in the fact that approximately 5500 messages were set by owners and approximately 770 notes were left by visitors to door displays. It is likely that visitor use could have been improved by including visitors in the design process to help uncover and understand the issues surrounding their use of Hermes.

There are likely to have been several issues surrounding the use of Hermes to leave notes by visitors but perhaps most importantly was whether visitors perceived that, for example, the door displays afforded the leaving of a private note for the occupant of the office (see section 1.5 for further discussion of Norman's perceived affordances). The user interface was designed to help convey that functionality to support this task existed (using the 'Leave Note' button on the door display user interface) and how to use it (via an 'Info' button added to the door display user interface in phase 2[10]), but further study is required to evaluate how successful this was. In addition, discouraging social factors when interacting with technology situated in a public place, such as embarrassment or fear of making a publicly visible mistake (this issue was discussed in section 1.5 when defining the term situated), might account for the small number of visitor notes. Another related dimension is that because interaction with Hermes was situated in a public place this appeared to help prevent misuse from visitors [Dix '04].

The remainder of this section presents a post-deployment e-mail questionnaire carried out to help investigate visitor's feelings towards Hermes and their use.

6.8.1 Door Display Visitor Questionnaire

As visitor notes were effectively anonymous in Hermes it was clearly challenging to then pursue authors to elicit feedback. The approach used in Hermes was to e-mail a short

[10] This change was not discussed in section 4.3 but is listed in Appendix A (Client Agent 2.1, change iv)

questionnaire to all persons at Lancaster University who were likely to have used a door display. This included staff in the Computing Department, undergraduate and postgraduate students. The intention was that visitors could reply with their answers via e-mail very easily. The questionnaire (see Appendix G) firstly gave some motivation as to its purpose, followed by ten relatively brief questions in order not to deter the reader. The questions were designed to investigate visitors' feelings towards public displays and issues such as usage, trust, perception of importance (compared to e-mail), expressiveness and ease of use. For example:

Would you consider that because [the door displays] are located in a public space anyone can use them?

Of the hundreds of people that received the e-mail only two replied, an undergraduate student (hereto referred to as visitor X) and a member of the technical support staff in the Computing Department (hereto referred to as visitor Y). In this section the most pertinent responses to the e-mail questionnaire are discussed.

Visitor X only replied to the first five questions (see G.2 in Appendix G), she had been told about the Hermes system during a lecture held by one of the door display owners, and thought that because the displays were in a public space anyone could use them. She had used a door display once when visiting the office of the lecturer mentioned previously and said that the message on the door display was useful, commenting:

"The message read 'gone for coffee' and was helpful in informing me that they would return within a short period of time."

Visitor Y had been told previously about the Hermes system and the purpose of the door displays. However, even though the door displays were situated in a public place Y was unsure whether they were intended for public use. He had used a door display twice to read the message left by an office occupant, both of which he had found useful. He had also used Hermes twice to leave messages for door display owners, despite not trusting that the messages he left would be delivered. He also commented that the touch-sensitivity of the display was too high and the space not big enough. He considered this method of sending messages:

"Informal but not as important as an email."

This visitor also commented that he would like a user guide or instructions, but did not specify what form these might take.

6.8.2 Analysis

The poor response to the e-mail questionnaire was unfortunate, however the two responses provided some interesting insights into visitor use. For example both visitors found the ability to read a message left by an office owner at a door display useful, visitor X using it to help inform her as to when the occupant would return. Both visitors had prior knowledge of the Hermes system, although they may not have realised that it was an experimental prototype, and it is therefore still unclear as to the feeling of a visitor with no prior knowledge.

Visitor Y only had negative comments about his experiences of leaving a visitor note. However, he did express an interesting opinion that Hermes provided an informal method of communication and that he perceived visitor notes as having less importance than e-mail. These comments are interesting as there was no existing precedent to compare this form of communication to, aside from paper notes (where a message left at a door by a visitor is a more tangible entity and remains publicly visible). Additionally, messages sent using an experimental system are unlikely to have the same importance as an established method such as e-mail.

The limited responses to this visitor questionnaire highlight some interesting issues, clearly indicating the need for more qualitative analysis of the usage of door displays by visitors. Qualitative analysis of use from a visitor's perspective is an area for investigation in future work.

6.9 Issues

Experiences from the longitudinal development of the Hermes system coupled with the qualitative analysis of usage logs and both formal and informal feedback from door display owners (including a semi-structured interview described previously) have enabled the following inter-related issues to be identified:-

i) Adoption and Appropriation – the extent to which an owner did (or did not) use Hermes as part of his or her daily routines e.g. to set a message when leaving his or her office.

ii) Appropriate Methods of Interaction – the methods of interaction owners found appropriate (and therefore assisted initial adoption) and why.

iii) Reliability, Trust and Feedback – how trust and reliability affected adoption and use, and also the value of feedback to help encourage trust.

iv) Sharing of Personal Context – the methods and attitudes towards providing awareness information to others via the Hermes system.

v) Temporal Granularity of Messages Set – the timescales on which messages set by door display owners were intended to be valid.

vi) Point of Realisation/Opportunity – the time or place where an owner wished to set a message on his or her door display.

vii) Salience – the prominence of the door display device and user interface for visitors and passers-by.

viii) Expressiveness – the degree of expressivity provided for owners when setting a message.

ix) Accuracy and Ambiguity – the accuracy and ambiguity of the content of messages set by owners.

x) Control vs. Effort – the trade-off between an owners' desire for control over messages displayed and the need for low-effort interaction methods to assist initial adoption and continued use.

xi) Access – access to messages set by owners on door displays.

These issues were important to considering when designing functionality to lower the barriers to use and support adoption in Hermes. The issues are discussed in the following sub-sections.

6.9.1 Adoption and Appropriation

One could argue that the simplicity of Hermes not only enabled adoption by door display owners, but also enabled appropriation processes to take place. For example, during his interview (discussed in section 6.3.1), owner *F* commented that if he forgot to update his door display, his colleagues would do it for him. This represents an interesting (and unintentional) feature enabled by the trading-off of security for ease of use where a visitor to a door display was effectively acting as its owner by proxy. Additionally, owner *K* found that Hermes was particularity useful to act as an indicator of the location in which he was working, with 'temporary' messages being valid for far longer periods of time than the typical "Gone for Coffee" popular with many other owners.

When deploying the last two door displays for owners L and M a sheet was provided listing all the interaction methods together with useful information (such as the URL of the web portal, the number of the SMS gateway etc.). The two owners found this sheet useful and the approach seemed to complement the two other approaches of attempting to provide an information appliance and providing inductions for new owners. Additionally, owners were encouraged to contact the system developers if they had any questions or problems.

In order to investigate this issue further, two questions were included in the Hermes owner interview (Appendix D). The first asked if door display owners thought Hermes *should* be sufficiently simple in terms of functionality that it did not need a user guide. The second asked if owners thought Hermes *was* sufficiently simple that it did not need a user guide. Owners *F, K* and *J* strongly agreed with the first question and *M* agreed: *F* commenting specifically that it had to be simple enough for visitors with no prior knowledge to use it. In response to the second question, *F, J* and *M* agreed, but *M* (a non-technical owner) admitted that without the sheet listing the interaction methods she may have struggled. Owner *K*'s response was between 'disagree' and 'not sure' commenting that some features (for example the interaction method that involved setting and removing messages touching on the door display screen – the design of this feature is discussed in detail in Section 4.5.1) owners would not be able to tell existed without being told, and also that some features of Hermes he only learned about through conversations with other Hermes door display owners.

A user guide was not provided for visitors (aside from small instructional pieces of text on the user interface such as 'Draw your note in the space below') the intention was to design extremely simple user interfaces which required no explanation. From the logs collected during deployment 676 visitor notes were left in total (although a small number were set for testing purposes). The limited feedback from visitors (discussed in section 6.8) suggested that one visitor had no problems leaving messages for door display owners but commented that he would like some form of user guide. Providing additional guidance, via the door display user interface, or a simple posted positioned next to the display will be considered in the design of the forthcoming Hermes 2 system.

From the four owner interviews examined in detail, all owners managed to integrate Hermes into their daily routines to some extent and made regular use of it. Each of the four owners (*F, J, K* and *M*) described receiving a wide range of visitors (of differing importance) to their offices and this made the functionality provided by Hermes a useful part of their daily routines. Additionally, owner *F* described how he set messages in order to help make others aware of what he was doing and how to find him.

6.9.2 Appropriate Methods of Interaction

Arguably the most important factor which influenced adoption (and appropriation) of the Hermes system was the provision of interaction methods which were appropriate for each owner. Crucial to providing appropriate interaction methods was the use of a user-centred design approach to enable interaction methods to fit well with owners' daily routines. The primary example of this was the functionality that enabled owners to set temporary messages at door displays without authentication (this feature is discussed in detail in section 4.5.1), designed in response to feedback from owners (primarily that a low-effort method of interaction was needed).

Door display owners made a distinction between local (co-located with a door display) and remote (geographically separated from a door display) interaction methods when considering ease of use. For example many owners disliked the 'cumbersome' web portal, which was the primary (local and remote) method of interaction in the early phases of Hermes. However, the web portal has remained a relatively popular remote interaction method throughout deployment. The ability to interact with a Hermes door display remotely, especially via SMS, seemed to make the system very valuable to door display owners. This is evident from the owner interviews analysed earlier in this chapter (sections 6.3 to 6.7).

Table 6-1 shows the total number of responses in each category from all owners when asked to estimate use of the interaction methods provided by Hermes, for each interaction method a five point scale from 'Only Once' to 'Daily' was provided. It is clear that more owners use the later interaction methods (door display temporary message list, e-mail, MSN Messenger) on a daily basis than the original methods of the web portal and SMS. Additionally, the most frequently used interaction method if the local 'Doorplate – Message list' feature, perhaps unsurprising as owners are usually stood in front of their door display when closing their office door (the issue of point of realisation/opportunity is discussed in section 6.9.6).

Interaction Method	Estimated Use				
	Only Once	Rarely	Monthly	Weekly	Daily
Doorplate – Message list (see section 4.5.1)	2	1	-	-	4
Doorplate – Freehand (see section 4.3.3)	2	-	-	-	1
Web portal (see section 3.7.3)	-	4	1	3	1
SMS (see section 3.7.3)	2	-	1	-	-
MMS (see section 4.4.2)	1	-	-	-	-
E-Mail (see section 4.4.2)	-	-	-	1	1
MSN Messenger (see section 4.6.1)	-	-	-	2	2
Tangible Interface (see section 4.5.4) -Only accessible by 1 owner.	-	-	-	-	1

Table 6-1: Results of Owners Estimated Use of the Different Interaction Methods.

Another important factor affecting appropriate methods for interaction is the level of complexity, which is closely coupled with the time taken for an interaction to take place. Owner *K* commented how the simplicity of an interaction method needed to be inversely proportional to the length of time the message set would be valid, i.e. when leaving his office for a short period of time he was only likely to use an extremely easy and fast method to set a message. This was a common theme that emerged from all four interviews, if leaving their office for a long period of time (e.g. days or weeks) owners were more prepared to expend effort when setting a message.

Two crucial and interlinked factors which affected owner's use of interaction methods (and the entire Hermes system) were reliability and trust (discussed in detail in section 6.9.3). Experiences of poor reliability, for example an unsuccessful attempt to use an interaction method that had failed, negatively impacted owner trust and the likelihood of future use. A clear demonstration of this was when one owner experienced initial reliability problems with the iButton interaction method and did not use it again even though it would have simplified his interactions with Hermes (see section 4.3.6 for further discussion of this owner).

6.9.3 Reliability, Trust and Feedback

Door display owners' experiences of failure severely damaged trust, affected adoption and future use. An extreme case of this was seen with door display owner *C* who abandoned

the Hermes system entirely after several experiences of failure, despite the cause of the reliability eventually being resolved. She explained her reasoning for this as:

"…when I did try and use it sometimes it was frustrating because when I decided to use it rather than put a yellow sticker on the door it sometimes didn't work and that frustrated me, so two or three times of that and I sometimes then didn't want to try again, it was a waste of time… it looks good, people admired it, but because mine had a slightly faulty [wireless network] signal it wasn't reliable, and reliability is the absolute key".

In order to investigate the issue of trust, owners were asked how often they checked whether messages they set had appeared. Owner *F* admitted to *"often"* checking on both messages set from his predefined list at the door display and set using e-mail. The owner went on to explain that there had been periods where the system had been working flawlessly and he came to trust it completely. However, it only took a few failures to begin undermining that trust. Owner E's door display crashed showing a picture annotated with "I'm here" (indicating that he would be in his office that day) but as he could not change this message it quickly became out of date. After receiving e-mails due to his door display message being inaccurate (for example, "your door says you are here but I can't find you") this owner lost trust in the Hermes system and temporarily went back to using paper notes. Additionally, after experiencing failure when attempting to use two different interaction methods for the first time this owner discarded them completely (see section 4.3.6 for further discussion of this owner). This highlights the crucial importance of the initial trust establishment phase discussed earlier in section 6.3.4.

An interesting observation was the extent to which an owner's technical knowledge and experience of the Hermes system affected his or her reactions to failure. A common example of this was when a particular interaction method (for example MSN Messenger) had failed but the remainder of Hermes was still functioning correctly. In this case, an experienced or technically savvy owner would be able to tell that the failure was localised and use a different interaction method. However, owner *F* described that not being able to use his usual interaction methods definitely caused problems (see section 6.3.3 for further discussion of this owner).

Owners also built up coping strategies to deal with failure. For example, if owner *K* found that his door display was not working he was unlikely to use it for the rest of the day but would try it again the next day. Owner *J* worked through several logical steps when encountering failure, testing different interaction methods, resetting her door display and finally contacting the system administrator.

When asked if failure reduced their likelihood of using Hermes again *F*, *J*, *K* or *M* either agreed or strongly agreed. For example, after owner *K* explained his methods of coping with failure he summarised:

"[failure is] more likely to get you to stop using it in the short term, that's not to say it's going to stop you using it the next week or next month"

Additionally, owner *F* explained that he was such an advocate of the Hermes system because it worked very well at the beginning of deployment, again highlighting the importance of the initial trust establishment phase.

In order to want to use the system door display owners must trust in it, for a trust relationship to build the system must be reliable. Early versions of the system were unreliable and could crash leaving an out of date message displayed on screen. In the owner questionnaire, one response to a new feature was *"I'd use it if I were absolutely certain it would work"*. However, visitors must also trust in the reliability of the information they read. Finally, owners must believe that visitors will see (and trust) the messages they set.

One of the key methods identified during the deployment of Hermes to help maintain trust in the face of poor reliability was to provide feedback to owners. Feedback can be used, on various levels, to help inform owners of failure and prevent owners attempting to interact with a part of the system which has failed and therefore damage trust. A primary example of the value of feedback was demonstrated by the MSN Messenger interaction method (the design of which is discussed in section 4.6.1) where despite very low initial reliability the feature still proved popular. In this case, owners could easily tell if the MSN Messenger component of Hermes was working and were forced to use other interaction methods if not. Additionally, the MSN Messenger interaction method provided positive feedback to the owner when a message had been set successfully. The issue of feedback is discussed in detail in section 4.9.4.

6.9.4 Sharing of Personal Context

In Hermes, personal context (e.g. an owner's current location) was shared by manually setting a message, which contrasts with the popularity of investigating the technical feasibility automatically capturing and sharing personal context (e.g. via an active badge [Harper '92] or sensor-rich coffee mug [Gellersen '99]). Hermes gave an owner complete control over context shared, but the trade-off was the need to consciously set a message every time this was necessary (either at the door display or remotely), which essentially relied on an owner adopting the system as part of his or her daily routines.

Some owners liked this fine-grained control over the information displayed (for example owner *F* was very clear that he wanted the *"final say"* over what was shown on his door display). However, to investigate this issue further several questions included in the Hermes owner interview (Appendix D) and questionnaire (Appendix C) were intended to investigate whether door display owners were prepared to forego control in order for their location (or an activity inferred from a location) to be displayed automatically. From the owner questionnaire the majority of respondents were prepared to have their location sensed and displayed on their door display. However, none of the four owners analysed in detail (in the owner interview) entirely agreed that they would like their location sensed and displayed. *K* was the only owner to actually agree but stated that he had concerns over how the information might be used and said that he would like to restrict access to specific groups of visitors. When owners were asked if they would be happy for their current activity to be inferred from their location and automatically displayed, there was a split between technical and less technical owners. Both *F* and *K* (the more technical owners) expressed concerns over how accurate this kind of system would be and stated that they would need to test the system to see how accurate it would be in practise – both being 'not sure'. However, the less technical owners (*J* and *M*) agreed that the this kind of feature would be useful as it would be less effort for them, *M* stating that it would remove the problem of them accidentally forgetting to set a message.

From investigation of context sharing (described in detail in section 5.7 of the previous chapter) the highest percentage of messages shared some information about activity. It appeared that Hermes lent itself to the sharing of unspecific and expressionless messages indicating an activity, very popular messages being "Gone for lunch" and "Gone for coffee". These messages generally give an acceptable explanation of why a person is not in his or her office in the smallest number of words. Allowing owners to configure a list of predefined messages which could be selected quickly encouraged this behaviour (and, as discussed in section 5.5, increased use) as this interaction method required the smallest amount of effort. In the case of many door display owners, for the majority of use, Hermes was acting as a digital message 'whirler' an owner selecting from the predefined list of temporary messages when leaving his or her office.

In order to investigate whether owners found this ease of use vs. message detail trade-off acceptable a question to this effect was asked in the owner interview. An additional question asking if owners felt they left enough detail when setting temporary messages from their door display was also asked (see question 8.2 in Appendix D). Owners *F*, *K* and *M* agreed to both of these questions, *F* and *M* stated that while very easy to use, the ability to set

temporary messages from the predefined list was not ideal and that they preferred methods which could include more detail. Both *F* and *M* made use of the other interaction methods where free text messages could be set, *M* preferring e-mail. Owner *J*, a previous user of a message 'whirler', strongly disagreed that messages set from her predefined list of temporary messages did not include enough detail, stating that she carefully customised her predefined messages. Owner *J* also gave the example that if she set the message "Photocopying", her colleagues would be able to infer her location and estimate when she might be back. This is perhaps an unusual case where the owner's daily routines are relatively unchanging and well known to others.

6.9.5 Temporal Granularity of Messages Set

Some owners used door displays to say what they were doing on a particular day e.g. "Am in today" or "Away Tues at Viva in Bristol". Others used it for occasional critical messages e.g. "stuck in traffic - 10 mins late". While some used it for fine grain activities e.g. "gone to meeting", one such owner commented that the information which he shared via messages set on his door display could effectively act as a fairly accurate journal of his activities. This latter owner did not use paper notes to share messages relating to fine-grained activities before the deployment of Hermes.

Owner *K* consistently used 'temporary' messages in order to display messages that were valid for longer periods of time than the usual 'Gone for lunch'. Due to this owner working in two different locations, Hermes essentially acted as an indicator of whether the person was in the Computing Department or not.

6.9.6 Point of Realisation/Opportunity

This is linked to the notion of effort but more to do with the fact that an owner needed to be able to share context at the moment in time at which it occurred to them to do so. For example, the act of closing the office door served as a prompt for many owners to set a message. In order to support this response, interaction methods were provided for an owner to set a message using the door display's user interface (such as the interaction method described in section 4.3.3 allowing a free-hand message to be drawn). When using a door display to set a message upon leaving an office, owners required the interaction method to be very easy and quick to use (this requirement motivated the features described in section 4.5.1 allowing messages to be set and removed by simply tapping the screen of the door display).

One of the motivational scenarios for the Hermes system included the facility to interact with a door display remotely via SMS using a mobile phone (as discussed in section 1.1). Both owner *K* and *F* found the SMS interaction method very useful when unexpected

delays while away from the university meant that they would be late for a pre-arranged meeting. When discussing the SMS interaction method, owner *F* recounted several examples of where this feature had been particularly useful such as when he had been unexpectedly delayed by a queue at the post office which he knew would make him late for a meeting (these are discussed in section 6.3.1).

From the perspective of a visitor, the Hermes door displays were situated in an ideal place. In more detail, when a visitor wants to know where the office owner is or how long they will be away the information is, very likely, there at the point and place it is required.

6.9.7 Salience

While the door displays were located in an ideal place for use by visitors, there was an inherent trade-off between the salience of the each display and the social acceptance required for deployment in a public space. For example, the door displays could have employed bright colours and sound in order to attract the attention of visitors but this kind of design would have been distracting for members of staff working in the Computing Department and would most likely met strong opposition. Conversely, in the case of very low salience, a new visitor may not realise that the digital door display should be consulted and hence miss a message. One of the early door display owners used to have a yellow Post-It note on the actual door saying *"look at display!"* Strongly associated with the notion of Salience is the notion of calmness. Weiser suggests that a calm technology [Weiser '97] is one which *"...engages both the centre and the periphery of our attention, and in fact moves back and forth between the two."*

Several door display owners commented that they had been able to infer from a visitor's subsequent behaviour that the visitor had seen the message on their door display. However, when probed further, owners seemed unable to remember specific instances and none of the owners interviewed recalled discussing their door displays with visitors.

One of the final features added during the last phase of Hermes was the ability to change the colour and formatting of text (the design of this feature is discussed in section 4.7.2), the motivation being the possibility to chance the salience of a textual message. Unfortunately this feature was not in place long enough to receive significant use.

6.9.8 Expressiveness

In phase 1 of Hermes door display owners were able to set messages which were either textual or image files. While image files could be set as messages, potentially allowing for a relatively high degree of expressivity, to author an image file obviously requires the use of a computer, is often more time consuming than a paper note and can provides less

expressivity than a paper note. In phase 2 of Hermes one owner specifically requested a feature to help provide the expressiveness available with the paper notes he used previously.

While the issue of expressiveness when setting a message proved extremely important for one owner, other owners found the ease and speed of interaction more important. Owners *F*, *J*, *K* and *M* were all heavy users of the predefined list of temporary messages which could be set easily and quickly using the door display. When using this method owners were restricted to the list of messages they themselves had configured, effectively trading-off expressiveness for ease of use. Owners *J* and *K* found that they could include the level of detail they desired by customising the list of messages, while *F* and *M* occasionally used alternative interaction methods to include additional detail. Owner *F* clearly identified that the different interaction methods could be used for different levels of expressivity i.e. from textual messages (low), to free hand draw (medium), to images files (high).

6.9.9 Accuracy and Ambiguity

A feature added in phase 6 gave owners the option of including a time stamp, visible to a visitor, when setting a message (discussed in detail in section 4.7.3). This feature was introduced after specific requests from a door display owner, as this extra piece of context might make messages more useful to visitors. While no door display owners actually decided to disable this feature using the owner preferences, the feature was available for such a short time that little investigation was possible into its use.

One potential feature to improve the accuracy of messages left by owners on door displays may be attaching a ‘countdown timer’ to messages. For example, when setting the message “Back in 5 minutes” if the message was not removed in five minutes it could simply be removed or changed to something more ambiguous such as “Back Shortly”. Clearly there is much scope for altering messages based on time in order to improve accuracy, but these features might increase the complexity of user interfaces and rely on successfully conveying new interaction models (which proved difficult in phase 6, as discussed in section 4.7.6). Additionally, increasing the accuracy of messages removes an element of plausible deniability as an owner might set a message “Back in 5 minutes” knowing that they will be away for longer.

6.9.10 Control vs. Effort

This issue concerns the owner’s need to perceive that they have a strong level of control over what context is displayed on his or her door display. The Hermes system required owners to actively select or express context for display. In contrast, other awareness systems, such as the Active Badge system [Harper '92] allowed the owners to maintain a passive role

by automatically capturing their context, e.g. location. There are a number of tradeoffs to be considered here, but the most obvious is that between effort (on behalf of the door display owner wishing to share their context) and control.

When owners were asked if they would like to have their location sensed automatically (for example using Active Badges) and displayed on their door displays responses were mixed, with two major concerns being privacy and the control over information displayed on door displays. When asked if they would like their activity automatically inferred and displayed on their door display, the two less technical owners (*J* and *M*) agreed, owner *M* said:

"…you often forget if you're in a bit of a rush… it would be useful to just have it done automatically."

However, the two more technical owners (*F* and *K*) were unsure about this idea, largely because they recognised the difficulty in implementing it accurately:

"I wouldn't have a problem with trying to infer it, but I'd have a concern that the inference is correct."

As discussed in section 4.5.1, Hermes allowed the setting of temporary messages by simply touching the screen (rather than completing an authentication process, as shown in Figure 3-4 of chapter 3). One implication of this was that the owner was effectively giving up some element of control in favour of reducing the effort required to set a message sharing his or her context. Owners were prepared to accept the fact that a mischievous passer by could select a temporary message on the door display. It is important to note, however, that the mischievous passer-by could only select a message from the prescribed set of messages available and that the owner has ultimate control over this prescribed set. Initial discussions with owners and the results of the questionnaire revealed that allowing the possibility for unauthenticated visitors to leave 'inappropriate' free-hand messages on door displays was not acceptable to owners.

Also recall from section 4.5.1 that in order to reduce the effort of removing temporary messages, they can be removed by simply touching the display. Prior consultation with owners suggested that this trade-off between effort and control was acceptable. However, a questionnaire (see Appendix C) revealed that a minority of owners were concerned that temporary messages could be removed by a mischievous passer-by. The system was modified in order to give owners control over whether a temporary message required authentication before being removed via a door display (as described in section 4.7.1).

The interaction method allowing messages to be set from a predefined list without any authentication (the design of which is described in section 4.5.1) clearly traded off control (or security) for ease of use (i.e. effort). In order to investigate this trade-off, owners were asked whether they found malicious or accidental changing of their temporary message to be a problem. The majority of door display owners reported that they had found their temporary message had been changed by others (no owners suspected that this had been done maliciously), but that it had not caused them much concern, a typical comment being:

"I did have it changed a couple of times, but it wasn't a problem."

This specific issue is also related to dependability, as the system's dependability is adversely affected if others can (accidentally or otherwise) remove a message the door display owner intends to be displayed. However, one door display owner found that this feature enabled his colleagues to appropriate his displays and change his temporary message if he had forgotten to configure one (this is discussed further in section 6.9.1). Recall from section 4.7.1 in chapter 4 that features added to help prevent temporary messages being modified maliciously or accidentally.

6.9.11 Access

Although owners were prepared to share personal context they invariably wish to have some control over who has access to the context, and when and where the context can be accessed.

Of the four owners *F, J, K* and *M* all stated that they would allow others within the Computing Department to be able to view the message on their door displays remotely (evident in both the questionnaire and interview), but disliked or were unsure about the idea of their message being accessible by anyone with internet access. A formative study carried out into location disclosure by Consolvo *et al* [Consolvo '05] revealed that the most important factors in this context were *"who was requesting, why the requester wanted the participant's location, and what level of detail would be most useful to the requester"*. This area clearly requires further instigation, as when sharing a message via the internet a door display owner has little or no control over these three factors. Owners *J, K* and *M* disagreed that making their messages available to a wider audience would affect their decision to leave a message, while *F* said that theoretically this would reduce his likelihood of leaving messages but was unsure whether this would affect his usage in practice.

All four owners reacted differently when asked how this would affect the content of their messages, owners *F* and *M* stated that this would greatly reduce the level of detail they included in their messages. *K* was concerned that criminals would potentially be able monitor

his door display to see when he would be away from his home. Owner *J* felt that she would be more formal and precise about her messages, as people may be travelling modest distances across campus dependent on her message.

6.10 Summary

Qualitative analysis of use provided through a door display owner questionnaire and interview yielded numerous interesting insights into eleven primary usage issues in Hermes. These issues emerged primarily from the use of a user-centred design approach and will be used in informing the design and analysis use in Hermes 2 (discussed in appendix J). These issues, which may have appeared relatively uncomplicated from the outset, now appear complex and interlinked. For example, in order to enable regular use, a door display owner may require an appropriate interaction method that fits in with her existing daily routines and enables the desired level of personal context to be shared. Once this interaction method is available she may start to expend additional effort to adopt Hermes as part of her daily patterns, using it more and more. However, if this interaction method is unreliable (as was the case with the early SMS and MSN Messenger integration features) then she is likely to abandon expending this extra effort, meaning adoption will not take place and perhaps severely impacting the likelihood of future use.

Chapter 7

Conclusion

7.1 Summary of the Thesis

This thesis has explored the longitudinal design, deployment, use and evaluation of a system of interactive digital displays situated outside office doors. These displays provided a groupware system to support awareness and coordination between members of the Computing Department at Lancaster University. An approach combining technology led and user-centred design was used in order to help support adoption and maintain use from door display owners during deployment. Through both quantitative and qualitative analysis of longitudinal use two key areas of adoption and context sharing were explored in detail. This work has demonstrated how the development and longitudinal deployment of a display-based ubicomp system raises challenges on a range of levels from hardware through to human factors.

The first chapter introduced and motivated the work presented in this thesis and highlighted the relevance of situated interactive displays to the research areas of CSCW groupware and ubiquitous computing. Definitions of key terms were also discussed and the aims of the work presented in this thesis were given.

The second chapter surveyed existing work in the area of situated display-based technology and contrasted it with the aims of this thesis. This chapter highlighted the relatively small number of existing systems deployed for use outside of the typical lab scenario and the scarcity of these systems deployed and evaluated over a longitudinal period of time. Additionally, relevant design methodologies were discussed.

The third chapter introduced the Hermes system together with a description of the design and development approach used. The implementation and deployment of the initial (phase 1) prototype was also discussed. This chapter highlighted the challenges involved in building this early prototype along with the requirements that arose from its deployment.

The fourth chapter chronicled the phased development and deployment of the Hermes prototype system subsequent to the initial prototype. More specifically, this chapter showed the evolution of the Hermes prototype during 'real-world' deployment, using a form of rapid prototyping and user-centred design to produce new requirements. This chapter also highlighted the challenge of managing reliability and discussed the user-centred design approach used during the development of the Hermes.

In chapter five I used logs to provide quantitative analysis of the daily use received from the twelve[11] door display owners during the twenty-seven months of deployment. This chapter highlighted the importance of logging in ubicomp deployments in order to help understand adoption and use. A set of requirements for a logging system in this context were also presented. Additionally, logs were analysed in order to quantatively investigate personal context sharing by door display owners. The quantitative analysis carried out in this chapter uncovered a need for both quantitative and qualitative analysis in order to help understand use.

The sixth chapter presented a qualitative analysis of the use Hermes received. Firstly, responses to a post-deployment interview were analysed in order to identify pertinent issues and areas which evoked strong feelings from owners. Secondly, using previous analysis (quantitative and qualitative) and feedback generated from owners throughout deployment, a set of eleven inter-related issues which impacted adoption and use were identified and described.

7.2 The Challenges of Building a Ubicomp System

The building of a ubicomp system raises challenges on a range of levels. This has been demonstrated by the development of the Hermes system and the following sections discuss the most salient issues that have been raised.

7.2.1 Communication Technology

The Hermes system utilised an experimental wireless network (part of a research initiative by another project) in order to simplify deployment which caused several reliability problems. Primarily, the wireless network connection to a door display was often lost when an

[11] Due to door display removal and redeployment there were a total of twelve owners and ten door displays.

owner or visitor interacted with it. This was due to the location of the wireless access points and the fact that human bodies blocked wireless network signals. Due to the client-server design of the Hermes system, loss of network connectivity prevented the door display application functioning.

7.2.2 Hardware

In the Hermes system, 'off the shelf' hardware (a PDA) was tailored to meet requirements which enabled a prototype system to be developed quickly. The use of off the shelf hardware also meant that there were no unexpected problems such as overheating. However, there were initial stability problems with the operating system and hardware device drivers.

In order to enable the display devices to be deployed a secure housing was necessary, the design of which proved problematic. Additional deployment challenges included adhering to relevant legislation.

7.2.3 Software

The Hermes system was developed in Java in order to provide platform independence, however finding a Java virtual machine for the chosen hardware platform proved challenging. The main problem being that the majority of available solutions did not support the required Java Communications API required to support iButtons. Information on available Java virtual machines for this hardware platform proved so scarce that a web site produced by myself and presenting findings from this work in order to help other researchers proved extremely popular.

7.2.4 Development Approach

One of the main aims of the Hermes system was to develop an information appliance with intention of developing a basic application initially to allow functionality to evolve with feedback from owners. A phased development approach was used where in each phase functionality was added or modified, primarily in conjunction with feedback from owners. However, trade-offs must be considered when selecting new features to implement. For example, when adding a feature requested by one owner this might cause an increase in user interface complexity for all owners.

7.2.5 Deployment Issues

The deployment of the Hermes door displays over a longitudinal period of time for daily use raised many challenges. A primary challenge was addressing hardware and software reliability problems in order to maintain an owner's perceptions of dependability. Some

reliability problems were only apparent after the system had been deployed. For example, multiple people congregating around a display would block the wireless network signal causing packet loss which forced retransmissions of the Java RMI invocations used to communicate with the Central Server. This led to long delays for the user as RMI requires a large sequence of message exchanges to be sent and acknowledged between the client and server in order to complete a single RMI call. During periods of poor signal strength the overhead generated by these RMI calls prevented the user interface from responding to user actions and gave the impression the door display had crashed.

Another key challenge was that of managing the deployment. For example, manually installing software updates became a tedious and time-consuming task (highlighting a requirement for remote updating of software as presented in section H.1.1.3 and discussed in section J.5). Other problems were caused by unforeseen use of the door display application, one example being mischievous visitors 'overwriting' an owner's message with an inappropriate drawing.

7.2.6 Human Factors Issues

Through the use of user-centred design approaches during the development of Hermes together with quantitative and qualitative analysis of use a range of human factors issues have emerged.

Adoption of the Hermes system by door display owners appeared to be heavily dependent on owners finding appropriate methods of interaction that, for example, fitted in with existing daily routines. However, two extremely important interlinked issues, which affected adoption and use of interaction methods by owners, were owner's trust and perception of the dependability of Hermes. One method which successfully encouraged owner's trust was the provision of feedback.

Throughout the deployment of Hermes, control and expressivity emerged as important issues when owners set messages on door displays. Owners chose to set messages sharing varying levels of personal context in order to support cooperation.

7.3 Evaluation of Aims

The work presented in this thesis has explored four interrelated aims which are stated then evaluated in the following sections.

7.3.1 Aim 1

To explore the design, development and deployment of a prototype interactive digital office door display system to support asynchronous messaging. To do this using a

development approach which involves technology driven and user-centred design, including both qualitative and quantitative investigation of use in order to refine the system and observe emerging requirements.

The design and deployment of Hermes prototype door display system, combined with quantitative and qualitative analysis of use, together with the use of a user-centred design approach uncovered many relevant issues. Deployment outside of the 'lab' raised many pragmatic issues such as challenges of technical problems adversely affecting reliability and managing a deployed ubicomp system. Additionally, a wide range of usability issues emerged which impacted upon adoption and use.

An additional part of this aim was the use of both technology driven *and* user-centred design approaches. In order to meet this aim feedback was sought from users (primarily door display owners) throughout the development of Hermes. This was in the form of informal feedback (such as verbal comments, problems and ideas for improvement), questionnaires and a semi-structured interview. From the phased development of Hermes it is evident how new features and requirements emerged from the use of this approach, some features were requested directly and the need for others emerged through analysis of feedback.

7.3.2 Aim 2

To use the prototype office door display system to investigate the different affordances enabled by a digital approach to supporting situated messaging in a university department, compared to traditional approaches such as paper notes and message 'whirlers'.

Exploration of each of the key affordances explored by the Hermes prototype are listed below together with the requirements or design considerations they motivated:

i) remote setting of messages - requirement 1 in section H.1.3.1,

ii) remote viewing of visitor notes - requirement 3 in section H.1.3.1,

iii) control over visibility - requirement 2 in section H.1.3.2,

iv) security/authentication - design considerations 4 and 6 in section I.1.1.4,

v) semi-automated reply procedure - requirement 4 in section H.1.3.2.

However, other interesting affordances enabled by the digital approach (to existing paper-based messaging systems) emerged during development. These were:

vi) automatic inclusion of additional context in messages – requirement 7 in section H.1.3.1.

vii) notification of failure - requirement 5 in section H.1.3.1,

viii) feedback on remote interaction - requirement 6 in section H.1.3.1,

One key affordance not explored in Hermes was the use of context to automatically generate owners public messages, for example using information from electronic calendars or location aware technologies. These features were not explored primarily due to the associated high development cost. However, due to a positive response when asked about the feature, the requirement for integration with owner's electronic calendars is listed as requirement 8 in section H.1.3.1 of Appendix H.

It is important to note that while scenarios providing aspects of these affordances might be possible with traditional paper-based approaches they would require assistance from a colleague. For example in ii) above, a colleague would be required to check if a message had been attached to an office door remotely. Additionally, in a digital system it is easier to replicate information such as text, for example one door display owner would send an e-mail message to a door display and a departmental e-mail list in the same action. However, paper notes do provide some desirable properties not possible with a digital system, such as no hidden complexity. Additionally, it was difficult to achieve the expressivity provided by paper notes in Hermes. It is clear that both systems (paper notes and Hermes) have different strengths when used to support awareness, underpinning the intention for Hermes to augment rather than replace existing use of paper notes and message 'whirlers'.

Perceived affordances, especially from the perspective of visitors, were not considered extensively in the design of Hermes. Whether visitors perceived the functionality provided by Hermes (displaying messages left by owners, leaving notes for owners etc.) is one key issue to be addressed in the forthcoming Hermes 2 system (discussed in Appendix J).

7.3.3 Aim 3

To design a prototype digital interactive office door display information appliance (and produce an associated set of requirements) that is intuitive to walk up and use without prior training.

Feedback from door display owners and visitors suggested that the functionality provided in Hermes was both simple and useful to its users. Requirements for application functionality have been generated from the evaluation of Hermes and are presented in Appendix H.

7.3.4 Aim 4

To utilise the prototype digital office door display system to investigate issues of initial adoption and continued use through the long-term deployment, evolution and evaluation of prototypes 'in situ'.

The Hermes system was operational for approximately twenty-seven months (from March 2002 to July 2004) with a maximum of ten door displays being deployed for twelve different owners. From quantitative and qualitative analysis of use, it is clear that the door displays played a part in their owners' daily routines. During deployment approximately 5500 messages were set by owners (although a small proportion of these were set for testing purposes) and approximately 770 visitor notes were left at door displays (although a small proportion of these were set for testing purposes). It has been interesting to note how the system was adopted and appropriated in different ways by door display owners, largely influenced by existing role, working routines and technical experience.

7.4 Major Contributions

The major contributions of this thesis can be summarised as:

i) an exploration of the longitudinal deployment of a digital display-based ubicomp system providing asynchronous messaging within a university department,

ii) an understanding of the adoption and appropriation of the system,

iii) an understanding of the use of the system to share personal context in order to support awareness and coordination.

7.4.1 An Exploration of Longitudinal Deployment

The Hermes system was deployed for twenty-seven months with up to ten door displays used by a range of owners, during deployment approximately 5500 messages were set by owners and 770 notes left by visitors. All use of the Hermes system was logged in order to allow investigation of use, which raised challenges for the collection, storage and analysis of such information in a ubicomp deployment. These logs provided a rich resource which, to date, has enabled quantitative investigation of failure and various aspects of use (including analysis of context sharing) which motivated further qualitative analysis.

The longitudinal deployment of this display-based ubicomp prototype raised unexpected challenges on a broad range of levels, these included:

- communication technology – such as dealing with users blocking wireless network signals when interacting with door displays,

- hardware – such as adhering to relevant legislation when deploying the door displays,
- software – such as finding an appropriate Java virtual machine for the chosen platform,
- development approach – such as carrying out user-centred design with limited resources,
- deployment issues – such as the challenge of detecting and reacting to failure,
- human factors issues – such as the unique trade-offs owners desired when interacting with Hermes (for example expressivity vs. ease of use when leaving a message).

A major challenge in this work was balancing the need to explore research aims with the need to maintain the deployment with limited resources. For example, in order to include owners in the design process an eclectic approach was taken which combined technology driven design and user-centred techniques (both formal and informal) in order to generate new requirements. Owners were involved in the design process to help support their adoption of Hermes, for example, by adding features to fit in with existing daily routines to lower barriers to use. Supporting adoption was the main motivation used to select features for implementation, along with issues such as technical feasibility and development cost. Owner's perceptions of dependability were crucial to encourage use during the longitudinal deployment, in order to address this a phased deployment approach was used which began with deployment for the system's developers (tolerant of problems such as failure) and then expanded to less tolerant door display owners as aspects such as reliability improved.

7.4.2 An Understanding of Adoption and Appropriation

From quantitative analysis of daily use the Hermes system was used by door display owners to set messages on a regular, almost daily, basis. However, quantitative analysis gives little information about the adoption processes that have taken place. For example, an increase in daily use coincided with the addition of MSN Messenger as an interaction method, but qualitative analysis was required to ensure that these two events were connected. Qualitative analysis focussed on four owners selected to represent a range of users.

The primary use of Hermes by door display owners was to share contextual information using short textual messages in order to support awareness and coordination (between staff and between staff and students). Context sharing was performed manually and a key theme that emerged during development of Hermes was that when configuring messages owners were keen to trade-off control for effort. A key example of this was when an interaction method which allowed messages to be set (from a predefined list) extremely

quickly from a door display, but potentially allowed any passer-by to use this method, was widely accepted and increased use. This example also highlights the issues of point of realisation/opportunity. In more detail, an owner had to pass by his or her door displays when leaving or entering their office and this acted as a reminder for the owner to set a message. Therefore, the introduction of the interaction method enabled owners to quickly and easily set a message at the point where they were reminded to do so, helping enable adoption.

The introduction of the interaction method that allowed messages to be set quickly from a predefined list also uncovered issues of temporal granularity of messages set and expressivity. When setting messages from a predefined list an owner was restricted in the level of expressivity and detail they could use, highlighted by the fact that messages such as "Back in 5 minutes" and "Gone for coffee" were used heavily. For many owners this expressivity vs. ease of use trade off was acceptable but several owners preferred other interaction methods allowing more detail to be included. The high level of ease of use provided by the interaction method described previously helped support the use of Hermes to share relatively fine temporal granularity messages (such as "Back in 5 minutes"). This level of context sharing including fine temporal granularity was not seen with any other interaction methods.

It was evident from quantitative and qualitative analysis that different door display owners adopted Hermes in different ways and a range of issues affecting adoption emerged. For example the temporal granularities of messages set ranged from almost every time the owner left his or her office for a short period of time to only leaving a message when the occupant was going to be away for hours or even days. However, it was evident that the factor which affected adoption to the greatest extent was the provision of interaction methods which lowered the barriers to use. For example, allowing owners to easily integrate Hermes into existing routines. As such, this was one of the major factors that determined which features were selected for implementation and where the development effort was focussed.

7.4.3 Supporting Awareness and Coordination

The intention of Hermes (as described in the aims of this thesis) was to investigate its use to support awareness and coordination, and this was done using both quantitative and qualitative analysis. From both types of analysis, the primary use of Hermes for the majority of owners was to (explicitly) share awareness information of the type 'who is there' to help support coordination, examples from two different owners included "At CSCW'02 back Monday 25th Nov" and "Away from the office on Friday 15th April 2005. Back Monday 18th". To a lesser extent, Hermes was used to support awareness information of the type '*what* has happened' and messages of this type essentially provided a reason why the door display

owner was not in their office when they should have been, for example “Traffic jam!” and “in Q at post office”. The previous two examples (messages of type ‘*what* has happened’) were both received via SMS messages which highlights issues such as point of realisation/opportunity and appropriate methods of interaction. For example, SMS was likely to be a highly suitable interaction method for Hermes door display owners when unexpectedly delayed in a situation such as queuing at a post office.

Quantitative analysis of a sample of usage logs showed that the vast majority (over 83%) of messages set shared some aspect of context, with the highest proportion of messages (47%) referring to an activity. This high proportion was due to the fact that sharing an activity often gives a valid reason as to why a person is not in his or her office in the smallest number of words (e.g. “Lecturing”, “Gone to lunch”). Additionally, several door display owners had privacy concerns over making their location publicly accessible.

Qualitative analysis of use uncovered a range of interlinked issues related to the use of Hermes by door display owners to share messages to support awareness and coordination. The majority of owners were keen to share relatively fine temporal granularity messages (e.g. “Gone to photocopier”, “Back in 5 minutes”), but required ease of use to be proportional to the length of time the owner would be away from his or her office. In order to meet the level of ease of use required, trade offs between issues such as expressivity and accuracy had to be made which, in turn, affected the content shared in messages. For example, the interaction method allowing messages to be set from the predefined list at a door display only supported a limited range of unspecific messages. Therefore, it is easy to imagine scenarios where messages potentially containing specific locations and temporal aspects (which may have been useful to visitors) became “Back in 5 minutes”. When owners left offices for long periods of time, for example when attending a foreign conference, they appeared more concerned with sharing detailed messages (than issues such as ease of use) and chose an interaction method supporting this, such as the web portal.

7.5 Minor Contributions

The minor contributions of this thesis are:

i) the identification of requirements for building a digital display-based ubicomp system to support asynchronous messaging in a university department and a set of associated design considerations,

ii) a description of a design, development and evaluation approach that accommodated both technology driven design and involvement of door display

owners in the design process, informed through both quantitative and qualitative analysis of use.

7.5.1 Requirements

A full list of requirements for an interactive door display system deployed in a university department is provided in appendix H. These emerged from the development and deployment of a prototype of sufficient quality to provide a technology probe and do not to include technically detailed functional requirements. The terminology used is from RFC 2119 (Key words for use in RFCs to Indicate Requirement Levels) [Bradner '97]. Many of these requirements were generated by the exploration of the affordances provided by the digital approach used in Hermes (compared to paper-based approaches). The requirements are categorised using the levels of:-

i) Hardware – the underlying hardware components, including the door display itself and the associated server.

ii) Software – the underlying software platform, described from the perspectives of the door display and associated server.

iii) Application Functionality – functionality provided by software components, described from the perspectives of a door display owner, a door display visitor and a system administrator.

These categories include both high and low level requirements. The following provides examples from each category:-

i) The door display hardware MUST adhere to appropriate legislation governing electrical installations. For example, in order to adhere to appropriate guidelines at Lancaster University, door displays in Hermes had to use a low voltage (less that 50 volts) power source.

ii) The hardware supporting a server MUST provide (or have access to) a reliable storage medium. In more detail Hermes demonstrated that reliable storage was vital for log files and owner profiles and that failure of hard disk drives, while relatively rare, does occur.

iii) The capability SHOULD be provided to allow software components running on a door display to be updated remotely. In the Hermes system physical access to each door display individually was required to install updated software component and this proved time consuming for the system administrator.

iv) The server software components SHOULD be designed to be scalable to support the addition of extra door display devices and additional services (without, for example, negatively impacting system performance). This requirement will be especially important in the forthcoming Hermes 2 system with a deployment of 40 door displays and potential for a wide variety of novel applications.

v) A door display owner SHOULD be provided with feedback in the case of failure of system components wherever possible. If an owner is notified of the failure of system component which they might encounter this may help reduce trust-damaging encounters of failure. However, it is equally important to manage the granularity and number of feedback messages sent to avoid high numbers of messages becoming a burden to owners.

vi) A visitor SHOULD be provided with a suitable low effort method to leave a note for a door display owner. For an able-bodied visitor examples might include the facility to draw a note onto a touch sensitive screen by hand or use an on-screen keyboard, while for a disabled visitor, not able to access the display device, this might include interaction using a mobile phone via SMS or Bluetooth.

vii) An administrator SHOULD be automatically notified of the failure of any door displays and related system as soon as feasibly possible (i.e. minimising the possibility of erroneous failure notification).

A set of design considerations has also been distilled from the work on the Hermes system. These emerged primarily from qualitative analysis as potentially important considerations for future work on Hermes (that did not translate directly into requirements) which may be useful to other researchers working in a similar area to help inform design decisions. A complete list of the design considerations is provided in Appendix I and the following provides examples from the two perspectives of a door display owner and visitor:-

i) A door display owner SHOULD be allowed to select an appropriate level of expressivity in order to affect changes in the effort required to set a message. In more detail, an owner may wish to author a message with a high degree of expressivity (similar to a paper note) or might find it acceptable to trade-off expressivity in order to set a message in a low-effort manner (e.g. choosing from a predefined list of textual messages).

ii) A visitor SHOULD be able to leave a visitor note at a door display with no prior knowledge of the system. In more detail, a very small (or zero) time to learn is important to encourage use from visitors.

7.5.2 Design, Development and Evaluation Approach

The development of Hermes was divided into phases with each phase having a specific objective (motivated largely by user-centred considerations). A phase involved several rapid prototyping iterations, initially to provide the desired features then validate and refine the prototype until it met door display owners' expectations. A primary aim of the Hermes system included long term deployment in a 'real world' scenario allowing not only initial adoption and appropriation to take place, but also for the system to evolve in response to emerging requirements and door display owner feedback. To achieve this aim the use of user-centred design techniques was crucial.

There is an inherent tension between the goals of technology driven design and user-centred design methodologies. To combine user-centred design with technology driven design for a deployed system receiving daily use, an eclectic approach was taken [Fitton '05]. This involved the use of a range of techniques to gather qualitative feedback, for example, informal verbal feedback, a questionnaire and a semi-structured interview in order to inform new requirements. Qualitative analysis of use by visitors was also investigated using a questionnaire with limited success.

In Hermes a variety of both quantitative and qualitative approaches were required to help inform the design process and evaluate use. The use of logging in the deployment of Hermes enabled several aspects of use to be quantified, for example failure of door displays, daily use, types of use and context sharing. From the quantitative analysis of was clear that this alone did not provide sufficient insights in order to understand use and further qualitative analysis was required.

7.6 Future Work

The design and analysis of use in Hermes focussed primarily on the door display owners with visitors to door displays receiving comparatively little attention. This lack of attention was due to limited resources but also, in part, to the difficulty of obtaining feedback from visitors to a public display and the lack of response to a visitor questionnaire sent via e-mail. Future work on the Hermes system should include door display visitors in the design process to a larger extent, at the very least allowing visitors to evaluate the mechanism for viewing owner messages and leaving messages for visitors.

The redesign process of the Hermes 2 system has already begun, with initial investigation into possible new requirements which may have emerged after the move to a new Computing building (discussed in Appendix J) and a proposed design for an improved underlying architecture (discussed in Appendix J). Hermes 2 will involve the deployment of forty door displays, which will require careful consideration of the design of management and maintenance tools. An additional consideration has been the appropriate design of the door displays and supporting hardware to be used in the new deployment (discussed in Appendix J).

The Hermes Photo Display [Fitton '05] is closely related to the work on the Hermes door display system, focusing on providing a community photo display for sharing digital pictures. In the future, the Hermes 2 architecture should both be able to support these types of applications and allow them to be integrated with the door display system. A possible future use of the Hermes 2 door displays is support for navigation [Kray '06], this functionality will be especially interesting with such a large deployment of door displays. A crucial factor when running multiple applications on door displays will then be the sharing of display space and how owners feel about the possibility of having their current message 'hidden' behind another application.

The Hermes@Home prototype system has begun to explore how the message sharing and remote interaction mechanisms provided in the original Hermes system can be used in the home. In more detail, the initial Hermes@Home prototype was designed to support awareness and coordination between a single family member temporarily working away from home and the rest of the family group via a display situated in the home. In this scenario the remote family member is effectively the display 'owner', being able to remotely set messages visible on the Hermes@Home display, and the remaining family members are effectively display visitors, being able to send messages (i.e. visitor notes) which the remote family member can access via the web. This system is currently at a relatively early prototype stage, however situating such technology in the home has already raised a range of interesting issues. As with the initial Hermes prototype, the approach taken has involved 'real-world' deployment and user-centred design.

7.7 Concluding Remarks

Work on Hermes has provided many insights into the design, deployment, use and evaluation of interactive digital office door displays. It is clear that the design, deployment and evaluation of ubicomp systems such as those presented in this thesis raises numerous challenges on a range of levels from low level hardware through to human factors issues. It is

hoped that the challenges and associated solutions/guidelines presented in this thesis prove useful contributions to others working in this area and help stimulate further research.

References

[Andersson '05] Andersson, P.: Project SMSLink (2005) http://smslink.sourceforge.net/ (last accessed December 2005)

[Apache Software Foundation '05] Apache Software Foundation: Apache Tomcat Project (2005) http://jakarta.apache.org/tomcat/ (last accessed December 2005)

[Appliance Studio '02] Appliance Studio: Appliance Studio launches SMS txTboard. Press Release (2002)

[Blomberg '90] Blomberg, J.L., Henderson, A.: Reflections on participatory design: lessons from the trillium experience. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '90). Seattle, Washington, USA (1990) 353-360

[Bradner '97] Bradner, S.: Request for Comments 2119: Key words for use in RFCs to Indicate Requirement Levels. (1997) http://www.ietf.org/rfc/rfc2119.txt (last accessed August 2006)

[Brand '94] Brand, S.: How Buildings Learn. Viking, (1994)

[Brignull '06] Brignull, H.: Understanding and Designing for the Voluntary Adoption of Community Displays. PhD Thesis. Sussex University (2006)

[Brignull '03] Brignull, H., Rogers, Y.: Enticing People to Interact with Large Public Displays in Public Spaces. Proceedings of International Conference on Human-Computer Interaction (INTERACT '03), Zurich, Switzerland (2003) 17-24

[Browne '01] Browne, H., Bederson, B., Plaisant, C., Druin, A.: Designing an Interactive Message Board as a Technology Probe for Family Communication. University of Maryland Technical Report HCIL-2001-20 (2001)

[Cheverst '01] Cheverst, K., Smith, G.: Exploring the Notion Of Information Push And Pull With Respect To The User Intention And Disruption. Proceedings of the

International Workshop on Distributed and Disappearing User Interfaces in Ubiquitous Computing at CHI '01, Minneapolis, USA (2001) 67-72

[Cheverst '02] Cheverst, K., Fitton, D., Dix, A., Rouncefield, M.: Exploring Situated Interaction with Ubiquitous Office Door Displays. Proceedings of the Workshop on Situated Interaction at CSCW '02, New Orleans, USA (2002)

[Cheverst '03a] Cheverst, K., Clarke, K., Fitton, D., Rouncefield, M., Crabtree, A., Hemmings, T.: SPAM on the menu: the practical use of remote messaging in community care. Proceedings of the Conference on Universal Usability (CUU '03). Vancouver, British Columbia, Canada (2003a) 23 - 29

[Cheverst '03b] Cheverst, K., Dix, A., Fitton, D., Friday, A., Rouncefield, M.: Exploring the Utility of Remote Messaging and Situated Office Door Displays. Proceedings of Human Computer Interaction with Mobile Devices and Services (MobileHCI '03). Udine, Italy (2003b) 336-341

[Cheverst '03c] Cheverst, K., Dix, A., Fitton, D., Rouncefield, M.: 'Out To Lunch': Exploring the Sharing of Personal Context through Office Door Displays. Proceedings of the Australasian Computer-Human Interaction Conference (OzCHI '03), Brisbane, Australia (2003c) 74-83

[Cheverst '03d] Cheverst, K., Fitton, D., Dix, A.: Situated Office Door Displays. In: O'Hara, K., Perry, M., Churchill, E., Russell, D. (eds.): Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies. Kluwer (2003d) 141-169

[Churchill '03] Churchill, E., Nelson, L., Denoue, L., Murphy, P., Helfman, J.: The Plasma Poster Network: Social Hypermedia on Public Display. In: O'Hara, K., Perry, M., Churchill, E., Russell, D. (eds.): Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies. Kluwer (2003) 233-260

[Consolvo '05] Consolvo, S., Smith, I.E., Matthews, T., LaMarca, A., Tabert, J., Powledge, P.: Location Disclosure to Social Relations: Why, When, & What People Want to Share. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '05), Portland, Oregon, USA (2005) 81-90

[Dey ‘99] Dey, A.K., Abowd, G.D.: The Context Toolkit: Aiding the Development of Context-Aware Applications, Proceedings of Workshop on Software Engineering for Wearable and Pervasive Computing at CHI '99, Pittsburgh, USA, (1999) 434-441

[Disability Rights Commission '02] Disability Rights Commission: Code of Practice - Rights of Access: Goods, Facilities, Services and Premises, Vol. III (2002)

[Dix '95] Dix, A.: Cooperation without (reliable) Communication: Interfaces for Mobile Applications. Distributed Systems Engineering **2** (1995) 171-181

[Dix '97a] Dix, A.: Challenges for Cooperative Work on the Web: An Analytical Approach. Computer Supported Cooperative Work **6** (1997a) 135-156

[Dix '97b] Dix, A., Finlay, J., Abowd, G., Beale, R.: Human-Computer Interaction. Prentice-Hall Inc. (1997b)

[Dix '04] Dix, A., Cheverst, K., Fitton, D., Friday, A.: The Auditability of Public Space - Approaching Security Through Social Visibility. Proceedings of the 2nd UK-UbiNet Workshop, Security, Trust, Privacy and Theory for Ubiquitous Computing, Cambridge, UK (2004)

[Dourish '99] Dourish, P.: Evolution in the Adoption and Use of Collaborative Technologies. Proceedings of Workshop on Evolving Use of Groupware at ECSCW '99, Copenhagen, Denmark (1999)

[Dourish '92a] Dourish, P., Bellotti, V.: Awareness and coordination in shared workspaces. Proceedings of the ACM conference on Computer-Supported Cooperative Work (CSCW '92), Toronto, Ontario, Canada (1992a) 107-114

[Dourish '92b] Dourish, P., Bly, S.: Portholes: Supporting awareness in a distributed work group. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '92). , Monterey, California, USA (1992b) 541-547

[E Ink Corporation '05] E Ink Corporation: E-Ink: Paper-Like Display Products. (2005)

[Ellis '91] Ellis, C.A., Gibbs, S.J., Rein., G.L.: Groupware: Some issues and experiences. Communications of the ACM **24** (1991) 38-58

[Finney '96] Finney, J., Davies, N.: The FLexible Ubiquitous Monitor Project. Proceedings of the Third Computer Networks Symposium, Manchester, UK (1996)

[Fitton '03] Fitton, D., Cheverst, K.: Experiences Managing and Maintaining a Collection of Interactive Office Door Displays. Proceedings of the European Symposium on Ambient Intelligence (EUSAI '03). Eindhoven, The Netherlands (2003) 394-409

[Fitton '04a] Fitton, D., Cheverst, K., J, F., Dix, A.: Supporting Interaction with Office Door Displays. Proceedings of the Workshop on Multi-User and Ubiquitous User Interfaces (MU3I) at IUI/CADUI, Madeira (2004a) 19-23

[Fitton '04b] Fitton, D., Cheverst, K., Rouncefield, M., Dix, A.: Probing Technology with Technology Probes. Equator – Record and Reuse Workshop, London (2004b)

[Fitton ‘05] Fitton, D., Cheverst, K., Kray, C., Dix, A., Rouncefield, M., Saslis-Lagoudakis, G.: Rapid Prototyping and User-centred Design of Interactive Display-based Systems. IEEE Pervasive Computing **4** (2005b) 58-66

[Fleck '88] Fleck, J.: Innofusion or diffusation? The nature of technological development in robotics. Edinburgh PICT Working Paper No 4 (1988)

[Franke '78] Franke, R.H., Kaul, J.D.: The Hawthorne experiments: First statistical interpretation. American Sociological Review **43** (1978) 623-643

[Gaver '99] Gaver, W., Dunne, A., Pacenti, E.: Design: Cultural Probes. Interactions: New Visions of Human-Computer Interaction **6** (1999) 21-29

[Gellersen '99] Gellersen, H., Beigl, M., Krull, H.: The MediaCup: Awareness Technology Embedded in a Everyday Object. Proceedings of International Symposium on Handheld and Ubiquitous Computing (HUC '99). Karlsruhe, Germany (1999) 308-310

[Gibson '77] Gibson, J.J.: The Theory of Affordances. In: Shaw, R.E., Bransford, J. (eds.): Perceiving, Acting, and Knowing. Lawrence Erlbaum Associates, Hillsdale, NJ (1977)

[Gibson '86] Gibson, J.J.: The Ecological Approach to Visual Perception. Erlbaum, Hillsdale, NJ (1986)

[Greenberg '01] Greenberg, S., Rounding, M.: The notification collage: posting information to public and personal displays. Proceedings of the SIGCHI Conference

on Human Factors in Computing Systems (CHI '01), Seattle, Washington, USA (2001) 514 - 521

[Gutwin '95] Gutwin, C., Stark, G., Greenberg, S.: Support for workspace awareness in educational groupware. The First International Conference on Computer Support for Collaborative Learning (CSCL '95). Bloomington, Indiana, USA (1995) 147-156

[Harper '92] Harper, R.: Looking at ourselves: an examination of the social organization of two research laboratories. Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW '02). Toronto, Ontario, Canada (1992) 330-337

[Harrison '96] Harrison, S., Dourish, P.: Re-Place-ing Space: The Roles of Place and Space in Collaborative Systems. Proceedings of Conference on Computer Supported Cooperative Work (CSCW '96). Cambridge MA (1996) 67-76

[Hartson '03] Hartson, R.H.: Cognitive, physical, sensory, and functional affordances in interaction design. Behaviour and Information Technology **22** (2003) 315-338

[Hemmings '02] Hemmings, T., Crabtree, A., Rodden, T., Clarke, K., M Rouncefield, M.: Probing the Probes. Proceedings of Participatory Design Conference (PDC 2002), Malmo, Sweden (2002) 42-50

[Hewlett Packard '05] Hewlett Packard: HP Compaq iPAQ Pocket PC H3800 Series - Features and Specifications (2005) http://www.comp.lancs.ac.uk/~fittond/h3800/h3800info.html (last accessed December 2005)

[Huang '03] Huang, E.M., Mynatt, E.D.: Semi-public displays for small, co-located groups. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03), Ft. Lauderdale, Florida, USA (2003) 49-56

[Huang '04] Huang, E.M., Russell, D.M., Sue, A.E.: IM Here: Public instant messaging on large, shared displays for workgroup interactions. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '04). Vienna, Austria (2004) 279-286

[Hutchinson '03] Hutchinson, H., Mackay, W., Westerlund, B., Bederson, B.B., Druin, A., Plaisant, C., Beaudouin-Lafon, M., Conversy, S., Evans, H., Hansen, H., Roussel,

N., Eiderback, B.: Technology probes: inspiring design for and with families. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03), Ft. Lauderdale, Florida, USA (2003) 17-24

[IEEE ‘03] Institute of Electrical and Electronics Engineers: IEEE P802.3af DTE Power via MDI Task Force (2003) http://www.ieee802.org/3/af/ (last accessed December 2005)

[Izadi '03] Izadi, S., Brignull, H., Rodden, T., Rogers, Y., Underwood, M.: Dynamo: A public interactive surface supporting the cooperative sharing and exchange of media. Proceedings of the 16th Annual ACM Symposium on User Interface Software and Technology (UIST 2003), Vancouver, Canada (2003) 159-168

[Izadi '05] Izadi, S., Rogers, Y., Brignull, H., Rodden, T., Fitzpatrick, G., Lindley, S.: The Iterative Design and Study of a Large Display for Shared and Sociable Spaces. Proceedings of Designing for User eXperience Conference (DUX 2005), San Francisco, CA, USA (2005) 59

[Jeffrey '02] Jeffrey, N., Jacob, O.W., Darren, G., Jodi, F.: Mediator and medium: doors as interruption gateways and aesthetic displays. Proceedings of Designing Interactive Systems (DIS 2002), London, UK (2002) 379-386

[Jordan '96] Jordan, B.: Ethnographic Workplace Studies and Computer Supported Cooperative Work. In: Shapiro, D., Tauber, M., Traunmüller, R. (eds.): The Design of Computer-Supported Cooperative Work and Groupware Systems. Elsevier Science, (1996) 17-42

[Joseph '95] Joseph, A.D., Lespinasse, A.F., Tauber, J.A., Gifford, D.K., Kaashoek, M.F.: Rover: a toolkit for mobile information access. Proceedings of the fifteenth ACM symposium on Operating systems principles Copper Mountain, Colorado, USA (1995) 156-171

[JXTA Project '06] JXTA Project: JXTA project web site (2006) http://www.jxta.org (last accessed January 2005)

[Kistler '92] Kistler, J.J., Satyanarayanan, M.: Disconnected operation in the Coda File System. ACM Transanction on Computer Systems **10** (1992) 3-25

[Kray '06] Kray, C., Cheverst, K., Fitton, D., Sas, C., Patterson, J., Rouncefield, M., Sas, C., Stahl, C.: Sharing Control of Dispersed Situated Displays between Nomadic and Residential Users.Proceedings of International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI ’06), Espoo, Finland (2006) 61-68

[Laprie '85] Laprie, J.C.: Dependable Computing and Fault Tolerance : Concepts and Terminology. Digest of Papers FTCS-15: 15th International Symposium on Fault-Tolerant Computing. IEEE Computer Society Press (1985) 2-11

[Lauesen '04] Lauesen, S.: User Interface Design: A Software Engineering Perspective Addison-Wesley (2004)

[Lovejoy '03] Lovejoy, T., Grudin, J.: Messaging And Formality: Will IM Follow in the Footsteps of Email?, Proceedings of International Conference on Human-Computer Interaction (INTERACT '03), Zurich, Switzerland (2003) 817-820

[Markus '90] Markus, M.L., Connolly, T.: Why CSCW applications fail: Problems in the adoption of interdependent work tools. Proceedings of the Conference on Computer Supported Cooperative Work (CSCW '90), Los Angeles, CA, USA (1990) 371-380

[Maxim '05] Maxim: What is an iButton? (2005) http://www.maxim-ic.com/products/ibutton/ibuttons/index.cfm (last accessed December 2005)

[McCarthy '01a] McCarthy, J.F., Costa, T.J., Liongosari, E.S.: UniCast, OutCast & GroupCast: An Exploration of New Interaction Paradigms for Ubiquitous, Peripheral Displays, Proceedings of the Workshop on Distributed and Disappearing User Interfaces in Ubiquitous Computing at CHI '01, Seattle, USA (2001a)

[McCarthy '01b] McCarthy, J.F., Costa, T.J., Liongosari, E.S.: UniCast, OutCast & GroupCast: Three Steps Toward Ubiquitous, Peripheral Displays. Proceedings of International Conference on Ubiquitous Computing (UbiComp '01), Atlanta, Georgia, USA (2001b) 332-345

[McGrenere '00] McGrenere, J., Ho, W.: Affordances: Clarifying and Evolving a Concept. Graphics Interface 2000. Lawrence Erlbaum Associates, Montreal (2000) 179-186

[Microsoft '05a] Microsoft: Windows Mobile-based Pocket PCs (2005a) http://www.microsoft.com/windowsmobile/pocketpc/ppc/default.mspx (last accessed December 2005)

[Microsoft '05b] Microsoft: Windows XP Tablet PC Home Page (2005b) http://www.microsoft.com/windowsxp/tabletpc/default.mspx (last accessed December 2005)

[Microsoft '06] Microsoft: Socio-Digital Systems - HomeNote (2006) http://research.microsoft.com/sds/Homenote.aspx (last accessed February 2006)

[Mitchell '05] Mitchell, W.J.: Placing Words: Symbols, Space, and the City. MIT Press (2005)

[Modulex '05] Modulex: Modulex Signage (2005) http://www.modulex.com/ (last accessed December 2005)

[Muller '91] Muller, M.J., Blomberg, J.L., Carter, K.A., Dykstra, E.A., Madsen, K.H., Greenbaum, J.: Participatory design in Britain and North America: responses to the "Scandinavian Challenge". Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '91), New Orleans, Louisiana, United States (1991) 389-392

[MySQL '05] MySQL: MySQL: The World's Most Popular Open Source Database (2005) http://www.mysql.com/ (last accessed December 2005)

[Nguyen '00] Nguyen, D., Tullio, J., Drewes, T., Mynatt, E.D.: Dynamic Door Displays, GVU Technical Report GIT-GVU-00-30, Georgia Tech (2000)

[Norman '98] Norman, D.A.: The invisible computer. MIT Press (1998)

[Norman '99] Norman, D.A.: Affordances, conventions, and design. Interactions 6 **3** May/June (1999) 38-43

[Norman '02] Norman, D.A.: The Design of Everyday Things. Basic Books (2002)

[Norman '86] Norman, D.A., Draper, S.W.: User Centered System Design; New Perspectives on Human-Computer Interaction. Lawrence Erlbaum Associates, Inc. (1986)

[Noyes '99] Noyes, J., Baber, C.: User-Centred Design of Systems. Springer-Verlag, London (1999)

[NSICom '05] NSICom: CrEme, the JVM for Windows CE (2005) http://www.nsicom.com/ (last accessed December 2005)

[O'Hara '03] O'Hara, K., Perry, M., Lewis, S.: Social coordination around a situated display appliance. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03). Ft. Lauderdale, Florida, USA (2003) 65-72

[O'Hara '04] O'Hara, K., Perry, M., Churchill, E. (eds.): Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies. Kluwer (2004)

[O'Hara '05] O'Hara, K., Harper, R., Unger, A., Wilkes, J., Sharpe, B., Jansen, M.: TxtBoard: from text-to-person to text-to-home. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '05), Extended Abstracts, Oregon, USA (2005) 1705-1708[Object Management Group '06] Object Management Group: CORBA 3 Specification (2006) http://www.omg.org/technology/documents/formal/corba_2.htm (last accessed August 2006)

[Ortiz '03] Ortiz, S.: New Monitor Technologies Are on Display. Computer **36** (2003) 13-16

[PalmSource Incorporated '05] PalmSource Incorporated: Palm OS (2005) http://www.palmsource.com/palmos/ (last accessed December 2005)

[Philips '05] Philips: BBC Public Space Broadcasting (2005) http://www.business-sites.philips.com/vidiwall/organisation/article-14700.html (last accessed December 2005)

[Preece '02] Preece, J., Rogers, Y., Sharp, H.: Interaction Design: Beyond Human-Computer Interaction. John Wiley & Sons (2002)

[Rodden '91] Rodden, T.: A Survey of CSCW Systems. Interacting with Computers **3** (1991) 319-353

[Russell '03] Russell, D.M., Sue, A.: Large Interactive Public Displays: Use Patterns, Support Patterns, Community Patterns. In: O'Hara, K., Perry, M., Churchill, E., Russell, D. (eds.): Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies. Kluwer (2003) 3-17

[SavaJe '05] SavaJe: SavaJe OS (2005) http://www.savaje.com/ (last accessed December 2005)

[Schmidt '02] Schmidt, A.: Ubiquitous Computing – Computing in Context. Computing Department, PhD. Lancaster University (2002)

[Segawa '99] Segawa, N., Murayama, Y., Nakamoto, Y., Gondo, H., Miyazaki, M.: A Message Board on WWW for On-Door Communication. Proceedings of International Conference on Multimedia. Orlando, Florida, USA (1999) 187-190

[Siau '03] Siau, K., Shen, Z.: Building customer trust in mobile commerce. Communications of the ACM **46** (2003) 91-94

[Sillence '04] Sillence, E., Briggs, P., Fishwick, L., Harris, P.: Trust and mistrust of online health sites. Proceedings of the SIGCHI Conference on Human factors in Computing Systems (CHI '04). Vienna, Austria (2004) 663-670

[Sommerville '93] Sommerville, I., Rodden, T., Sawyer, P., Bentley, R.: Sociologists can be surprisingly useful in interactive systems design. Proceedings of the Conference on People and Computers VII. York, UK (1993) 342-354

[Sommerville '01] Sommerville, I.: Software Engineering, 6th Edition. Addison-Wesley, Pearson Education Ltd (2001)

[Sun '05a] Sun: Java Remote Method Invocation (Java RMI) (2005a) http://java.sun.com/products/jdk/rmi/ (last accessed December 2005)

[Sun '05b] Sun: Java Servlet Technology (2005b) http://java.sun.com/products/servlet/index.jsp (last accessed December 2005)

[The World Wide Web Consortium '03] The World Wide Web Consortium: SOAP Version 1.2 Part 1: Messaging Framework (2003) http://www.w3.org/TR/soap12-part1/ (last accessed August 2006)

[Torpel '05] Torpel, B.: Participatory design: a multi-voiced effort. Proceedings of the 4th Decennial Conference on Critical Computing. Aarhus, Denmark (2005) 177-181

[Trumler '03a] Trumler, W., Bagci, F., Petzold, J., Ungerer, T.: Smart Doorplate. Personal and Ubiquitous Computing **7** (2003a) 221-226

[Trumler '03b] Trumler, W., Bagci, F., Petzold, J., Ungereral, T.: Smart Doorplate - Toward an Autonomic Computing System. Proceedings of International Workshop on Active Middleware Services (AMS2003). Seattle, WA, USA (2003b) 42-47

[Virgin Mobile Telecoms '04] Virgin Mobile Telecoms: Text the fest (2004) http://www.virginmobilelouder.com/live/index.php?page_id=166 (last accessed December 2005)

[W3C Working Group '04] W3C Working Group: Web Services Architecture W3C Working Group Note 11 (2004) http://www.w3.org/TR/ws-arch/ (last accessed August 2006)

[Weiser '91] Weiser, M.: The Computer for the 21st Century. Scientific American, Vol. 265 (1991) 94-104

[Weiser '97] Weiser, M., Brown, J.: The Coming Age of Calm Technogy. In: Denning, P.J., Metcalfe, R.M. (eds.): Beyond Calculation - The Next Fifty Years of Computing. Springer-Verlag (1997) 75 - 85

[Wichary '05] Wichary, M., Gunawan, L., Ende, N.V., Hjortzberg-Nordlund, Q., Matysiak, A., Janssen, R., Sun, X.: Vista: interactive coffee-corner display, Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '05), Extended Abstracts. Portland, OR, USA (2005) 1062-1077

[Xerox '05] Xerox: Electronic Reusable Paper (Gyricon) (2005) http://www2.parc.com/hsl/projects/gyricon/ (last accessed December 2005)

Appendix A

A.1 Hermes Changes Log

This appendix chronicles the changes made to Hermes during deployment. The deployment is broken down into phases and each time a new or modified software component was deployed the changes and date were noted.

Phase 1

20/7/02

Central Agent 1.1

Initial release deployed. This supported the following usability features:

i) Notification of new Notes to users via SMS.

ii) Ability to set a Public Message via SMS.

iii) SMS sent to the *Central Agent* by a User sets an owner public message.

This version also supported the following technical features:

iv) Persistent storage of Message Images.

v) Persistent storage of Notes.

vi) Persistent storage of key User information.

vii) Storage of User preferences.

viii) Updating of appropriate Client Agent when new Public or Private Message set via Web or SMS.

Client Agent 1.1

Initial release deployed. This supported the following usability features:

i) Displaying of a Public image or textual message visible to all passers-by.

ii) Displaying of a Private image or textual message visible to other Hermes.

iii) Users after authentication via a user name/PIN.

iv) Displaying of office number and occupant name.

v) Displaying of current date and time.

vi) Displaying of a short line of instructional text.

vii) Authentication via user name/PIN.

viii) Ability for a Visitor to leave an anonymous Note at a Door display for its Owner.

ix) Ability for a User to leave a Note at a Door display for its Owner after authentication via user name/PIN.

This version also supported the following technical feature:

i) Logging of Messages set and Notes received.

Web Portal 1.1

Initial release deployed. This supported the following usability features:

ii) Authentication via user name/PIN - no features available without authentication.

iii) User can set a Private Message - text or image.

iv) User can set a Public Message - text or image.

v) User can view Notes left for them.

vi) User can delete Notes left for them.

vii) User can reply to Notes left for them by authenticated users via e-mail.

22/7/02

Client Agent 1.2

This next release included two major usability functions:

i) Ability for a User to view Notes left for them after authentication at any Door display via user name/PIN.

ii) Ability for a User to delete Notes left for them after authentication at any Door display via user name/PIN.

26/7/02

Central Agent 1.2

This release required a technical change to support the new *Client Agent* feature:

i) Run-length decoding of Note images sent by Client Agents.

Client Agent 1.3

This release supported a technical feature to reduce the network bandwidth between *Client Agent* and *Central Agent*:

i) Run-length encoding of Note images before sending to the *Central Agent*.

1/7/02

Client Agent 1.4

This release incorporated a useful new usability feature:

i) Messages received are displayed in a table.

5/8/02

Client Agent 1.5

These usability features were added mainly to prevent Visitors being effectively able to leave a Public message image on a Door display by not selecting send or cancel after drawing a note; the note would remain visible.

i) Added timer to ensure display returned to current Public message after a period of inactivity.

ii) Added timer to log out a user after a period of inactivity.

21/8/02

Client Agent 1.6

This is technical maintenance required for a recently added feature:

i) Fixed small timer error bugs occasionally causing erratic UI behaviour.

21/9/02

Client Agent 1.7

This technical feature was added to improve usability:

i) iButton support on equipped Client Agents.

The following usability features were added in response to owner feedback:

i) User authentication at Doorplates via docking of an iButton.

ii) Ability to set a hand drawn Public image from a door display.

7/10/02

Client Agent 1.8

The following usability feature was introduced to encourage users to set images as Messages on their Doorplates:

i) Support for animated GIF files as Public and Private image Messages.

1/11/02

Central Agent 1.3

This usability features was implemented to encourage Users to read Notes left for them at their doorplates:

i) Notes left for owners are sent to them in an e-mail.

A further technical feature was added:

i) Modifications reduce the number of RMI called needed between *Client Agent* and *Central Agent*.

Client Agent 1.9

These technical features were introduced to improve the UI response time on Client Agents:

i) Force Swing animated gif thread to die gracefully.

ii) Modifications to reduce the number of RMI called needed between *Client Agent* and *Central Agent*.

iii) Improve UI performance (reduced unnecessary screen redraw etc).

The following important usability feature was used to prevent the UI pausing for long periods with no apparent explanation when network connectivity was lost:

i) Added 'Please wait a moment' screen before potentially time consuming operations.

Phase 2

In the second phase of deployment, the notion of a Temporary Message was introduced, and what was called a Public Message now called a Default Message. The notion of a Private message was removed through lack of use.

5/11/02

Central Agent 2.1

The main technical feature added here was the first introduction of the Temporary Message functionality on the *Central Agent*:

i) Support of Temporary message.

ii) Improved e-mailing of Notes to users to support a wider range of e-mail clients.

Client Agent 2.1

This usability feature was the first introduction of the Temporary Message on Client Agents:

i) Added Temporary Message, taking precedence over Default (Public) Message.

ii) Removed Private Message.

iii) Door display Owner can leave a hand drawn Temporary Message at their Door-plate after authentication via user name/PIN or iButton.

iv) Information screen provided to give visitors to a Door display further information, accessible by an 'Info' button on the UI.

Web Portal 2.1

The web portal required usability changes to allow Temporary Message support:

i) Ability to set and remove Temporary Messages - text or image.

ii) Renaming of Public Message to Default Message.

5/12/02

Client Agent 2.2

These technical changes on the *Client Agent* were added to assist the smooth running of the system:

i) Lowered registration with *Central Agent* interval to account for periods of lost connectivity.

ii) Improved UI update mechanism to avoid unnecessary screen refresh.

iii) Improve logging to include additional information This was the initial addition of the 'display-press' usability functionality to the *Client Agent* to speed up the setting and removal of Temporary Messages.

iv) Addition of ‘display-press’ UI action, generated if a certain portion of the screen is pressed for a predefined amount of time.

v) Ability to remove a Temporary Message (if set) by using the ‘display-press’ UI action without authentication.

vi) List of predefined Temporary Messages displayed (if no Temporary Message set) by using the ‘display-press’ UI action without authentication, selection of one of the Messages from the list causes it to be set as the current Temporary Message.

1/5/03

Central Agent 2.2

This release of the *Central Agent* saw the addition of technical features to support the storage and retrieval of user preferences:

i) User preferences now includes a list of ten Temporary Messages and the ‘display-press’ interval.

ii) Measures for a Client Agent and Web Portal to retrieve and modify new user preferences.

Client Agent 2.3

This next usability feature was the ability to personalise the list of Temporary Messages which could be set from the Door display:

i) List of predefined Temporary Messages retrieved from User’s preferences stored on a *Central Agent*.

ii) Length of press generating ‘display-press’ action retrieved from User’s preferences stored on a *Central Agent*.

iii) Support for list of ten predefined Temporary Messages, five visible without scrolling.

Web Portal 2.2

The web portal now required features enabling a user to view and modify their preferences:

i) Addition of a ‘Preferences’ page for authenticated users.

ii) Ability to modify list of ten predefined Temporary Messages on preferences page.

iii) Ability to modify ‘display-press’ interval on preferences page.

iv) Temporary Message on web page updated (in real time) if the Message is changed form the Client Agent.

Phase 3

During the third phase of deployment an Administrator Agent was added to help solve reliability problems and increase user trust.

21/5/03

Management Agent 3.1

This was the initial version of the *Management Agent*, supporting the following technical features available to administrators:

i) Ability to 'ping' a door display to see if it is responding.

ii) E-mail sent to administrator when a door display is perceived to have died (no response for a long period of time) and again when door display is working again.

iii) Ability to Set a Temporary Message on multiple Doorplates with e-mail notification of this sent to users.

Central Agent 3.1

The following technical features were added to the *Central Agent*:

i) Support for Administration Agent.

ii) Support for Administration sections of Web Portal. Phase three also included a new usability features provided at the *Central Agent*.

iii) Ability for a user to set a Temporary Message (textual or image) by including it in an e-mail sent to the *Central Agent*.

iv) Ability for a user to set a Temporary Message image by sending it as an MMS to the *Central Agent* (using an e-mail address).

Web Portal 3.1

The present web portal was extended to prove a separate Management section providing usability features for administrators:

i) Ability to view the current status of all doorplates, including the last time each door display was known to be alive.

ii) Ability to view what is currently displayed on a Door display.

iii) Ability to verify the status of a Door display.

iv) Ability to view the preferences for a user. A single usability features was also added to the User's Web Portal:

The web portal for door display owners also received a modification:

i) Selection of 'thumbnail' images added to main web page, if a User clicks on one of these a larger version is set as their current Default Message Image.

28/5/03

Management Agent 3.2

This release saw the addition new usability features:

i) Management web interface allows multiple displays to be set/pinged simultaneously.

ii) Email notification of failure to owners enabled.

11/7/03

Management Agent 3.3

A slight technical modification was required to make more accurate estimations about whether a Client Agent is alive or not:

i) Change 'dead' door display interval from 10 to 20 minutes to reduce erroneous dead/alive e-mails to users.

Phase 4

Phase 4 saw the deployment of an experimental version of Hermes, running alongside the 'Main' version, on a separate Central Agent and selected Doorplates. In this version, MSN Messenger support was added and the ability to set Temporary images Messages through e-mail.

16/2/04

Central Agent 4.1e

This was the initial release of the experimental *Central Agent* with usability additions to support MSN Messenger:

ii) Ability for a user to set a textual Temporary Message via MSN Messenger.

iii) Ability for a user to set a textual Default Message via MSN Messenger.

iv) Notification of a Note left at Door display via MSN Messenger.

v) Storage of MSN Messenger user preferences in owner profiles.

Client Agent 4.1e

Some minor technical changes were required to the Client Agent to support the *Central Agent* changes:

i) Common class file changed for MSN integration, requiring rebuild.

Web Portal 4.1e

Some minor usability changes were made to the Web Portal to support the MSN Messenger Integration:

i) Addition of MSN Messenger integration preferences fields in User preferences.

19/2/04

Central Agent 4.2e

After initial deployment some technical changes were required to fix problems:

i) Modifications to implementation and exception handling of MSN client to handle problems when connecting to MSN messenger service.

5/3/04

Central Agent 4.3e

Several more technical changes were required to solve problems:

i) Modifications to implementation and exception handling of MSN client to handle problems connecting to MSN messenger service.

2/4/04

Central Agent 4.4e

In this subversion of the *Central Agent*, the technical changes included support for an additional public display system:

i) Modification to Email checker to allow 'intermediate' files to be produced from e-mail parts for external public display system.

ii) Modification to exception handling of MSN Messenger support to prevent it being disabled on network errors.

iii) Modification of error messages reported to users via MSN Messenger to make them easier to understand.

Phase 5

Phase 5 involved further improvement of MSN Messenger support as it had been unstable in phase 4 and the removal of RMI callbacks between the *Central Agent* and Client Agents to remove the need for wireless hardware at the *Central Agent*. Persistent storage of user information in a database was now added, so users' preferences were not lost when the server was restart due to an upgrade or technical problems.

15/5/04

Central Agent 5.1e

This release included technical support of the previously mentioned new features:

i) MySQL tables used for persistent storage of user information/preferences, Messages and other technical information.

ii) Removal of RMI callbacks.

iii) Notifications of Message (etc) updates sent to Client Agents over sockets.

iv) Logging integral to server to ensure logger is always running.

v) Improved SMS integration using MySQL backend.

vi) Improvements to MSN Messenger support exception handling.

vii) Changes to e-mail checker file naming algorithm.

viii) Some new usability features were also introduced.

ix) Users given more control over their preferences.

x) Improved e-mail support, uses subject if body empty.

Client Agent 5.1e

In the initial release of this phase many necessary technical changes were made:

i) Improvements to networking code to ensure network calls timeout quickly if there is no connectivity.

ii) Removal of RMI callbacks between *Central Agent* and Client Agents.

iii) Listening for communication over sockets from *Central Agent* for notification of updates.

iv) Client UI redraw optimisation to prevents unnecessary screen redraw. This version also included some new usability features to encourage use.

v) Text formatting off all textual Messages on Client Agent (foreground and background colours and bold).

vi) Client can no longer crash on 'Please Wait' page.

vii) Client does not hang on selecting new temporary Textual Message from pre-defined list screen if network connection fails.

Web Portal 5.1e

Several technical modifications were required to support the latest changes:

i) Web portal uses MySQL backend.

ii) Management web portal modified to use MySQL backend. Also several usability features were introduced:

  i) Check box on main web page to disable the Display-Press Action when setting a Message.

  ii) Owners can configure their personal information on the preferences page (name, office number etc).

  iii) An owner can configure the delivery and notification of new Notes.

28/5/04

Central Agent 5.2e

A minor technical change was required at the *Central Agent* to support one of the new features introduced at the Client Agent:

i) Storage of time a Message was set.

Client Agent 5.2e

In this release several features were requested by users:

i) Displays the date and time the current Message on a Door display was set - this option can be set in user preferences.

ii) Option to prevent a hand drawn Temporary Message image being removed by 'display-press' UI action - option is set when leaving the Message.

Web Portal 5.2e

A couple of usability feature were added to the web portal, the first to help support one of the Client Agent Changes:

i) Option to display the date and time a Message was set on a door display added to user Preferences.

ii) Top five temporary messages displayed on main web page.

Phase 6

In phase 6, due to the success of the previous experimental version, it was deployed on all doorplates and adopted at the 'main' version.

3/6/04

Central Agent 6.1

In this release several technical changes were made to fix bugs and improve performance:

i) Changes to way PIN is verified from Client Agent to support Client Agent change.

ii) Changes to the way text formatting tags are added to Messages.

iii) Improved checking for updates from database and updating Client Agents.

iv) Improved support for new Note notification and delivery options in user preferences.

v) Fixed e-mail notification of Notes bug preventing e-mails displaying correctly on some e-mail clients.

vi) Improved logging method to ensure correct time stamps.

Client Agent 6.1

In this version several usability features requested by the users of the previous experimental release were added:

i) 'display-press' UI action can be disabled for Temporary Messages - this option can be set in user preferences in the Web portal.

ii) Owner is now top of list of users when logging in with user name/PIN.

Web Portal 6.1

Several usability features were added to the Web Portal to help users:

i) Changes to way text formatting schemes are configured and applied.

ii) Option to disable ‘display-press’ UI action on main web page.

7/6/04

Central Agent 6.2

This technical changed was added to solve a bug in the previous release:

i) Fixed e-mail Temporary Message bug preventing some Messages being set.

Client Agent 6.2

A single technical change was added to the Client Agent to improve performance:

i) Improved start-up of application (ordering of events etc) to increase stability.

Web Portal 6.2

This subversion saw the resolution of some minor bugs previously unnoticed:

i) Prevent text foreground and background colours being identical when formatting textual Messages.

ii) Improving use of frames to prevent nesting.

10/6/04

Central Agent 6.3

This final technical change was required to ensure that the MSN integration part of the *Central Agent* always survived network problems without crashing:

i) Improved exception handling in MSN integration - errors now sent to console and reconnect attempted repeatedly after 30 seconds delay.

Appendix B

B.1 Log Extract from Hermes Deployment

This short extract from a Hermes log shows *Client Agents* sending 'heartbeats' to the *Central Agent* (e.g. '(Carol-C6) Registered ok'), owners changing their messages (e.g. 'changed temporary message from: At ISS to:') and UI component actions on *Client Agents* (e.g. 'actionPerformed - source: java.awt.Button[button1,110,0,73x26,label=Log In]'):

```
Data: User: danf (EC00000000AAA496) IP: 194.80.34.15 (Dan) Registered ok
From: /194.80.34.19 on: 22/05/04@19:39
Data: User: aireyc (1500025051564176232257) IP: 194.80.34.19 (Carol-C6) Registered ok
From: /194.80.34.11 on: 22/05/04@19:39
Data: User: joe (647062606467124577713) IP: 194.80.34.11 (Jo-c30) Registered ok
From: /127.0.0.1 on: 22/05/04@19:39
Data: User: 1132360731072257413251 changed temporary message from: At ISS to:
From: /194.80.34.18 on: 22/05/04@19:39
Data: User: race (1132360731072257413251) IP: 194.80.34.18 (Nick-c34) Registered ok
From: /194.80.34.18 on: 22/05/04@19:39
Data: actionPerformed - source:
javax.swing.JButton[,0,172,235x43,layout=javax.swing.OverlayLayout,alignmentX=0.0,alignmentY=n
ull,border=javax.swing.plaf.BorderU
IResource$CompoundBorderUIResource@a23c9,flags=48,maximumSize=,minimumSize=,preferredSi
ze=java.awt.Dimension[width=167,height=41],defaultIcon=,disabledIcon=,disa
bledSelectedIcon=,margin=javax.swing.plaf.InsetsUIResource[top=2,left=14,bottom=2,right=14],paint
Border=true,paintFocus=true,pressedIcon=,rolloverEnabled=false,r
olloverIcon=,rolloverSelectedIcon=,selectedIcon=,text=Gone for lunch,defaultCapable=true]
From: /127.0.0.1 on: 22/05/04@19:39
Data: User: 1132360731072257413251 changed temporary message from:  to: Gone for lunch
From: /194.80.34.18 on: 22/05/04@19:39
Data: User: race (1132360731072257413251) IP: 194.80.34.18 (Nick-c34) Registered ok
From: /194.80.34.15 on: 22/05/04@19:39
Data: User: danf (EC00000000AAA496) IP: 194.80.34.15 (Dan) Registered ok
From: /194.80.34.18 on: 22/05/04@19:39
Data: actionPerformed - source: java.awt.Button[button1,110,0,73x26,label=Log In]
From: /194.80.34.19 on: 22/05/04@19:39
Data: User: aireyc (1500025051564176232257) IP: 194.80.34.19 (Carol-C6) Registered ok
From: /194.80.34.11 on: 22/05/04@19:40
Data: User: joe (647062606467124577713) IP: 194.80.34.11 (Jo-c30) Registered ok
From: /194.80.34.18 on: 22/05/04@19:40
Data: actionPerformed - source: java.awt.Button[button19,47,0,47x31,label=1]
From: /194.80.34.18 on: 22/05/04@19:40
Data: actionPerformed - source: java.awt.Button[button20,94,0,47x31,label=2]
From: /194.80.34.18 on: 22/05/04@19:40
Data: actionPerformed - source: java.awt.Button[button21,141,0,47x31,label=3]
From: /194.80.34.18 on: 22/05/04@19:40
Data: actionPerformed - source: java.awt.Button[button6,119,0,119x26,label=Login]
From: /194.80.34.18 on: 22/05/04@19:40
Data: actionPerformed - source: java.awt.Button[button6,119,0,119x26,label=Login]
From: /194.80.34.18 on: 22/05/04@19:40
```

Appendix C

C.1 Hermes Questionnaire Results

This appendix presents the results of a questionnaire given to ten door display owners during phase 4 of Hermes. The total responses in each category for each question are give together with any comments (along with the owner who gave the comment and responses to questions in that section).

1. Sharing Personal Context

1.1 I would be like to have a link from my home page to the contents of my Hermes display (given the currently supported set of features).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
0	1	1	7	1

1.2 I would like to have public entries in my calendar automatically displayed on my Hermes display.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1	1	2	4	2

1.3 I would like to have a link from my home page to the contents of my Hermes display - with it potentially showing my calendar information.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1	2	1	4	2

1.4 I would like to have my current (sensed) location displayed on my Hermes display when I am not in the office.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
0	1	2	7	0

1.5 I would like to have a link from my home page to the contents of my Hermes display - with it potentially showing my (sensed) location.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1	4	3	2	0

Any comments on the above?….

I (sa,sa,sa,a,a): Limited ability to lie – or requires more ingenuity. I'm not bothered about privacy
G (a,a,sa,a,a) 1.2: some scope for privacy control on visibility of appointment
C (d,d,d,ns,d): 1.1: Privacy only for people here. Reactions: 'local area' – 'big brother', 'in turn' – prepared if everyone took part if everyone sharing info
D (a,sa,a,a,ns) 1.1: With control, 1.5: But I would want a mob service

H (ns,sd,sd,a,d) 1.1: Privacy concern, 1.5: There is a difference between a “local” person looking at my Hermes Display and a “remote” person. Issue is – how is information being used? Why is it being accessed? Not even fellow Hermes user
F (a,ns,a,a,ns): 1. ease of calendar sharing?

2. Control

2.1 I would be prepared to allow other people (anonymous staff/students) to use my display to browse the web, play simple games etc. – providing the display was returned to my outgoing message.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1	1	2	4	2

Comments….

I (a) : As long as it wasn’t lots of people, all day, every day – I assume/trust the novelty would wear off
B (ns): Would be more willing if users had to authenticate themselves e.g. so it could be restricted to just staff
J (ns): Not sure about people gathering outside office, could be distracting
G (d): acceptable if instantly returned (change to agree)
C (sd): Not the place!
H (sa): I don’t care

2.2 I would be prepared for my display to be used as part of a department wide navigation system – providing the display was returned to my outgoing message.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
0	0	0	1	9

Comments….

2. 3 I would like anonymous users to be able to ‘leave’ notes on my Hermes display remotely, i.e. without having to physically write on the Hermes display.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
2	1	2	4	1

Comments….

I (sa): As long as there was the facility to remove it if spammed to frequently
B (a): Not sure how useful this would be
G (a): Like source to be recorded, e.g. ‘I came to see you, and, …’
H (sd): Can’t see the point. What’s the difference between this and e-mail
F (a): 1. Sender must know consequences (sms etc) 2. Like to restrict classes of user/individuals (e.g. sms/msg profs) 3. How about a don’t alert option?

3. New features

3.1 The ability to set temporary messages on my Hermes Display (by touching the display) will significantly increase the likelihood of me setting a temporary message.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
0	0	1	3	7

Comments….

G (sa): I Like this, as I tend not to set things

3.2 I am concerned that anonymous users can set temporary messages (from the prescribed set available) that appear to be from me.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
	4	4	2	

Comments….

I (d): I assume that if it happened too frequently I would contact you to arrange for ID entry
G (ns): Like ease of setting but obvious trade-off
C (a): Open for abuse
H (ns): Exactly the same situation as with paper-based system

3.3 I would have been prepared to allow anonymous users to set temporary messages that were not prescribed, e.g. free text.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
5	2	0	2	1

Comments….

I (a): Where too much obscenity etc would contact you to arrange for ID entry
G (sd): Better having fixed message to limit misuse
H (sd): Leaves system open to abuse

3.4 I am concerned that anonymous users can remove my temporary messages by touching the display for a short period of time.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
0	5	2	2	1

Comments….

I (d): Not really – it depends on how frequently it happened
G (ns): As above, slightly more +ve about this
H(d): Same as paper-based system

4. Any Other Comments…

F: 5 ‘hot’ topics is probably sufficient (ie don’t want to use the scroll bar) rather not use the pen, so plenty of finger room please (even if this reduces to 4 choices|)

Appendix D

D.1 Hermes Owner Interview Transcriptions

This appendix firstly presents the purpose statement for the Hermes owner questionnaire then presents transcriptions for owners M and K (where questions posed by interviewer are denoted by 'Q' and answers denoted by 'A').

D.1.1 Purpose Statement

Overall aim of this interview is to gather information about Hermes from the owners of doorplates in several areas:

i) Background information - e.g. to see if any key user requirements were overlooked/undiscovered

ii) Current use - e.g. to investigate how Hermes has become part of daily routines

iii) Users' perception of Hermes (e.g. Reliability) - e.g. to see if perceptions match reality (using logs)

iv) Users' thoughts on the tradeoffs encountered during design - e.g. whether tradeoffs were appropriate

v) Users' opinions of proposed future changes - e.g. what users would find acceptable, opinions on tradeoffs

Once collected, this information will be used to evaluate the success of design decisions, usability, and tradeoffs, drawing general conclusions and 'lessons learned' from the Hermes project.

D.1.2 Owner M

Name: Owner M

Date: 30/9/04 Period of Use: 3/6/04 – 19/7/04

1. Role

1.1a Job Title (e.g. Lecturer, secretary, etc)

Departmental Officer

1.1b Responsibilities (e.g. 1st year tutor, head of part 1 etc)

A: Looking after departmental finance, HoD, exams

1.2 Based on 1a and 1b, roughly how often (and what types of) people come to see you & how important is it that they find you?

A: It'll be internal people, the Deans office, finance office faculty accountants and then general enquires, students.

Please briefly describe a scenario where Hermes is used:

1.3a regularly as part of your daily routine?

A: Just to let people know when I was in the office , away from the office for any length of time, lunch times Q: As you were leaving? A: Yeah

1.3b in an ad-hoc fashion (i.e. not regularly)?

A: In an ad-hoc fashion would be for meetings wouldn't it? Q: Yeah, so did you ever use it from home or anywhere like that? A: No I didn't, I could have done, if you find you're going to be away at short notice then it would be very useful, but I had it such a short time I think. I liked using it, I though it was useful for people coming to the door Q: Did you find that you got any comments on it, people saying it was useful? A: No actually on it, no, there was one or two messages.

2. Contact ability/Availability

How often do you come into the department:

2.1a during term time?

Daily 9-5	Daily (other)	3-4 days/week	1-2 days/week	Rarely
x				

Comments

2.1b out of term time?

Daily 9-5	Daily (other)	3-4 days/week	1-2 days/week	Rarely	Never
x					

Comments

Briefly describe the different ways people might arrange or reschedule meeting with you:

2.2a a colleague?

A: Usually via e-mail, more often than not via e-mail, or they come to see me

Q: To sort out a time?

A: Yeah

2.2b an undergraduate/postgraduate student?

A: They're more likely to call into the office to see if they can arrange a time

Q: SO do they come expecting to talk to your or to arrange a time?

A: I think they come expecting to talk to you, students and post graduates, yeah

2.2c someone not met before (visitor, new member of staff etc)?

A: They might ring or e-mail

2.3 If you were not in your office, how might a colleague tell that you were in the department that day? (e.g. MSN Messenger status?)

A: Probably, yeah, because your door would be open, and my desk would be like this [indicates desk piled high with papers and folders] If I'm away it's all tidied away.

Q: So they'd look into your office and see?

A: Yeah, and if I'm not around they tend to hover, or just ask somebody else or you can generally tell can't you.

2.4 How do you show your availability when in your office? (e.g. leaving door open when available for meeting etc)

A: No, just because you've no means of doing that

Q: Would you leave your door open?

A: Depends what sort of job you've got on, if you've got a job that you need to concentrate on then you tend to leave if it closed if I can, but that doesn't stop interruptions [laughs]

Q: So do you leave it open when you're a bit less busy?

A: Yeah, possibly, I can't tell a pattern yet, when we first cam here I left it open all the time

Q: But did you find you got interrupted too much?

A: No difference, absolutely no difference I think, I think people still stick their head round if they see you're in, they come in. If I'm going to be away for any length of time I tend to just leave a post-it on the door to say that we're out, in meeting, university house, whatever.

From analysis of the logs looking at context sharing in messages set:

31% shared some aspect of location

37% shared some temporal information (relating to time)

47% shared information about activities

2.5 When not in my office I find it more acceptable to share information about my activity (e.g. gone to lunch) rather than my location (e.g. gone to lunch at the Venue).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			X	

Justification & Comments

A: Yeah, agree

Q: So why do you agree?

A: It's not something that I've even thought of before, just 'gone for lunch' I think is enough information, I've never even considered saying where I'm going for lunch, no

Q: Some people have say they specifically don't say where they're going because they don't want people coming and disturbing them

A: Yeah, I suppose if you're a lecturer you might have students bobbing in, It's just never, perhaps I'm not… You've got to go out of the department to get a proper lunch break, if you just go and sit down somewhere you don't get a break. But it's not something I've every considered

Q: really?

A: I don't do it so nobody can find me, it's just gone for lunch, that's it!

Q: It's just one of those things

A: Yeah

Q: That's interesting, I wonder why that it?

A: [laughs] because I've escaped when I've gone for lunch

Q: That's your time

A: I've never given it any sort of conscious decision

2.6 I would like to have my location sensed and displayed on my doorplate (e.g. using active badge, active bat etc)

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
		x		

Justification & Comments

A: It that like, sort of a…

Q: An active badge type thing

A: Yeah, I'm not sure about that actually, I don't know about that one

Q: Do you think it would bother you people being able to know where you were when you're out of your office?

A: No, I don't think so. Not sure I think for that

Q: but the privacy aspect doesn't bother you that much?

A: No, because when you're at work you're at work and that's it isn't it

Q: I guess you wouldn't want to be tracked on you lunch break?

A: [laughs]

2.7 I would like to have my activity inferred automatically from my location and displayed on my doorplate (i.e. exact location hidden)

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: Yeah, I agree with that

Q: Do you think that would be useful?

A: Yeah, because sometimes you find yourself If you did have a… when you've to do it yourself you often forget if you're in a bit of a rush, which you often are, to go to a meeting, it would be useful to just have it done automatically.

Q: Yeah, so it would be no effort at all

A: Yeah, yeah, that would be good

3. User Expertise

3.1 In what situations do you use the different interaction methods?

Doorplate – Message list	A: Did you use that? Q: Not a great deal, but I think that's a question of familiarity isn't it – because I felt I was reasonably new at it, I think the longer you had it the more functions you'd find on it. Q: Yeah A: I tapped into it to read my messages that were left there, but I tended to use it through e-mail the most
Doorplate – Freehand	
Web portal	Q: Did you use the web portal? To log in on the web? A: No
SMS	
MMS	
E-Mail	Q: When did you use the e-mail? A: Generally before I went to a meeting, or if I was going to be away, you know before I left my office.
MSN Messenger	
Tangible Interface/other	

Justification & Comments

	Never	Only Once	Rarely	Monthly	Weekly	Daily
Doorplate – Message list	x					
Doorplate – Freehand	x					
Web portal					x	
SMS	x					
MMS	x					
E-Mail						x
MSN Messenger	x					
Tangible Interface/other	x					

Justification & Comments

Q: The same way that someone could leave a note for you, you could leave a note that would stay there

A: No I don't think I did that, just because I like things typed

Q: And e-mail?

A: Yeah,

Q: How often did you use that?

A: Probably daily, perhaps, I can't remember now, it's a while ago isn't it

Q: Well from the usage it was about 3 times a day, something like that

A: Oh right – that's interesting to know then, I would have said it was that… you know.

Q: [find usage graph] it's about 2 or 3 times a day on average

A: Right, that is surprising

Q: You used it more than you thought?

A: Probably, yeah, I liked it, yeah

3.3 For your most often used interaction method in question 3.2, why do you use this method over all the others?

A: I think probably it was a question of familiarity, isn't it, you're used to e-mail so… perhaps if I'd forgotten to do a note, I might have maybe tried the freehand one.

3.4 Please describe (with justification) your favourite feature of Hermes

A: I liked leaving my office, or leaving wherever I was going and people knowing where I was and when they could expect to catch me if they needed something, it's traceability I suppose, I liked that

Q: Did you find that useful – did people come and find you because they'd read your doorplate?

A: I never actually asked them that, but It would seem so

Q: I think it's quite hard to know if someone has seen your note and found it useful

A: Yeah, I'm trying to think back if anyone actually commented, yeah, I think one or two people did come across and say it was useful, perhaps, maybe, I think it was Helen Lowe from the Deans office, she commented on it.

3.5 Please describe (with justification) your least favourite feature of Hermes

A: No I don't think I did really, because I didn't think I'd used it that often… nothing that really irritated me about it no.

3.6 Have you ever used the public display on A floor? (Why? When?)

A: No

On the 15th of May 2004 a much improved used preferences system was introduced (providing persistent storage and many more options):

3.7a Have you changed you user preferences before this date?

Regularly	Occasionally	Once	Never	Not sure

Justification & Comments

3.7b Have you changed your user preferences since this date?

Regularly	Occasionally	Once	Never	Not sure
	x			

Justification & Comments
Q: I'm guessing if you never used the web portal you never changed your preferences?
A: I can't remember what they were
Q: You know those predefined list of messages?
A: Yeah, actually I probably did, because I changed the picture once of twice on it, so did that come under the we portal
Q: yeah
A: I did use the web portal then, because if it was the weekend that I would put the Lancaster university on it. So I did, more than I thought I did, sorry
Q: It's ok – so would that be weekly? Maybe at the weekend?
A: Yeah
Q: So did you find that useful? Did you like the pictures?
A: There weren't that many where there? I just used to put the logo on it
Q: Did you change that list of predefined messages?
A: No, I don't think I actually made any alterations to the messages, was there one that say out or something like that?
Q: There was a few, there was gone for lunch, gone for coffee
A: Yes, I used those, but I don't think I actually changed the working on them
Q: Ok

3.8 I find the preferences features provided by the Hermes web portal useful

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Justification & Comments Q: So do you think it would have been useful to change the wording on those messages? A: No, I wouldn't say Q: They fit in pretty well? A: Yeah				

4. HERMES as an Information Appliance

4.1 I think that Hermes should be sufficiently simple in terms of functionality that it does not need a user guide.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	
Justification & Comments A: Agree with that, yeah				

I think that Hermes is sufficiently simple in terms of functionality that it does not need a user guide.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: Yeah agree with that, I think

Q: A gave you that A4 sheet

A: You did, yeah

Q: Did you find that useful?

A: I did yeah, I used it quite a bit when I first got it

Q: It was handy to have that?

A: Yeah, because it was always on the top there [indicates the top of a pile of papers in a stacking tray]

Q: That's good, so how do you think you would have got on without that?

A: I might have struggled bit.

5. Trust/ Dependability

5.1 How often do you set a message on your doorplate?

Never	Only Once	Monthly	Weekly	Daily		
				< 5	5-10	> 10
				x		

Justification & Comments

5.2 Do you leave a message every time you leave your office? Why?

A: No, probably not, like if you're going down to the photocopier perhaps, I don't think I would have left one then, just depends how much of a rush your are in as well, if I was out for any length of time I certainly did.

Q: So it's kind of time and how busy you are

A: yeah

5.3 Do you regularity check to see if the message you set has appeared?

	Never used	Initially		Subsequently			
		Yes	No	Always	Often	Rarely	No
Doorplate – Message list	x						
Doorplate – Freehand	x						
Web portal		x			x		
SMS	x						
E-Mail		x			x		
MSN Messenger	x						
Tangible Interface/other	x						

Justification & Comments

A: Yeah

Q: Did you check it every time?

A: I think it wore off as I got used to it

Q: Really

A: Yeah, because the first few times I can remember sticking my head out of the door to se if it had…

Q: And the you started to trust it?

A: Yeah, yeah

Q: That's good, yeah

A: Yeah, because you're surprised – oh yeah it works! [laughs] I did it!

Q: So would you say often? [explains layout of table]

A: I would say perhaps about the first week often, then after that not very often

A: I think after each one I did I had a look

What would it take for you to completely trust (>99% certainty) that the message you set has appeared on your doorplate?

Q: Did you start to trust it a lot

A: Yeah, I think after the first week, once I'd confirmed that I'd actually done it, the message had appeared, yes

Q: Once you'd seen it working?

A: Yeah, I was happy with it then, it was reliable

Q: Would you say you trusted it getting towards this 99%

A: Yes

5.5 How often do you find that Hermes does not seem to be working correctly?

Never	Only Once	Monthly	Weekly		Daily
			1-2	3-4	
			x		

Justification & Comments

Q: Did you ever find that Hermes wasn't working?

A: No, but I think shortly after I got it it went down altogether didn't it?

Q: Yeah, there was a bit of a glitch

A: It was just perhaps one day where it was a bit of a… I think there was maybe one day where I noticed it wasn't working, but that's all.

Q: So you found that once it wasn't working?

A: Yeah, but I think it might have been down to general problems because I seem to recall you coming to fix something on it

Q: Yeah I think there was glitch – I little wrinkle that needed ironing out.

5.6 Please describe a typical scenario that would cause you to think that there is some sort of problem with Hermes, including your perception and scope of the problem

A: I probably sent a message to it perhaps, and then seen it when I came back into my room

Q: That it hadn't appeared

A: I honestly don't remember to be honest..

5.7 Are you aware of factors that affect the reliability of Hermes? What impact do you think the following factors have on/how often do they affect, reliability?

	Aware?	Perception of impact/occurrence			
		V. Low /yearly	Low /~monthly	High /~weekly	V. High /Daily
Wireless network					
PDA device					
Server					
Wired Network					

Comments

A: I think if there was any problems I think I'd put it down to a network error, but what type of error, I don't know

5.8 If Hermes does not appear to be working properly (e.g. wrong message on doorplate, problems logging into web portal) I am not inclined to use it again.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree

Justification & Comments

A: No, no, I think once it was up and running again, it's just a habit that you get into a habit of leaving a message.

Q: So disagree?

A: Yeah

5.9 Could you describe what takes place between discovering that Hermes does not appear to be working properly, and using Hermes again (e.g. do you 'test' the system to see if the problem has gone at regular intervals?)

Q: You've probably not experienced this, I think I sent out an e-mail to say that everything was working again, after you got that did you try and find if it was working again?

A: I think so, yeah… yes

5.10 Does your answer to 5.9 depend on your perception of the problem you have encountered? (e.g. do you use 'workarounds' for problems that you think are minor/temporary?)

6. New Feature 1 – Remote Accessibility

6.1 I would be happy for anyone to view the message on my doorplate remotely over the web.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
	X			
Justification & Comments Q: So this would be anyone in the world A: That's a funny one isn't it, because it's a bit of a security issue isn't it? Q: Yeah A: I depends who it is, doesn't it? Q: In this case it would be anyone in the world would be able to.. A: I think internally I would be happy, but not anywhere in the world Q: disagree? A: Yeah, I think so				

Given that anyone could monitor my doorplate (e.g. to see when I am in or out) this would this affect:

6.2.1a my decision to leave a message.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
	x			
Justification & Comments A: Yeah, yeah, it would affect what sort of information I would put on it, I would be more vague. Q: So it would affect your content? A: Yeah Q: But do think it would affect your decision to leave a message? Do you think you would still keep leaving messages but make them more vague, or do you think there is some messages wouldn't out on? A: Yeah, possibly, yeah, agree				

6.2.1b the content of my messages.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	
Justification & Comments [see 6.2.1a]				

6.3.1 I would be happy to have to individually specify the people who could view my doorplate remotely on a per message basis (i.e. high security and high user overhead).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Justification & Comments A: Yeah, I'd be happy with that Q: You wouldn't mind putting in that extra bit of effort? A: No Q: For it to be secure? A: yes				

6.3.2 I would be happy for staff in the department to be able to view my doorplate remotely.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	
Justification & Comments A: Yes I would				

I would be happy for undergraduate students in the department to be able to view my doorplate remotely.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	
Justification & Comments A: yeah				

6.3.4 I would be happy for other Hermes users to be able to view my doorplate remotely only if I could view theirs (mutuality).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Justification & Comments A: That wouldn't bother me I don't think, I disagree with that Q: So you wouldn't mind if anyone in the department could view it A: No Q: and I suppose Hermes users are a subset of them so A: Yeah				

6.3.5 I think it would be useful to have a ‘private’ message only accessible by certain persons (accepting that two separate messages may have to be configured instead of one)

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: Would that be a private message that somebody, I don’t know, like Gordon would, say if I needed to leave a message for Gordon.

Q: Yeah, like you could say gone home, and someone like Gordon could see your home phone number, so somebody could contact you in an emergency

A: yes, it would be useful, yes

Q: So where do you think you would fall in these categories?

A: Agree I think

Q: No strongly agree?

A: No

7. New Feature 2 – Visitor Feedback

7.1 I would be happy for visitors to my display (remotely or in person) to be able to leave feedback on how useful they found my current message.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: I agree, yeah I would be happy with that?

Q: you’d find that useful?

A: Yeah

7.2.1 I would want to see this feedback.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: yes, agree

Q: The positive and the negative?

A: Yeah

7.2.2 This feedback would affect my decision to leave messages

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			X	

Justification & Comments

Q: Do you think positive messages would encourage you to leave messages or negative put you off?

A: No I don't this it would discourage me, it might alter the messages that I do leave, but no it wouldn't, so I agree

8. Usability

8.1 Whether or not I leave a message on my doorplate is related to how busy I am (i.e. when I am busy I don't have time to use Hermes).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: Yeah, that's true. Sometimes it's just impossible to… if you have a meeting and somebody asks you for something at the last minute, it might be the last thing that you think about as you come out.

From the logs, a very common scenario is users setting their temporary message from a predefined list (on their doorplate) when leaving their office, using the 'single press' set and remove message functionality:

8.2a this functionality has affected my use of Hermes since it was introduced.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

Q: So I guess that's not really applicable to you is it.

A: no

Q: Did you find it useful? The message list

A: That you tapped?

Q: Yes

A: I think if I got into the habit of using it probably very useful, it comes back to this, if you're too busy you often remember as you're locking your door, so I probably would have go into the habit of using it if I'd had it a bit longer.

8.2b when using this method I feel that I do not include enough detail in my messages (e.g. ‘Back shortly’ covers everything from trips to the photocopier to going to the gym)

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree

Justification & Comments

Q: Using them as kind of catch alls

A: Yeah, I agree with that, because I that’s perhaps why I tend to use e-mail, so that I can put more, so you can be more specific if you do your own message, but it’s a useful feature in a hurry isn’t it?

A: Yeah

Q: So It’s useful, but not ideal?

A: Yeah

Q: You prefer to put in an extra bit?

A: Yeah

8.2c the level of detail in messages set with this method is acceptable given Hermes ease of use (i.e. message detail/usability trade off is acceptable).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: Yeah

8.3 I find that the doorplates provide enough expressivity (i.e. screen resolution high enough, enough space).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: yeah

8.4 IF ANSWER TO 8.3 WAS NOT AGREEMENT: Do you think that this is a limitation of the user interface?

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree

Justification & Comments

8.5 IF ANSWER TO 8.3 WAS NOT AGREEMENT: Do you think that this is a limitation of the screen size?

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Justification & Comments				

8.6 I find the level of expressiveness provided is acceptable given Hermes ease of use (i.e. expressiveness/usability trade off is acceptable).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	
Justification & Comments A: Yeah				

8.7 I found accidental/malicious changing of my temporary message a problem. (i.e. was this security/ease of use trade off unacceptable?)

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
	X			
Justification & Comments A: I did have it changed a couple of times, but it wasn't a problem Q: So did people accidentally remove it or change it? A: I think they were just messing and they snapped the, I don't know if you remember but my pencil snapped off once Q: Oh yeah – so it that your only malicious… A: I had two in that short space of time [laugh] Q: So no one removed your message by accident? A: No Q: So would you agree? A: No sure, no, I think it happened at the weekend as well so it probably wouldn't have caused any... Q: No big deal? A: No				

8.8 I found accidental/malicious changing of my messages to be a problem when using post-it notes/'message whirlers' (before Hermes).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: No

Q: They didn't fall down or anything?

A: No. They did tend to fall down, or you'd leave them on your door when you're in [laughs] you forget to take them off. They're not reliable are pos-its, because they just don't stay up you always end up having to stick sellotape.

Q: So think Hermes is more reliable than a post-it?

A: Oh yeah – definitely.

Q: So would you agree no that? Or is it not quite that strong?

A: Yeah, I think I would agree, because if you're using it remotely it would be very useful, where as if you're away for any reason and you need to ring somebody it's a hassle for them to go and stick a post-it on your door, so yes.

9 Future Work

9.1 I would find it useful to be able to share (i.e. visible at the same time) two types of message: broad 'high level' (e.g. "busy marking this week") and narrow 'lower level' (e.g. "Gone for coffee")

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: Yeah, yes it would

Q: Do you think you would use it?

A: Yes I would, yeah, because I used the e-mail to be more specific, so it would

Q: So you'd like to have this broader message and the narrower one?

A: Yeah

9.2 If I was given the ability to share two different messages (as described previously) I would like this done via two physically separate displays

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
		X		

Justification & Comments

Q: Maybe one outside your door and maybe a bigger shared one, that belonged to quite a few different people?

A: Not too sure about that…

9.3 I would be happy for anyone to view my 'high level' message remotely (i.e. via the web)

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			X	

Justification & Comments

Q: So would you be less concerned about people viewing your broader message?

A: Yeah, I agree

9.4 I would like to have a Hermes doorplate in the new building

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: Yes, yeah

Q: So you found it useful?

A: Yeah I did, I only had it for a short term but I liked it

Q: Did you find yourself getting into the habit of using it?

A: Yeah, yes I did, and I think other people that came commented on it as well, and I missed it for a while, because when you don't have it anymore, because it went down and then I quite missed it. It really was quite useful…

Q: It's a shame because the software and everything was getting really good towards the end, it was really stable.

A: Yeah, it was good, it was just so much easier than writing out a note

Q: It was easier than a post-it note?

A: Yeah, as I say, you dash out and then realize that you've forgotten to do it and come back in, whereas it's much easier if you get into the habit of doing things like that.

9.5 I feel that Hermes in its current state is suitable for the new building

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree

Justification & Comments

A: The only thing I would think would be the little boxes might need tidying up a bit

Q: to look a bit smarter?

A: Yeah

Q: so there is no new features or anything you think it needs in the new department?

A: No, not that I can think of, other than the aesthetics.

D.1.3 Owner K

Date: 6/8/04 Period of Use: 7/10/03 to 16/7/04

1. Role

1.1a Job Title (e.g. Lecturer, secretary, etc)

Lecturer, network support at ISS (50/50)

1.1b Responsibilities (e.g. 1st year tutor, head of part 1 etc)

In computing: Mainly project supervisor for final year projects, supervisor for PhD students.

1.2 Based on 1a and 1b, roughly how often (and what types of) people come to see you & how important is it that they find you?

Mainly fyp students, PhD students, systems team in computer (X once or twice a week), FYP student can be "at your door quite regularly" ,"PhD students these days there is a tendency for them to use messenger as an initial communication mechanism, so they might use messenger to check whether I'm in first before popping round. Perhaps they'll find me via that mechanism first rather than randomly coming round to knock on my door and see if I'm in" The importance varies with PhD students slightly prioritised.

Please briefly describe a scenario where Hermes is used:

1.3a regularly as part of your daily routine?

"Normally I would change the status, what I would typically be doing is coming into computing at about 9 am in the morning that's where I'd use Hermes just to change the status for the pervious day to say that I'm in here. What I'm doing at the moment is tending to work in computing in the morning, spend a couple of hours here depending on the workload, and then I'll move across to ISS. I'll typically update the status when I'm on my way out … depending on what the workload is I may come back here at some time in the afternoon, so they way Hermes is really used for me is I guess as an indicator or when I'm here and when

I'm there"

"I think it's quite useful to tell people am I this end, am I down the other end. It's not like I'm just a case of in or out, I could be 'in' and in a number of locations and quite often I'm down in ISS".

1.3b in an ad-hoc fashion (i.e. not regularly)?

"I did try and use it once when I got a FYP student who was coming to see me I was just in town, We'd agreed to meet a something like 3 o'clock, there was just no time I could get back for it, so I used the mobile phone text message to try and update the status on the display. Which was a good example of when it was really really handy. You're just in town and, I can't remember what happened, but something had overran and it was clear I was not going to get back for the meeting that we'd set up, so you could just send a text message, that's clearly a great use of the Hermes system.

2. Contact ability/Availability

How often do you come into the department:

2.1a during term time?

Daily 9-5	Daily (other)	3-4 days/week	1-2 days/week	Rarely
x				

Comments

Split between computing and ISS depending on work load, always computing in the morning.

2.1b out of term time?

Daily 9-5	Daily (other)	3-4 days/week	1-2 days/week	Rarely	Never
X					

Comments

Briefly describe the different ways people might arrange or reschedule meeting with you:

2.2a a colleague?

"It does depend on what they use, a lot of just use e-mail. There is a tendency in ISS, because everyone uses outlook (it's a bit different from here where you've got people with all sorts of different mailers), in ISS it's often done through the automatic scheduling system, so they just do a calendar meeting request and that gets put in your calendar, that is great because there is less overhead in some sense, they just add things to the calendar."

Owner K also said that meeting where occasionally arranged verbally, but that he tended to forget them ("I loose track of so many meeting that everything has to go in my calendar, I've got to the stage where if it's not in my calendar I'll forget about it"). He said that the meeting scheduler was the easiest way to schedule a meeting, and that after having to arrange a

meeting time “manually” over e-mail, this was added to outlook .

2.2b an undergraduate/postgraduate student?

“For undergraduates and postgraduates it is mainly e-mail”

“it’s not the most efficient way as you can be bouncing a number of e-mails around to try & set up a meeting”

After asking Owner K how messenger was use he replied: “I don’t tend to use messenger for undergraduate students, for PhD students we might use messenger for setting up a meeting” he mentioned that he had had a bad experience giving his messenger details to an undergraduate. Owner K explained that he had just arranged a meeting with one of his PhD students, and showed me his screen with the messenger conversation on it.

2.2c someone not met before (visitor, new member of staff etc)?

“Email, potentially phone conversation”

2.3 If you were not in your office, how might a colleague tell that you were in the department that day? (e.g. MSN Messenger status?)

“They could use my calendar, but obviously that’s not publicly available, certain people (for instance Owner J) have access to that, so they should be aware of where I am on a day. MSN messenger might give a good indication of where I am, if I’m away or not”. Owner K also mentioned that the only other way people might know is if he has told them.

2.4 How do you show your availability when in your office? (e.g. leaving door open when available for meeting etc)

“Yeah, normally I’ll have my door open and I’ll normally update Hermes to say I’m in today, or in the office or in computing, I guess MSN messenger automatically changed so that makes it clear that I’m available.

From analysis of the logs looking at context sharing in messages set:

31% shared some aspect of location

37% shared some temporal information (relating to time)

47% shared information about activities

2.5 When not in my office I find it more acceptable to share information about my activity (e.g. gone to lunch) rather than my location (e.g. gone to lunch at the Venue).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

"I guess I agree, it depends, this is where it gets interesting because it depends who that person is that's looking at that information, because obviously and undergraduate student, you don't want them tracking you down while you're down at the Venue or gone for lunch. Whereas if it was someone who had some urgent problem that they wanted sorted out then you might be a little less upset if they turned up at the Venue saying 'I've got this immediate emergency, can you help?'"

"Something that I'm quite interested in this whole granularity of what access you give to different classes of people" Owner K went on to talk about a FYP project giving out different levels of location information using messenger.

2.6 I would like to have my location sensed and displayed on my doorplate (e.g. using active badge, active bat etc)

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

"I wouldn't have any issues of having my location sensed, it all comes back to how that information is then used"

"I don't have too much concerns, I would say that I think if there was some way in which different people can have different levels of information" Owner K gave the example that colleagues would have more detail that undergraduate students.

2.7 I would like to have my activity inferred automatically from my location and displayed on my doorplate (i.e. exact location hidden)

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
		x		

Justification & Comments

Owner K did not identify with the example I gave, "Inferring could be very difficult to be accurate about, that would have to be something that was quite personalised."

"I wouldn't have a problem with trying to infer it, but I'd have a concern that the inference is correct.

3. User Expertise

3.1 In what situations do you use the different interaction methods?

Doorplate – Message list	"The move to ISS every day, typically the message list setting that would be first thing when I come in, 9 o'clock in the morning, and then again probably at 10:30 when I'm changed to update for if I move to ISS, and at the end of the day. As I'm not normally out for lunch it's not something that I would set that often" "As I'm in and out really"
Doorplate – Freehand	-
Web portal	"I would often use that for reading messages, obviously, and sometimes for setting my status, occasionally it may be that I forgot to set it down here, so could easily be at ISS and just tweak the display down there. The other thing just tended to be setting the preferences after there had been an outage"
SMS	".. It's not something that I've used that often. Of course you get the SMS alert which is very useful when a message has been sent to you"
MMS	"I've never sent an MMS message but that shouldn't be a reflection on Hermes, that should be a reflection that I just haven't sent an MMS message ever!"
E-Mail	-
MSN Messenger	"I've used that certainly when it was the testing phase with the MSN messenger client. Definitely was using that as an alternative really to me setting it on the display itself. That was quite handy … when that was up and running it was quite useful"
Tangible Interface/other	

Justification & Comments

How often do you use the different interaction methods?

	Never	Only Once	Rarely	Monthly	Weekly	Daily
Doorplate – Message list						x
Doorplate – Freehand	x					
Web portal					x	
SMS		x				
MMS	x					
E-Mail	x					
MSN Messenger					x	
Tangible Interface/other						

Justification & Comments

3.3 For your most often used interaction method in question 3.2, why do you use this method over all the others?

"I just think it's the easiest for me. The web portal is another way I would set it, but I always found that a) it would have been useful to have some sort of URL that was immediately memorable, as I always had problems remembering what the Hermes [address was], often it would be sent out as an IP and I could never remember what it was, I'm sure there might have been a domain name for it but I don't know whether that was always announced .. I could never remember the URL for it. I tended to use it more when I needed to change something in the configuration particularity if I wanted to set up new [messages], adding 'out to lunch' or adding items to there." "I think the message list is easiest .. I don't know if there is something better than that .. the ultimate I think would be something where I could just press a button on my way out, almost as if I had a push-button press .. so you haven't actually got to do anything" After explaining that Owner D had actually built a tangible interface Owner K said he had already seen it "I had already actually seen that from Joe and though it would be really good, I could just have that on the inside when I'm walking out .. that would be just so easy.." "It's about having something that is so easy to use it's just a seamless part of everyday [life] … It's not like you are going out of your way to use it " "If it's going to take more than a few seconds, whereas if I press a button, well that's going to take me about 1 second" "…the message list was the nearest thing for me to doing that, but I think the tangible interface would be the next step … it's almost like switching off the light, pressing a button, that straightforward"

3.4 Please describe (with justification) your favourite feature of Hermes

"... I quite like the MSN, when that arrived, the MSN messenger interface, that was nice. The ability to just press a button … you've not go to go out of your way to do anything … It wants to be something you don't have to go out of your way to do

3.5 Please describe (with justification) your least favourite feature of Hermes

"something that I would rarely do it logging into my display using the PIN code system, because that just seems to be much easier to do on the web site, so it would never be a feature I'd use on the display itself"

3.6 Have you ever used the public display on A floor? (Why? When?)

"only walked past it"

On the 15th of May 2004 a much improved used preferences system was introduced (providing persistent storage and many more options):

3.7a Have you changed you user preferences before this date?

Regularly	Occasionally	Once	Never	Not sure
x				

Justification & Comments

"When the preferences were lost I would typically customise them each time, as I'd have one saying 'I'm at ISS' or 'I'm here' that would be something I would do regularity as there was a server problem, I liked to have that particular set of default messages to use. So yes, definitely.

3.7b Have you changed your user preferences since this date?

Regularly	Occasionally	Once	Never	Not sure
		X		

Justification & Comments

"Yes I would have done since the persistent storage" When asked if this was to put in his predefined messages, K agreed.

3.8 I find the preferences features provided by the Hermes web portal useful

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
				X

Justification & Comments

Owner K mentioned a feature that he had proposed (using the top 5 messages from the user preferences on the 5 message suggestions on the main Hermes 'Logged In' web page) and I replied that it had been implemented in the latest version of Hermes, "I found that useful once it had gone in. One of the main things I was doing on the web portal would probably be… before the May persistent storage, that would be updating the messages [temporary message list] and just looking at messages that had come in.

4. HERMES as an Information Appliance

4.1 I think that Hermes should be sufficiently simple in terms of functionality that it does not need a user guide.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
		X		X

Justification & Comments

"Between the agree and not sure, I think that going for that object of being so seamless and pressing buttons on the way out that bit needs to be very simple un functionality. The message retrieval bit should be simple, but then I'm not of the view that there shouldn't be a user guide at all, because even people trying to develop simplistic products these days still offer a user guide as there is someone who there who doesn't quite understand how to use it. That should be an objective I think, but I wouldn't be upset if somebody said 'well actually there is a user guide' because actually not everybody out there is going to be able to use that just as it is, that's definitely a clear objective, but I think there needs to be some information out there for people that just can't pick things up naturally. You've got to cater for everybody. "

I think that Hermes is sufficiently simple in terms of functionality that it does not need a user guide.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
	X			

Justification & Comments

"I'd probably have to disagree on some respects, it depends on what functionality you are talking about, and the different feature sets. I thing some of them are simple, but there are other things that I learnt only through conversations about other small features, like the tapping of the window. I used to, in the old days, set all of my status through the web portal because I didn't know that if you pressed and held down your finger that changed the display t bring up the list, then you pressed the button. I just didn't know that I don't think that there is any way.. if you've got a new user, how do you get that across that you hold down your finger and the display comes up." I explained that we tried this through demonstration "This changes my answer to the previous questions as I was assuming that you were going to go 'Here's Hermes, it's so simple that you don't need for me to tell you anything, no user guide required, off you go' Going back to the previous question, that's more of a STRONGLY AGREE on the proviso that you are actually telling people how to use it. Back to this question, then, I'm still DISAGREE/NOT SURE but if you're assuming that people are being given some information.

After some further discussion about the Hermes demonstration/instruction process, Owner K said "When it comes to the more sophisticated or less options then they will need a user guide, so you have some information to remind you"

5. Trust/ Dependability

5.1 How often do you set a message on your doorplate?

Never	Only Once	Monthly	Weekly	Daily		
				< 5	5-10	> 10
				X		

Justification & Comments

5.2 Do you leave a message every time you leave your office? Why?

"I would try to, that would normally because I'm moving between here and ISS, obviously there is the occasion when I would forget .. I would try an do one every time, with, obviously, the web portal available if I got down the other end and though 'damn I haven't set my display'"

You When asked is the majority of messages set were longer term ones (in ISS type ones) "It would probably be longer term, as obviously when I'm down in ISS it's difficult to get the granularity there of 'at Lunch and at ISS' or 'out in a meeting at ISS' there interesting thing would have been to have a display at ISS as well to have the extra granularity, My main use would be longer term 'I'm here' or 'I'm there' that would be my main use, I would also use it for short term messages 'I'm in a meeting or 'im out' when I'm here. The thing with short term messages is that you need to have a very quick way of doing it .. to et people so used to doing it just for the very short term 'I'm just out for 5 minutes' it's almost like you need a proportionately easier was of setting the message, but if you think 'if I'm going away for 5 minutes and it's a faff to set the message I won't bother'. Coming back to Joe's button pressing thing, it's like [snaps fingers] – if you press a button it's done, it doesn't really matter if it's a 2 minute meeting, If I'm going to pop to the loo for 2 minutes if it's just like I'm going to close my door and press a button then that's no problem, but if I've got to press a button, wait, click, set it… The more effort it is it seems it's less likely used for the smaller shorter messages… That's my way of thinking about it."

5.3 Do you regularity check to see if the message you set has appeared?

	Never used	Initially		Subsequently			
		Yes	No	Always	Often	Rarely	No
Doorplate – Message list				x			
Doorplate – Freehand	x						
Web portal					x		
SMS							x
E-Mail		x					
MSN Messenger		x				x	
Tangible Interface/other							

Justification & Comments

Web – often in early days when it was only used method

SMS – Only used once while away

MSN – "Initially, that was mainly to get confidence that it was actually working, and then rarely. For some reason I think updating with MSN messenger is more rapid, it's likely that I'm going to have to check every time .. you got messaging saying it had been set, that reassurance it has worked."

What would it take for you to completely trust (>99% certainty) that the message you set has appeared on your doorplate?

"Some confirmation, obviously is good" "When you were using the web portal, the thing that you had set, was the information every obtained directly from the display?" I explained that all state was on the server & doorplate reflected it. "As long as there was some way that I would get that state from the PDA … If it was the PDA that was telling me that 'this' is the message that I've got one me then I'd be entirely happy with that. Worst case scenario you could send a picture of what the PDA is actually showing, as a picture, out of the PDA – this is what I'm currently showing. I guess other than having a faulty display, I'd be pretty much 99% certain that was working.

5.5 How often do you find that Hermes does not seem to be working correctly?

Never	Only Once	Monthly	Weekly		Daily
			1-2	3-4	
			x		

Justification & Comments

"It was probably a weekly basis 1-2, it would tend to be in fits and starts though, so it would be ok for a couple of weeks then there would be a problem, either it was an issue with the server going down, which it did before may, and the preference were rest. I had issues changing the web portal and it appearing on the display. I guess it proportional to how much people actually use it as well. I would try to use it every day except for obviously the time when it was clear that it wasn't responding , or something wasn't happening, and when I'd try and reboot it and it wouldn't come back.

5.6 Please describe a typical scenario that would cause you to think that there is some sort of problem with Hermes, including your perception and scope of the problem

"trying to set a message on the display and something wouldn't work, or using the web portal and finding that my message isn't getting updated onto the displays". "You might get that there is no wireless coverage, or there is something there" "typically the fact that it's not responding to changes of messages, typically I come in and change the message and it's not playing ball"

5.7 Are you aware of factors that affect the reliability of Hermes? What impact do you think the following factors have on/how often do they affect, reliability?

	Aware?	Perception of impact/occurrence			
		V. Low /yearly	Low /~monthly	High /~weekly	V. High /Daily
Wireless network	x		x		
PDA device	x	x			
Server	x		x		
Wired Network	x	x			

Comments
Owner K knew that he was close to base station

5.8 If Hermes does not appear to be working properly (e.g. wrong message on doorplate, problems logging into web portal) I am not inclined to use it again.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
		x		

Justification & Comments

"It probably means that I'm less likely to use it that day, as I'm thinking if it's not working that day then there is no point in my trying to use it this afternoon, and then if you come back the next day and it doesn't work again you think, well I won't bother today. There is a time scale, I'm not likely to use it as much tomorrow, but that doesn't mean I'm not going to use it next week when I think somebody might have returned and the server will be back and running so I can start using it again."

"It's more likely to get you to stop using it in the short term, that's not to say it's going to stop you using it the next week or next month".

5.9 Could you describe what takes place between discovering that Hermes does not appear to be working properly, and using Hermes again (e.g. do you 'test' the system to see if the problem has gone at regular intervals?)

|"Usually there would be an e-mail saying that it's working again. But that's not always the case, I probably periodically just try and see if it is back up and running again, though that might be the following day, so I might not have used it for that day and try it again tomorrow.

5.10 Does your answer to 5.9 depend on your perception of the problem you have encountered? (e.g. do you use 'workarounds' for problems that you think are minor/temporary?)

"There was the time when I had a problem with the log on on the web portal and I couldn't use it at all, so it depends on the nature of the problem. I guess if it's that sort of problem then I'm going to think that there is an issue here, whereas the common problem is obviously that of the display not updating because there was a problem with the server, because that was a more routine event, I probably likely not to do anything particular because of that because there is the assumption that's probably affecting everybody, whereas when I had the web portal logon [problem] that was a specific issue that I was having at the time, that required specific attention. …in terms of using it again, if it'd clear that it's a problem that's just affecting me then I'm going to try and get that problem resolved and use it again immediately. Whereas if it's a problem that appears to be affecting everybody like the message updating, then that will mean that I'm probably not as likely to use it again for the rest of the next day unless it looks as though it's been fixed."

6. New Feature 1 – Remote Accessibility

6.1 I would be happy for anyone to view the message on my doorplate remotely over the web.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
		X		

Justification & Comments

A: Between agree and strongly agree

Q: No concerns over privacy?

A: It comes back to this granularity of information, If I'm happy to publicly display it on my PDA there, then I've not got too many concerns.. You've got concerns that somebody's going to break into your house while you're at work. I think it depends on the granularity of who might be accessing that information, is it the whole of the world? Is it Lancaster University restricted?

Q: This is taken as the whole of the world

A: Perhaps I want to down play that slightly then, perhaps not sure.."

Given that anyone could monitor my doorplate (e.g. to see when I am in or out) this would this affect:

6.2.1a my decision to leave a message.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
	x			

Justification & Comments

A: No, not really, I don't think

Q: Would that be Strongly disagree?

A: Disagree – it gets back to this issue that anyone can monitor anyone's e-mail, but that affect anyone's decision to send an e-mail out at all? People have got to take some things on trust, that… people aren't going to be doing that sort of activity, or at least they would be secure

6.2.1b the content of my messages.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			X	

Justification & Comments

A: Possibly, possibly.

A: You might think that you don't want to be giving out information that says I'm on holiday, as someone might go round and raid your house.

6.3.1 I would be happy to have to individually specify the people who could view my doorplate remotely on a per message basis (i.e. high security and high user overhead).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			X	

Justification & Comments

I clarified with Owner K that I meant grouping of users could be used.

A: Assuming there is the ability of having a default grouping per message, then I agree.

Q: So you'd be happy to put in extra effort?

A: Yeah, I mean you've got high overhead but that could be achieved in a low overhead scheme as possible, by saying a message can have this default grouping, and you can have these other well defined groupings. So it's a case of worst case it's and additional click or a change of status.

6.3.2 I would be happy for staff in the department to be able to view my doorplate remotely.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
				x
Justification & Comments A: Yeah, that would be fine, strongly agree with that.				

I would be happy for undergraduate students in the department to be able to view my doorplate remotely.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			X	
Justification & Comments A: Yeah, probably undergrads… it comes back to this content decision about being at the venue or at lunch, if I, of course, knew that this was open to undergraduate students and that impacted what as was putting as my content then I'm probably going to say well I'll adapt it to accommodate the fact that I know undergraduate students are there.				

6.3.4 I would be happy for other Hermes users to be able to view my doorplate remotely only if I could view theirs (mutuality).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
	X			
Justification & Comments A: Probably not, that's just limiting you to Hermes colleagues isn't it? Q: Yeah A: So I wouldn't be too bothered about it, I'd be happy for them to view my doorplate only, but the restriction of only if I could view theirs.. I'd say no				

6.3.5 I think it would be useful to have a 'private' message only accessible by certain persons (accepting that two separate messages may have to be configured instead of one)

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			X	
Justification & Comments A: Yes, of course there is the additional overhead, which is the problem there, but I think it would be useful to have a more private message service. Because it may be that there is a specific person coming to see you and you're not there so you want to tell everybody else that you're out at a meeting, when this other person has come and you're late then perhaps you can leave a message for them telling where you're reachable if they've arrived. I think it would be useful.				

7. New Feature 2 – Visitor Feedback

7.1 I would be happy for visitors to my display (remotely or in person) to be able to leave feedback on how useful they found my current message.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			X	

Justification & Comments

Q: [described smiley face idea]

A: I suppose I'd be happy for them to leave that feedback, I don't think it's that useful really.

Q: So you're happy for people to leave you feedback, but you're not sure about the use?

A: The problem I would have is that people are just going to abuse that sort of thing. Whenever you get feedback on anything then, unless people take it seriously it's not going to have a useful purpose I think.

7.2.1 I would want to see this feedback.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			X	

Justification & Comments

A: Yes… probably

7.2.2 This feedback would affect my decision to leave messages

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree

Justification & Comments

A: Yes, probably it would affect my decision to leave messages

Q: Do you think that you would me more inclined to update…

A: Well it depends what type of feedback it was really [laughs]. It depends if it's saying 'well this is useless this message' you'd think: why bother leaving messages?

Q: Yeah

A: It would affect… particularity if it was negative feedback, you'd think: well, what the point of putting in the slight overhead that you have of putting them in in the first place.

8. Usability

8.1 Whether or not I leave a message on my doorplate is related to how busy I am (i.e. when I am busy I don't have time to use Hermes).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
		X		

Justification & Comments

A: To some extent, yeah, I guess… There is particular things that I would do routinely, so irrespective of whether I was busy, I would come in in the morning and change my message status. But in terms of during the day for the more ad-hoc messages, if it's like a meeting, if I was really really busy and It was like a rush round, then I would guess it would affect my decision. It comes back to that sort of fine granularity of messages, so the longer lived messages, I think, you're more likely to set even in a bust environment. Whereas if it's a short term message, I personally would probably not set that proportionately to how busy I was, as it were, if that makes any sense…

From the logs, a very common scenario is users setting their temporary message from a predefined list (on their doorplate) when leaving their office, using the 'single press' set and remove message functionality:

8.2a this functionality has affected my use of Hermes since it was introduced.

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
				x

Justification & Comments

A: Temporary messages is something that I never really… See I used to have a number of main messages that I'd have, and the temporary message and the distinction between the temporary message and the permanent messages was something that I every personally found that useful, for me. Because I would find myself setting permanent messages, and changing those permanent messages, rather than just set a temporary message really.

Q: So the whole mechanism didn't really fit in?

A: It didn't work for me anyway, the distinction between two types of messages, I don't know whether that was just my using of the web site or the PDA, but I found what I'd be doing is I'd be customizing my own main messages, so that I included the types of messages that I'd be leaving within my main, sort of, messages set: and then using those, if that makes any sense

Q: Yeah, would you say that that mechanism of setting messages from a list increased you use?

A: Increased the use? You mean on the PDA itself?

Q: Yeah

A: Yeah

Q: So, a bit? A lot?

A: Probably a lot actually

8.2b when using this method I feel that I do not include enough detail in my messages (e.g. 'Back shortly' covers everything from trips to the photocopier to going to the gym)

Justification & Comments

A: Errm…. You see you're referring to these temporary messages like 'back shortly'

Q: yeah

A: I would normally have customized my own main messages to have very common things, so I particularity wouldn't use the 'back shortly' as an example actually. I would probably go and put more detail in. So in terms of answering that question….

Q: It's not really applicable is it?

A: Yeah, it's not that applicable because…. I'm trying to think of all the temporary messages that you had…

Q: Yeah, this is kind of set in the context of like, temporary messages

A: yeah

Q: It's also looking at the whole mechanism of setting messages from that list

A: I mean I would normally use the list on the PDA which is, because I always used the permanent messages and used the list on the PDA, and set those permanently messages on there, never really making any use of the temporary message set, because that was the second set of messages below that, if that's right? Or am I getting mixed up between the two?

Q: There was like a default message, and the idea was, that would be something you would share when you are in your office and didn't need to share a message. And the idea is that you put on a temporary message when you need to say something. Like you'd gone out.

A: Ok, so what I would do then is, let's just clarify, what I'd do is change all those temporary messages then, so I'd have my default message, and I would customize all of those temporary messages to be messages that I would use regularity.

Q: But that weren't temporary, as such

A: But that weren't temporary, as such: they could be more long lived messages, so 'I'm at ISS' for instance, or 'I'm at ISS or in a meeting' of 'I've gone home and I'll be back on Monday'. So that's one of the things I would do; spend some time in customizing all of those temporary messages, so that they would be slightly more detailed, and probably drop things like 'Back shortly' because it wouldn't be something that I'd particularity use, because I thought that, well, it doesn't really give that must information.

Q: So you would change these ones to more applicable messages…

A: Yes, more customized to me, based around what I tend to do, and the sort of things I'd be doing during the week, so I'd make sure that those were edited each time. So it was 'temporary' messages I was using, it was just that I customized them for my own purpose, and probably not using them in a temporary fashion, if that makes sense. That's why I say, I guess, about the temporary and permanent messages… I sort of treated them as one really.

Q: So would you strongly disagree - because you changed them?

A: Probably, yeah… well… 'I feel that I do not include enough detail' [read from question]… so if you kept being given 'Back shortly' then I'd probably agree… it depends how you interpret that question…

8.2c the level of detail in messages set with this method is acceptable given Hermes ease of use (i.e. message detail/usability trade off is acceptable).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			X	

Justification & Comments

A: Well you see then I customized mine, so I guess I'm disagreeing with that, because I'm actually customizing the level of detail. So if you're assuming that question is based on the default temporary messages.

Q: No, it would be messages that you set

A: Right ok..

Q: So it's really: Did you find you fit enough information…

A: Yeah I mean you've got quite a bit of display space to do that, and so… yeah... I mean I try and put as much information as possible. So, ok, I'm agreeing then.

8.3 I find that the doorplates provide enough expressivity (i.e. screen resolution high enough, enough space).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	

Justification & Comments

A: Probably enough space, yeah. I mean one of the things I'd asked about was having the time stamping as well, to include that information on there, but, yeah, I think there is enough acreage there. Perhaps more acreage with more resolution… I'm not entirely sure what other things you'd want to put on there

8.4 IF ANSWER TO 8.3 WAS NOT AGREEMENT: Do you think that this is a limitation of the user interface?

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree

Justification & Comments

8.5 IF ANSWER TO 8.3 WAS NOT AGREEMENT: Do you think that this is a limitation of the screen size?

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree

Justification & Comments

8.6 I find the level of expressiveness provided is acceptable given Hermes ease of use (i.e. expressiveness/usability trade off is acceptable).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			X	
Justification & Comments A: Yes, Yeah, I'd agree with that one				

8.7 I found accidental/malicious changing of my temporary message a problem. (i.e. was this security/ease of use trade off unacceptable?)

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
		x		
Justification & Comments A: Yeah I did. I wouldn't say that it was a massive problem, so it's… in the not sure range.				

8.8 I found accidental/malicious changing of my messages to be a problem when using post-it notes/'message whirlers' (before Hermes).

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Justification & Comments Q: Did you use any system before Hermes? Like post-it notes or anything? A: Not really, no. Well, probably occasionally, the odd post-it note, but not of any routine as it were. So, if I used it once or twice a year I don't think that constitutes significant use.				

9 Future Work

9.1 I would find it useful to be able to share (i.e. visible at the same time) two types of message: broad 'high level' (e.g. "busy marking this week") and narrow 'lower level' (e.g. "Gone for coffee")

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
				X
Justification & Comments A: Yeah, I'd say strongly agree on that one, I'm all for this sort-of granularity of messages with different audiences for different people.				

9.2 If I was given the ability to share two different messages (as described previously) I would like this done via two physically separate displays

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
		x		

Justification & Comments
A: Not necessarily, I'm not sure really, were you thinking you have the two different displays? Are you actually going to put them next to each other?
Q: I image something like the display on A floor
A: Right
Q: Maybe, sort-of, one of those per a few offices, where you can see these broad status's of people, then you could actually walk to their offices to see their narrower.. things..
A: I'm not sure about that actually…

9.3 I would be happy for anyone to view my 'high level' message remotely (i.e. via the web)

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	
Justification & Comments A: Yeah, on the low agree side, yeah… again it depends on via the web, that implies everybody. Q: yeah A: Rather than, perhaps, Lancaster or colleagues in the department.				

9.4 I would like to have a Hermes doorplate in the new building

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
				X
Justification & Comments				

9.5 I feel that Hermes in its current state is suitable for the new building

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
			x	
Justification & Comments A: Yeah, I think so, with the recent changes in the last few months, with the persistency, I think that was a biggy really. I think it would operate in the new building, yeah. Definitely agree.				

Appendix E

E.1 Publications Arising From This Work

This appendix briefly summarised the contributions made by publications that have arisen from this work.

Exploring Situated Interaction with Ubiquitous Office Door Displays - Cheverst, K., Fitton, D., Dix, A. and Rouncefield, M. [Cheverst '02]

This was the first publication arsing from work on the Hermes system and discussed in detail the initial aims, installation requirements and visitor/owner functionality provided in phase 1. This paper also presented some preliminary findings from the deployment of the phase 1 prototype, such as the need for high levels of user trust and the early problem of owners' messages being overwritten.

Exploring the Utility of Remote Messaging and Situated Office Door Displays - Cheverst, K., Dix, A., Fitton, D., Friday, A. and Rouncefield, M. [Cheverst '03b]

This paper investigates the use of SMS for remote messaging using the Hermes and SPAM systems as case studies. In addition to providing an overview of Hermes at phase 3 in the development process, the overall architecture is presented. Two main issues arising from the two case studies are discussed, firstly the issue of context sharing using SMS to support cooperation and how users are prepared to forego control of information access in some circumstances. Secondly, the high level of dependability systems require in order for users to trust (and therefore use) the system, and how this is a challenge for developers.

Experiences Managing and Maintaining a Collection of Interactive Office Door Displays - Fitton, D. and Cheverst, K. [Fitton '03]

The focus of this paper is the experiences and challenges of managing and maintaining the deployed Hermes system. An overview of the Hermes system during phase 4 is given, followed by a discussion of the technical problems encountered and solutions. The paper gives a detailed description of the *Management Agent* (discussed in section 4.9 of this thesis) and presents some preliminary findings.

'Out To Lunch': Exploring the Sharing of Personal Context through Office Door Displays - Cheverst, K., Dix, A., Fitton, D. and Rouncefield, M. [Cheverst '03c]

This paper, written during phase 4, presents my quantitative analysis of usage of the Hermes system in the form of investigation of context sharing for a large sample of messages set by door display owners. Qualitative investigation into context sharing is also presented, in the form of analysis of a questionnaire designed by myself to door display owners to probe owner opinions of current functionality and hypothetical changes. A set of inter-related issues arising from the use of Hermes are presented, along with a discussion of other factors such as update and appropriation.

Exploring the Evolution of Office Door Displays - Cheverst, K., Fitton, D. and Dix, A. [Cheverst '03d]

This book chapter discussed the evolution of Hermes from phases 1 to 4, including the features added in each phase together with qualitative analysis of the impacts these had on use. Experience and qualitative analysis of use is used to inform a set of primarily usability issues

Supporting Interaction with Office Door Displays - Fitton, D., Cheverst, K., Finney, J. and Dix, A. [Fitton '04a]

This workshop paper, written during the start of phase 5, discussed the interaction methods that have been provided for door display owners. It focused on why the different interaction methods had been developed for the Hermes community and how these were used by door display owners.

Probing Technology with Technology Probes - Fitton, D., Cheverst, K., Rouncefield, M. and Dix, A. [Fitton '04b]

This paper discussed the use of deployed prototypes which include logging of use as technology probes. The Hermes and SPAM system are used as case studies to discuss the collection of logs files and some of the more pragmatic issues of analysing logs to extract information. The paper goes on to discuss how the usage information extracted from logs can be used to help understand the user experience.

The Auditability of Public Space - Approaching Security through Social Visibility - Dix, A., Cheverst, K., Fitton, D. and Friday, A. [Dix '04]

This workshop paper explored how the public nature of situated displays can inherently provide security, as demonstrated by the fact that in Hermes potential security 'loopholes' (being able to set a temporary message without) were not exploited by pranksters.

Rapid Prototyping and User-Centred Design of Interactive Display-Based Systems - Fitton, D., Cheverst, K., Kray, C., Dix, A., Rouncefield, M. and Saslis-Lagoudakis, G. [Fitton '05]

This journal article discussed a range a display-based systems which have been developed and deployed by the authors, focussing on the combination of rapid prototyping and user-centred design using during development. The article presents a range of user-centred design-based approaches and their potential application, highlighting the importance understanding use of prototypes in order to drive a rapid prototyping process.

Appendix F

F.1 Terminology

This appendix defines the terminology used in this thesis in alphabetical order.

Administrator – A Hermes owner who is required to perform administration functions for the Hermes system, such as investigating failure, deploying devices etc. An administrator has access to the *Management Agent*.

Central Agent – A software component which runs on the Central Server providing centralised management, administration and other core services (such as persistent storage) required by Hermes Client Agents.

Central Server – A Linux-based PC which runs the *Central Agent* and associated software services (such as hosting web pages and Java Servlets).

Client Agent – A software component which acts as client node of the Hermes *Central Agent*, hosted on a public door display device and accessible to Hermes owners and visitors.

Default Message – This is a textual message or image file that is authored by a door display Owner and, typically, displayed on their door display when they do not need to display any information. This feature is usually used to customise a door display e.g. an image of some relevance to the door display Owner chosen. A Default Message has a lower precedence than a Temporary Message (i.e. it will be hidden by a Temporary Message) a textual Default Message takes precedence over an image file Default Message.

Door Display – A term used to describe the hardware (a PDA device mounted in its associated housing) on which the Client Agent software runs. So called because they were deployed outside offices adjacent to the door.

Management Agent – A tool which can be used to investigate the current status of the Client Agents and provide other useful tools. This service is only accessible by Administrators via a web interface provided by Java Sevlets.

Visitor Note – In the context of Hermes a Visitor Note is a free form message drawn by hand by a Visitor and intended to be read by a door display owner. A Note is left by a visitor co-located with a Doorplate, and is intended to be analogous to a paper Post-it note.

Owner – This term is used to describe a person that has a Hermes door display deployed outside her office for her use (occasionally prefixed with 'door display' for clarification). An owner has their own profile, stored on a *Central Agent* which they may customise as desired. An Owner also has the facility to authenticate themselves with any part of the Hermes system as required.

Owner Profile – A collection of information stored about an Owner, some of which is configured by an Administrator and some of which can be freely configured by the Owner. A profile is stored in persistent storage a Central Agent and is cached or accessed regularly by other parts of the Hermes System.

Registration – The process by which a new Hermes door display owner creates and populates an owner profile.

Temporary Message – This is a Message textual message or image file authored by a door display Owner and typically displayed on their door display when they need to display some information e.g. 'Back in 5 minutes'. A Temporary Message has a higher precedence than a Default Message (i.e. it will be cover a Default Message), textual Temporary Message takes precedence over an image file Temporary Message.

Visitor – This is a person visiting a Hermes door display, who may or may not have previous knowledge of the Hermes System. A Visitor would typically be 'visiting' a doorplate because they are attempting to find the Owner of that door display, or because they wish to leave a Note for the door display Owner. A Visitor may also be a Hermes door display Owner.

Web Portal – This refers to the collection of Java Servlets which provided a web interface for Hermes door display owners.

Appendix G

G.1 Visitor E-Mail Questionnaire

Subject: Hermes Doorplates on C floor, Computing

Hello,

During the past year or so you may have come into contact with [names of door display owners] – as you may have noticed, all of these people have Hermes doorplates outside their offices (PDA's in metal boxes). These are a large part of my PhD work, and if you have used (or even considered using) a Hermes doorplate I would be extremely grateful if you could answer some quick questions:

1. Have you been told what the Hermes doorplates are for and that you could use them?

2. Would you consider that because they are located in a public space anyone can use them?

3. How many times have you used a Hermes doorplate to find out about its owner? (i.e. read the message on it) 4. Did you find the messages useful? (Did it help you understand where the person had gone or when they would return? Why?)

5. How many times have you left a message on a doorplate for its owner?

6. Did you trust that your message would be delivered?

7. What was your perception of the importance of the message you left? (i.e. more/less important than e-mail? Formal/informal?) 8. Have you ever sent a message using Hermes instead of an e-mail? (Or, conversely, sent an additional e-mail referencing/mentioning a Hermes message from you?)

9. Did you find the method of leaving a message expressive enough? (Was there enough space? Was the resolution & sensitivity high enough?)

10. Did you find the user interface easy to use? (Do you think it requires a user-guide/instructions etc? Why?)

Thanks for your time!

G.2 Response 1

1) Have you been told what the Hermes doorplates are for and that you could use them?

Yes, during an introductory lecture I was informed that the doorplate could be used to leave messages for the tutor (Keith Cheverst).

2) Would you consider that because they are located in a public space anyone can use them?

Yes.

3) How many times have you used a Hermes doorplate to find out about its owner (i.e. read the message on it)

Once

4) Did you find the messages useful? (Did it help you understand where the person had gone or when they would return? Why?)

Yes. The message read "gone for coffee" and was helpful in informing me that they would return within a short period of time.

5)How many times have you left a message on a doorplate for its owner?

Never.

G.2 Response 2

> 1. Have you been told what the Hermes doorplates are for and that you

> could use them?

Yes

2. Would you consider that because they are located in a

> public space anyone can use them?

No

> 3. How many times have you used a Hermes doorplate to find out about

> its owner? (i.e. read the message on it)

Twice

4. Did you find the messages

> useful? (Did it help you understand where the person had gone or when

> they would return? Why?)

Yes

>

> 5. How many times have you left a message on a doorplate for its

> owner?

Twice

> 6. Did you trust that your message would be delivered?

No

7. What was your

> perception of the importance of the message you left? (i.e. more/less

> important than e-mail? Formal/informal?)

Informal but not as important as an email

8. Have you ever sent a message

> using Hermes instead of an e-mail? (Or, conversely, sent an additional

> e-mail referencing/mentioning a Hermes message from you?)

No

9. Did you

> find the method of leaving a message expressive enough? (Was there

> enough space? Was the resolution & sensitivity high enough?)

Not an expressive, too sensitive and not a high enough resolution

10. Did you

> find the user interface easy to use? (Do you think it requires a

> user-guide/instructions etc? Why?)

>

User guide and/or instructions would be good

Appendix H

H.1 Requirements

This appendix presents the most pertinent requirements that emerged from the design, development, deployment and evaluation of the Hermes prototype described in this thesis. The requirements are categorised using the levels of:

i) Hardware - Supporting hardware platforms, associated deployment issues and technologies. Firstly requirements that affect all hardware components are described, followed by requirements from the perspectives of a door display device and a server intended to support multiple door displays,

ii) Software - The software systems and components. Firstly requirements that affect all hardware components are described, followed by requirements from the perspectives of a door display and a server intended to support multiple door displays,

iii) Application Functionality - The functionality provided by software applications, described from the perspectives of a door display owner, a door display visitor and a system administrator. Many of these requirements in this category emerged from exploration the affordances provided by the digital approach used in Hermes compared to paper-based messaging mediums (this is discussed further in section 7.3.2).

When describing requirements for Hermes the terminology used is that defined in RFC 2119 [Bradner '97], the key terms can be summarised as:

MUST - This word, or the terms "REQUIRED" or "SHALL", mean that the definition is an absolute requirement of the specification.

SHOULD - This word, or the adjective "RECOMMENDED", mean that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.

MAY - This word, or the adjective "OPTIONAL", mean that an item is truly optional.

H.1.1 Hardware

1. Hardware systems MUST be reliable enough to run 24 hours a day 7 days a week for extended periods. The mean time between failure SHOULD be at least 1 year.

2. Door display devices MUST use a networking technology which is reliable in the deployment domain (see section **3.9.1**).

3. Door display devices MUST use an appropriate networking technology in terms of bandwidth and latency. In more detail, due to the asynchronous nature of Hermes wired and wireless Ethernet proved suitable.

H.1.1.1 Door Display Hardware

1. The door display hardware MUST adhere to appropriate legislation governing electrical installations. For example, in order to adhere to appropriate guidelines at Lancaster University, door displays in Hermes had to use a low voltage (less that 50 volts) power source.

2. Door display hardware SHOULD produce extremely small amounts of noise when operational if located inside an office. This emerged as an important requirement from an initial Hermes 2 user study (discussed further in section J.2.1).

3. A touch sensitive screen used for input SHOULD provide a suitable degree of accuracy. From evaluation of display hardware for the Hermes 2 project it was found that some touch sensitive screens did not detect movement to a suitable degree of accuracy to enable hand written text to be authored legibly (this issue is discussed further in section J.2.1).

4. The door display SHOULD be capable of emitting a short audible sound when a user touches the touch sensitive screen. Such auditory feedback is required to help reassure a user that his or her physical action has been acknowledged by the system.

5. The door display hardware MUST be fast enough to support a rapid feedback loop.

6. Placement of the door display hardware housing MUST adhere to appropriate legislation, for example disabilities legislation governing the height at which a display is

mounted.

7. A housing for a door display unit SHOULD be designed to prevent access to any buttons on display unit within which could be used to disrupt the door display application.

8. A housing for a door display unit SHOULD provide adequate security to prevent any of the hardware contained inside being removed by an unauthorised person.

9. The door display housing SHOULD provide appropriate access to hardware contained inside for both a door display owner and system administrator. In more detail, the device may need to be accessed to, for example, perform a reset in the event of a crash.

H.1.1.2 Server Hardware

1. The hardware supporting a server MUST provide the necessary physical capability and extensibility to enable the desired interaction methods. For example in order to support interaction via SMS a server must have a free serial port in order to connect a GSM Terminal.

2. The hardware supporting a server MUST provide (or have access to) a reliable storage medium which includes replication. In more detail Hermes demonstrated that reliable storage was vital for log files and owner profiles and that failure of hard disk drives, while relatively rare, does occur.

H.1.2 Software

1. Software systems and components MUST be reliable enough to run 24 hours a day 7 days a week for extended periods. The mean time between failure MUST be as high as possible given the available resources.

2. Software systems and components MUST support the associated hardware platforms on which they run. This requirement must be met from a range of levels, from operating system device drivers to higher-level software components which MUST, for example, fit within the appropriate memory footprint.

H.1.2.1 Door Display Software

1. The door display software platform MUST be fast enough to provide rapid visual or auditory feedback[12] (i.e. respond to user actions without perceptible delay).

2. The capability SHOULD be provided to allow software components running on a door display to be updated remotely. In the Hermes system physical access to each door display individually was required to install updated software component and this proved time consuming for the system administrator.

3. Door display software components SHOULD be designed to function independently of other system components such as a central server or centralised storage mechanism. The reliance of the Hermes door displays on a central server meant that any disruption to the wireless network link between them would cause user interactions to be unsuccessful, damaging users perceptions of dependability.

H.1.2.2 Server Software

1. The server software components SHOULD be designed to be scalable to support the addition of extra door display devices and additional services (without, for example, negatively impacting system performance). This requirement will be especially important in the forthcoming Hermes 2 system with a deployment of 40 door displays and potential for a wide variety of novel applications.

2. Server software components MUST include reliable storage of information. In more detail, reliable storage emerged as a key requirement in the Hermes system for information such as owner profiles and log entries.

---

[12] Rapid feedback in relation to user interfaces is discussed further in [Dix '97b] but no specific quantitative value is stated.

H.1.3 Application Functionality

H.1.3.1 Door Display Owner

1. A door display owner SHOULD be provided with a range of locally and remotely accessible interaction methods to set messages on his or her door display. In the Hermes system, interaction methods provided included:

    a. the door display user interface,

    b. the web,

    c. SMS,

    d. e-mail,

    e. MMS,

    f. a tangible user interface[13]

[13] This feature will not be provided in the initial Hermes 2 prototype, but will be included in subsequent phases.

2. A door display owner SHOULD be allowed to make choices over the level of expressivity when setting messages on his or her door display. In the Hermes system, levels of expressivity supported included:

   a. simple textual messages,

   b. simple textual messages with control over text formatting, such as text colour, background colour, and font size,

   c. hand drawn messages, authored using a touch sensitive screen such as that of a door display,

   d. an image file (of type JPEG, GIF or BMP format),

   e. an animated image file (i.e. an animated GIF file).

3. A door display owner SHOULD be allowed to choose a suitable means to be notified when a visitor leaves a note for them. In the Hermes system, owner could choose to be notified of new visitor notes via:

   a. SMS,

   b. E-mail (where the note was embedded in the e-mail),

   c. MSN Messenger (where the owner was sent a link allowing the visitor note to be accessed).

4. A door display owner SHOULD be able to identify the author of a visitor note, wherever possible, both to help understand the note and simplify the reply procedure. In more detail, one potential low-effort solution for the visitors would be the use of a webcam to take a picture of the author for identification.

5. A door display owner SHOULD be provided with feedback in the case of failure of system components wherever possible. If an owner is notified of the failure of system component which they might encounter this may help reduce trust-damaging encounters of failure. However, it is equally important to manage the granularity and number of feedback messages sent to avoid high numbers of messages becoming a burden to owners.

6. A door display owner SHOULD be provided with feedback when interacting with the system remotely wherever possible. In more detail, providing positive feedback when a message was set successfully encouraged trust in the Hermes system. Additionally, an owner should be provided with feedback if an interaction method they attempted to use failed; this is in order to ensure an owner is aware of the current state of the system and does not encounter unexpected failure.

7. A door display owner SHOULD be able to automatically include additional context in messages, such as the time a message was set, should they wish to do so. This feature was requested by owners of Hermes door displays in order to help make messages set more useful to visitors. Additionally, inclusion of timing facilities in messages (e.g. the message 'back in 5 minutes' could count down every minute) is one potential area for exploration.

8. A door display owner SHOULD be provided with the facility for their messages (publicly or privately accessible) to be generated based on contextual information, such as appropriate electronic calendar entries. Discussion of these features received a positive response from door display owners (as presented in section 4.7.10) but was not explored in Hermes due to limited development resources.

9. A door display owner SHOULD be provided with a central point from which all major functionality provided by the system can be accessed, and general maintenance can be carried out. In the Hermes system the web portal, while not the most popular interaction method, provided a 'failsafe' means for owners to set messages, view visitor notes, modify owner preferences and change PINs etc.

10. A door display owner SHOULD be provided with some form of user guide regardless of the level of complexity provided. One of the aims of Hermes was to provide an information appliance and while the majority of owners had no problems using Hermes without a guide, two owners that were provided with a brief guide found it useful.

H.1.3.2 Door Display Visitor

1. A visitor SHOULD be provided with a suitable low effort method to leave a note for a door display owner. For an able-bodied visitor examples might include the facility to draw a note onto a touch sensitive screen by hand or use an on-screen keyboard, while for a disabled visitor, not able to access the display device, this might include interaction using a mobile phone via SMS or Bluetooth.

2. A note left by a visitor SHOULD not remain publicly visible. This requirement is necessary in order to encourage visitors to leave messages when, for example, a visitor does not want to make their message accessible to all passers-by.

3. A user guide facility SHOULD be provided in the door display user interface which can easily be accessed by a visitor. This is required to allow visitors with no prior knowledge of the system to use it and a key issue is how to design this use interface to ensure this facility is perceptible to visitors.

H.1.3.3 Door Display Administrator

1. A door display administrator SHOULD be provided with access to analysis of system logs[14] wherever possible. This was identified in Hermes as one method to ensure a door display administrator was aware of changes in use, for example after deployment of a new feature, to allow investigation of potentially interesting issues as they occur.

[14] The requirements for a logging system are discussed in detail in section 5.3.

2. An administrator SHOULD be provided with a mechanism to update software components on door displays remotely (without requiring physical access to each door display individually). In Hermes, performing individual updates manually was very time consuming and would not have been practical in a larger deployment.

3. An administrator SHOULD be automatically notified of the failure of any door displays and related system as soon as feasibly possible (i.e. minimising the possibility of erroneous failure notification).

4. An administrator SHOULD be informed of the status of hardware associated with the door display server. For example, this may include the amount of credit available on the SIM card in the GSM Terminal, the amount of remaining storage available for log entries etc.

5. An administrator SHOULD have the ability to monitor the status of door displays remotely. In more detail, an administrator SHOULD be provided with a mechanism allowing them to view potentially useful information (current message, owner information, last time the display was known to be functioning correctly) to help diagnose problems and test the system.

Appendix I

I.1 Design Considerations

This appendix presents pertinent design considerations which emerged primarily from qualitative analysis. These are potentially important considerations for future work on Hermes which may be useful to other researchers working in a similar area, to help inform design decision. These are described from the perspectives of a door display owner and a door display visitor. The terminology used in these considerations is that defined in RFC 2119 [Bradner '97].

I.1.1 Door Display Owner

1. A door display SHOULD maintain a minimal level of complexity in terms of functionality and user interfaces to help provide an information appliance. In the Hermes system simple functionality and low barriers to use encouraged adoption and use. Additionally, this approach is also likely to have the added advantage of improving reliability due to low complexity.

2. A door display owner SHOULD be provided with a range of interaction methods to allow the selection of an appropriate interaction method as necessary. In more detail, an appropriate interaction method is likely to be dependent on an owner's technical experience, existing daily routines, situation, and the importance of the message to be set.

3. A door display owner SHOULD be allowed to select an appropriate level of expressivity in order to affect changes in the effort required to set a message. In more detail, an owner may wish to author a message with a high degree of expressivity (similar to a paper note) or might find it acceptable to trade-off expressivity in order to set a message in a low-effort manner (e.g. choosing from a predefined list of textual messages).

4. A door display owner SHOULD be allowed to select an appropriate level of control in order to affect changes in the effort required to author a message. In more detail, an owner may desire a high level of control and find the expense of making interactions more timely acceptable, while for another owner low-effort might be paramount.

5. A door display owner SHOULD be able to personalise his or her door display both in terms of its appearance and the functionality provided. In Hermes this was achieved using individual owner profiles (see section 4.5.3). The ability to tailor functionality assisted adoption and the ability to tailor appearance promoted a sense of ownership and familiarity.

6. A door display owner MUST maintain a high degree of control over messages (and content) displayed on his or her door display where appropriate. In more detail, malicious changes or changes as the result of failure have a negative impact on the trust an owner has for his or her door display. Additionally, there is a clear trade-off between control and effort, it is therefore important to provide owners with the ability to disable or modify such features via owner profiles.

I.1.2 Door Display Visitor

1. A visitor SHOULD be able to leave a visitor note at a door display with no prior knowledge of the system. In more detail, a very small (or zero) time to learn is important to encourage use from visitors (see section 6.8).

2. A door display MUST be designed in order to help a visitor perceive the functionality available to them. This requirement received relatively little attention in the design of the original Hermes system and is perhaps one of the reasons for the comparatively small number of visitor notes left compared to owner messages set.

3. A visitor note SHOULD only be accessible by the appropriate door display owner. In more detail, if a message left by a visitor at a door display remains visible this is clearly impacting the control an owner has over the information displayed (see section 3.9.3). Additionally, the visitor may not wish his or her note to be publicly accessible.

Appendix J

The Design of Hermes 2

J.1 Introduction

Following the move to a new Computing building, funding became available for the deployment of forty office door displays giving complete office coverage around two floors. This appendix considers the design of Hermes 2 (the second version of Hermes) following on from the issues uncovered during the development and deployment of the original Hermes system. Firstly, the requirements which emerged from Hermes (see Appendix H) are discussed in the context of Hermes 2. Next, this appendix presents two user studies carried out in order to uncover requirements for Hermes 2, the first was to investigate preferences for display size and layout, the second to investigate additional requirements for Hermes 2. Finally, this appendix presents work carried out on the design of Hermes 2 door displays and the proposed software architecture for the new system.

J.2 Uncovering Requirements for Hermes 2

In the original Hermes system a 'one size fits all' approach was used for door-display hardware configuration (with a small number having iButton support or wired networking). However, with the forthcoming redeployment there is the opportunity to investigate what door display owners find acceptable in terms of parameters such as display size, housing and supporting infrastructure. Consequently, the early aims at the first stage were to:

i) determine the physical form factor of displays desired by door display owners - in terms of the actual display devices (and supporting hardware) investigated through the 'showroom' experiment described in section J.2.1,

ii) ensure that no pertinent requirements had been overlooked by the Hermes system before beginning development of the Hermes 2 system - investigated through a cultural probe based user study in section J.2.2.

J.2.1 The ‘Showroom’ Experiment

To investigate the first aim described in section J.2, a ‘Showroom’ [Fitton ‘05] was designed to motivate discussion in an environment where potential door display owners could physically see a range of display technology and user interface configurations (‘show offices’) in order to help inform decisions. One appealing idea was that of providing both ‘owner’ and ‘visitor’ functionality simultaneously, removing the need for the user interface to switch modes (and additionally allowing the owner’s message to be continually visible when a visitor is interacting). This idea was rapidly prototyped using two PDAs side-by-side each running an appropriately modified version of the original *Client Agent* (show office B in Figure J-1 described later in this section). In addition to using PDA devices, several different sized displays were used to prototype different scenarios (show offices C-F).

A relatively high fidelity prototyping strategy was used, instead of lower fidelity alternatives such as paper prototyping, in order to help participants better appreciate how the prototypes might look and function when deployed. Additionally, this high fidelity prototyping process proved relatively low cost in terms of development time as it only required simple modification to the original Hermes door display application.

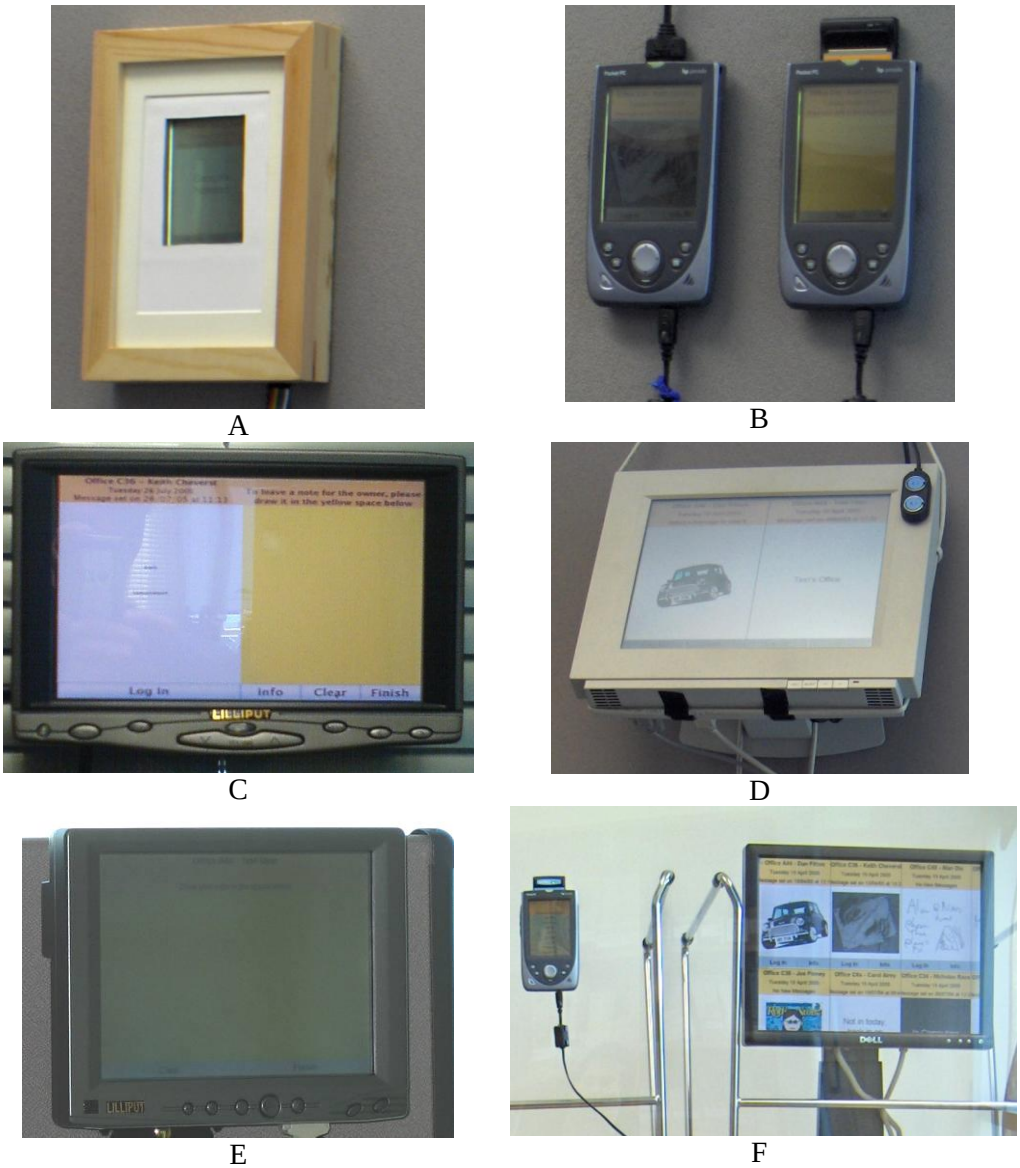

Figure J-1: Different 'Show Office' Configurations.

The six ‘show office’ scenarios are described in the following paragraphs:

Show Office A

One original Hermes door display (a HP Jornada 568’s) in new wooden picture frame housing (see A in Figure J-1) intended to investigate initial reaction to a new housing design.

Show Office B

Two original Hermes door displays, one specifically for the door display owner (i.e. no ‘Leave Note’ button) and another specifically for visitors (i.e. always on ‘Leave Note’ screen - see B in Figure J-1).

Show Office C

One seven inch 16:9 aspect ratio (widescreen) touch sensitive screen running at 1024x764 resolution, with display owner and visitor user interfaces provided side-by-side (see C in Figure J-1), powered by an Apple Mac Mini.

Show Office D

One fourteen inch 4:3 aspect ratio touch sensitive screen (see D in Figure J-1) deployed in an area between two offices and intended to be shared. The purpose of this shared screen was to allow office occupants to display messages intended for visitors. Additionally, each office had its own smaller touch sensitive screen (one eight inches 4:3 aspect ratio touch sensitive screen running at 1024x768 resolution) located adjacent to the office door for visitors to leave messages for the occupant. This configuration was powered by a single PC with a multi-head VGA card.

The scenario also included a 'binocular' webcam pointing at the shared screen to demonstrate an 'out of band' method for remotely monitoring. The intention with this was to allow owners to check the state of display remotely to improve trust (e.g. owners could check if messages set remotely had actually appeared).

Show Office E

One eight inch 4:3 aspect ratio touch sensitive screen (running at 1024x768 resolution), 'portrait' orientation and displaying the owner user interface in the top half of the screen and visitor interfaces in the lower half. Powered by a standard PC (see E in Figure J-1).

Show Office 6

A display serving multiple occupants in a shared office, using a large TFT screen (fifteen inch screen mounted behind a transparent partition) displaying owner interfaces for many office occupants simultaneously. A smaller interactive display (a PDA) is mounted on the outside for navigation and input (e.g. leaving visitor notes). See F in Figure J-1.

The configurations were prototyped using appropriate hardware and software, then mounted and arranged to give an impression of how they might appear when deployed, providing 'show office' scenarios for all six potential door-display configurations together at the same time. Ten future door-display owners, including six previous Hermes door display owners, were given a semi-structured tour around the show offices, which were video-taped. These tours took between ten and twenty minutes and each configuration was explained in the context of a scenario to highlight potential use.

Findings

The experiment appeared to engage the participants and the different prototypes arranged next to each other enabled owners to pick out the configurations they preferred; a typical comment being "*I like that [user interface] but I'd want it on that display*". The vast majority of participants included in the study preferred show office C which included a seven inch 16:9 aspect ratio touch screen, this aspect ratio enabled the inclusion of the owner and visitor user interfaces side-by-side. However, it should be noted that the majority of participants commented that this configuration (the touch screen and Mac mini) was the most aesthetically pleasing which may have played a part in the decision making process. Many owners seemed intrigued by the 'binocular' webcam scenario (this was explained after the demonstration of the six scenarios) but seemed unsure whether they would actually use this feature in practice. One interesting finding was that the large fourteen inch touch sensitive screen used in scenario D proved difficult for participants in the experiment to write text on (when leaving visitor notes). In order to investigate this issue further, participants were asked to draw a 'note' including text on each display in turn. The difficulty appeared to be attributed to several factors:

i) mounting of the larger displays – the larger displays were not mounted 'flat' against walls, but stood-off several inches, this made it difficult for participants to rest an arm or hand while drawing on the screen in order to draw steadily (this problem was not present with the Hermes original system),

ii) 'Blackboard' effect – without practice, writing large text on an upright surface such as a blackboard or whiteboard can be challenging. Providing a large area for drawing a message seemed to encourage the use of large text which caused some participants problems forming legible text and participants often ran out of space (this problem was less apparent with the original Hermes system),

iii) touch screen sensitivity – it became apparent that several of the screens being tested had not been designed to recognise fine-grained movement such as handwriting. Unfortunately this meant that some small drawing movements were not recognised, making handwritten text difficult to read.

These findings seem to highlight the success of the original Hermes screen size and housing form factor: simply proving a larger screen caused the two main problems described previously. Additionally, the PDA device used in Hermes was specifically designed to recognise fine-grained movements such as handwriting. Providing an area for visitors to draw

a message of similar size to a traditional Post-it note appeared to be a potentially important requirement. The two pragmatic issues of mounting of display and touch screen sensitivity require careful selection of hardware and housing design.

J.2.2 Cultural Probe Based User Study

The purpose of this study was to ensure that no requirements pertinent to context sharing and coordination had been overlooked during the Hermes system, by investigating messaging practices within the new Computing building. Probe packs [Gaver '99] were given to the ten participants in the showroom experiment [Fitton ‘05]. These packs contained a diary, instant camera, pen and glue (Figure J-2). The diary was intended to record messaging activities over a period of seven days, with pages for each day to record and describe messages left for others, for oneself and messages left by others. The camera allowed participants to takes pictures of messages, which could then be glued into the diary and annotated appropriately to describe their context.

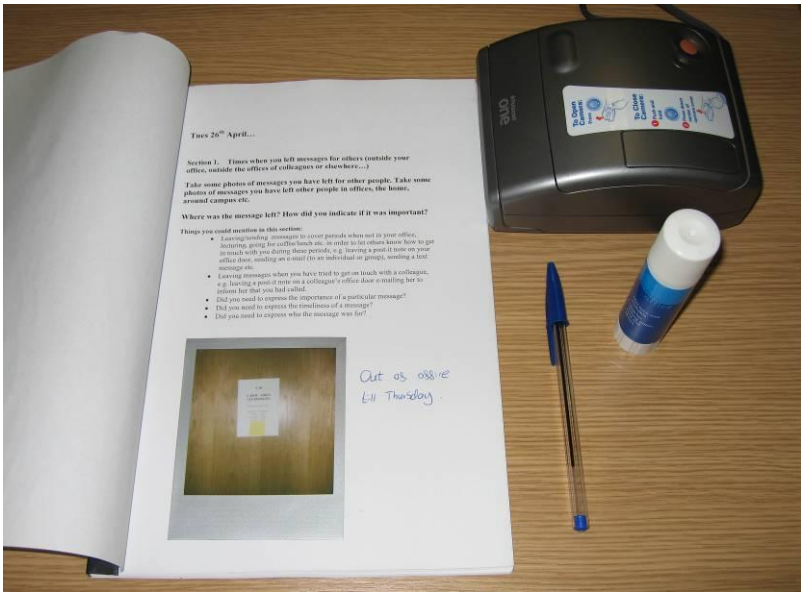

Figure J-2: A Hermes 2 Probe Pack.

Findings

Out of the ten participants five were either too busy to fill in their diary or did not send or receive any paper notes over the seven day period, returning blank diaries. The remainder of the participants typically included pictures of two or three messages with brief annotations. The results of this study yielded less information than expected and perhaps highlighted the shortcomings of this approach when used in a busy office environment. However, the diaries that did contain information demonstrated evidence of paper-based messaging activities in the new Computing Department. A common example being office

occupants (or their colleagues) placing Post-it notes on office doors to let visitors know if the occupant was away. Although no new requirements emerged from this study it did demonstrate an opportunity for a system such as Hermes 2 to augment these existing messaging practices.

J.2.3 Analysis

This section has presented the results of a 'showroom' experiment which allowed potential owners to express preferences for display hardware, the most popular choice being a compact seven inch 16:9 aspect ratio screen (scenario C). The use of high-fidelity prototypes highlighted shortcomings in the sensitivity of touch screen digitisers for some displays (or associated software drivers) and the general problem of writing on a vertical surface such as a touch screen. While the response to the cultural probe study was poor, existing paper-based messaging practices in the new Computing Department were clearly visible, demonstrating an opportunity for a system such as Hermes.

J.3 Initial Requirements for Hermes 2

From the design, development, deployment and evaluation of the original Hermes system (discussed in chapters 3-6) a wide range of requirements emerged (see Appendix H). This section discusses how these requirements have been applied to the design of Hermes 2 using pertinent examples from the three categories used in Appendix H:

i) hardware,

ii) software,

iii) application functionality.

In addition, the design consideration from Appendix I are also discussed in the following sub-sections. It should be noted that the new deployment will also be used as a development platform by other researchers within the department. Consequently, some of the hardware requirements (e.g. inclusion of a microphone and speaker) are included primarily to support other research efforts e.g. in multimedia.

J.3.1 Hardware

From the numerous reliability problems caused by the use of a wireless network in the original Hermes system (see section 4.8.1 for example) it is clear that using a highly reliable wired network technology is a requirement for Hermes 2. Hermes 2 should also use a private network to further avoid potential problems. Additionally, the bandwidth provided by a wired network will enable the development of additional multimedia applications such as video and audio conferencing by other researchers within the department.

Reliability of hardware in the larger Hermes 2 deployment will be a crucial factor, as poor reliability will generate much additional work for system administrators (and, of course, have a negative impact on owner's trust). A discussed in section H.1.1 of appendix H, a high mean time between failure (MTBF) is required for both the door display and supporting servers (with an MTBT of 1 year). It will be vital to be able to restart door displays remotely in the event of a crash.

The results of the 'showroom' user study showed that a screen size larger than that used in Hermes was required. The user study also highlighted the impact a larger screen had on expressivity and ease of use. Additionally, in order to adhere to relevant legislation the Hermes 2 door display will have to use a low voltage (less than 50 volts) supply (as demonstrated in Hermes).

J.3.2 Software

As demonstrated by the requirements presented in section H.1.1 and the deployment of Hermes, there is a high reliability requirement on software platform for door displays and supporting server(s). A vital area to consider during the development of the software architecture will be the remote deployment of software updates. In more detail, in Hermes physical access to each door display was required to deploy software updates and this proved extremely time-consuming and not scalable for the larger deployment envisaged in Hermes 2.

Another important requirement to consider will be provision of persistent replicated storage for information such a log entries. Additionally, the client-server architecture used in Hermes demonstrated several shortcomings (such as loss of networking connectivity with the Central Server preventing a door display from functioning correctly) and will be replaced with some form of more appropriate architecture providing distributed storage.

J.3.3 Application Functionality

While it will be important to provide the basic functionality available at the end of Hermes in the initial Hermes 2 prototype, features will be considered carefully to avoid adding unnecessary features and associated complexity. For example, the functionality allowing visitor notes to be viewed from a door display was added during the initial phase of Hermes (see section 3.7) but was seldom used in practice (logs indicated this feature had been used to view 390 visitor notes during deployment, primarily for testing and demonstration purposes) . This was an example of adding a feature because it was technically possible rather then because it was requested by an owner. This feature will not therefore be included in Hermes 2, although it could easily be added if requested.

An additional important feature included in Hermes was the need for owner preferences (see section 4.4.4). This functionality will be maintained and expanded in Hermes 2. One important feature that will be included for all interaction methods, to encourage trust, is that of feedback when a message has been set successfully and when a problem has occurred.

The original Hermes system demonstrated the importance of a *Management Agent* for system administrators (see section 4.9) and this functionality will be even more important in a larger deployment. Additionally, it will be important that administrators and appropriate owners are notified of failure at different levels in the Hermes 2 system.

J.3.4 Design Considerations

The design considerations that emerged from Hermes (see section 6.9) are being used to inform the design of Hermes 2. For example, the importance of trade-offs such as control vs. effort in methods of interaction. The interlinked issues of reliability and trust, which underpin an owner's perceptions of dependability are of paramount importance. As emphasised throughout this thesis, if an owner encounters failure this will negatively impact trust, thus reducing the likelihood of initial adoption and continued use.

As demonstrated in the last phase of Hermes (see section 6.6.3) a simple user guide proved useful for non-technical owners. It will be important that this idea is extended and a thorough user guide is available for door display owners and visitors while a one-to-one demonstration might also be appropriate.

J.3.5 Summary

This section has discussed how many of the more pertinent requirements resulting from Hermes are being used to inform the design and development of Hermes 2.

J.4 The Hermes 2 Deployment

The proposed deployment of forty door displays in the new Computing building is particularity challenging for two main reasons:-

1. The required door display hardware – the requirements for the new door displays to include a seven inch touch screen, webcam and enough computing power for tasks such as video conferencing .

2. The new door display deployment domain - this included glass partition walls to which door displays would have to be fixed, and a strong requirement for any door display housing design to be sympathetic to the deign ethos of the building in order to be granted approval.

These two issues are discussed in detail in the following sections.

J.4.1 Hermes 2 Door Display Hardware Configuration

From the 'showroom' users study the most popular configuration with participants was the seven inch widescreen format screen. However, due to an external requirement for the door display systems to run Linux and the relatively high cost of the Mac mini devices, a small form-factor PC based solution was chosen. Figure J-3: One Potential Small Form-Factor PC-Based Solution. shows this potential solution, a Mini-ITX form factor PC in a specially designed case (similar in size to 1U height rack-mount equipment) which included a power supply, hard disk and a modest specification AMD CPU designed for a desktop PC.

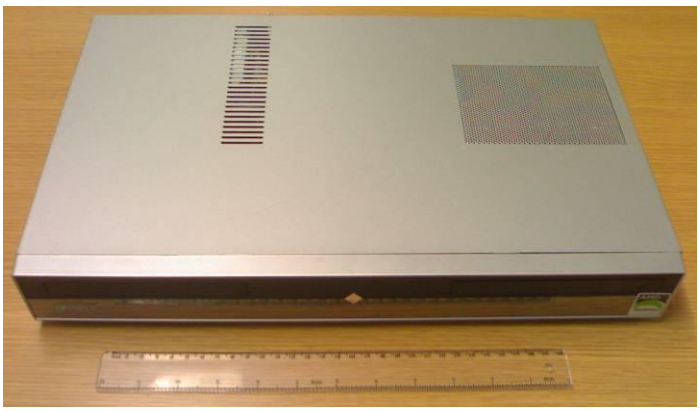

Figure J-3: One Potential Small Form-Factor PC-Based Solution.

Participants in the showroom experiment had no objections to an additional small computer being placed in offices as long as it was silent. However, after experimentation it was found that due to the heat produced by CPUs intended for desktop PCs small fans were necessary, producing small but significant levels of noise. Additionally, location inside an office would have meant extra cabling, power, network points etc. and it would not have been possible to reboot all door displays in a single operation. For these reasons it was decided to locate the hardware driving the displays under the floor.

The next main issue to address was how to power the door displays and driving hardware in a scalable and cost effective manner, that would adhere to appropriate electrical safety regulations. One potential solution to the power distribution problem was networking technology implementing the IEEE 802.3af specification [IEEE '03], more commonly known as Power over Ethernet (PoE). PoE technology provides power and networking connectivity over a single Ethernet cable. This approach would lead to a very simple and cost effective installation process, also the low voltage technology is governed by fewer guidelines (unlike the provision of main voltage). Additionally, it would prove very simple to power-off or reset a door display by simply unplugging its network cable in the appropriate server room.

While PoE technology appears to provide an ideal solution, the maximum power the specification is intended to handle is 15.4 watts per Ethernet port. The seven inch screen consumes less than 10 watts, but a typical modern PC requires a power supply with an output upwards of 145 watts (the AC-DC power supply provided in the case shown in Figure J-3 is rated at 200 watts), which would require an unfeasibly large number of PoE ports and associated Cat5 cable runs providing power simultaneously.

PoE was such a desirable solution that further investigation was carried out, along with research into PC-based products with lower power requirements. Research into suitable PoE products revealed a single manufacturer producing high power PoE equipment providing almost three times the power output stated in the 802.3af specification. Research also uncovered a Small Board Computer (SBC) form factor product (shown in the top left of Figure J-4) including a 600Mhz Intel processor, network interface (including remote boot capability), VGA hardware, USB 2.0 and sound support with expansion for up to 512MB of RAM. Additionally, this product has far lower power requirements than alternative products of similar specification.

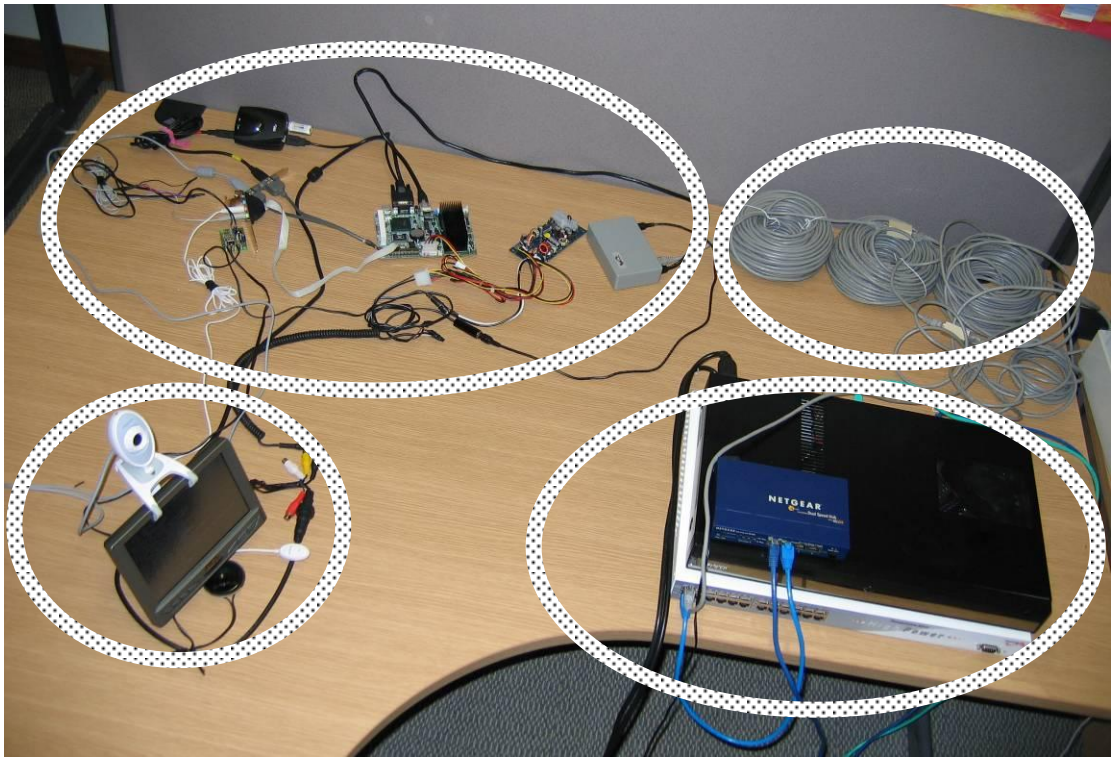

Figure J-4: Power Over Ethernet Test Configuration.

The configuration which proved successful included a high-power PoE midspan (to inject power into network cables) together with a high-power PoE splitter (to extract power from the network cable). The high-power splitter powered the screen directly and a small DC power board was required to power the SBC. The solution has been tested using a simulated

Ethernet run 120 meters long, in excess of the actual distance between offices and the machine room where the infrastructure will be housed. This test configuration is shown in Figure J-4 where each component is highlighted, bottom right is the high-power PoE midspan, top right is the simulated Ethernet run, top left is the high-power PoE splitter, SBC and associated hardware for deployment under the floor outside offices, bottom left is the seven inch screen, webcam and associated components.

In order to reduce cost, improve reliability and simplify management the driving SBCs will remote boot a Linux operating system over a network from a server, rather than include a local hard disk drive and individual operating system install. The operating system to be booted by the door displays will be installed and configured once on a single high capacity server machine.

J.4.2 Hermes 2 Door Display Housing

From initial investigation it was clear that a lightweight housing was necessary to include the touch screen (and prevent access to the buttons on the front of display), webcam, speaker microphone and associated cabling. Three medium-fidelity prototypes were constructed to help demonstrate what a potential housing may look like and proved useful in helping to motivate discussions.

Figure J-5: A Medium-Fidelity Hermes Display Housing Prototype.

Figure J-5 shows one such prototype, this included a webcam above the screen with a microphone on one side and a speaker on the other. These prototypes assisted the more detailed design of display housings, Figure J-6 shows a sample produced by a local plastic manufacturing company based on one of the detailed designs.

Figure J-6: An Early Door Display Housing 'Sample'.

J.4.3 Analysis

This section has provided an overview of existing work carried out as part of the Hermes 2 deployment. It is clear that that this deployment has raised many challenges, several of which were greater than originally anticipated (for example the problem of powering the door displays). The solution discussed previously in this section has proved successful over prolonged testing. The final design and manufacture of the door display housing is, at the time of writing, an ongoing task.

J.5 Proposed Software Architecture for Hermes 2

It is perhaps typical with the deployment of a prototype system, that the underlying architecture evolves in an ad-hoc manner in order to support new features as necessary (see Chapter 4). In order to provide the flexibility, scalability, efficiency and reliability to support Hermes 2 the Hermes architecture will be redesigned and re-implemented.

This section outlines one proposed architecture[15] for the redesign of the Hermes system, primarily for the *Client Agent* (the application running on a door display – see section 3.7.6). The primary motivation for the design of this revised architecture was to solve the problem of manual software updates which would be crucial in a large deployment. The design is also intended to provide several other improvements over the previous Hermes system such as:

i) the potential to easily replicate server components to improve reliability (see section 4.8.1),

[15] At the time of writing the design of the Hermes 2 architecture is still in progress.

ii) support for heterogeneous display systems (with different display sizes, processing power etc.).

This is achieved through the use of management and storage components at three levels in the architecture (see Figure J-7):

- DisplayDevice – this represents a display hardware configuration i.e. screen and associated computing resources,
- DisplayManager – this represents the layout of DisplayPanels on a display,
- DisplayPanel – this represents an individual user interface and associated functionality.

The management and storage components are based around a persistent tuple-space storage system with integrated notification of updates (one example of an appropriate supporting technology being Sun's JavaSpaces). At each level in the architecture information is retrieved from the appropriate management service to enable configuration, for example in the case of a DisplayManager this configuration would include the layout and types of DisplayPanels to use in order to construct the required user interface.

The DisplayDevice application is not intended to be dynamically updated (in the way DisplayManagers and DisplayPanels objects are) and its main purpose is to download, instantiate, and manage (through the DisplayManager Interface) a DisplayManager object in order to support the dynamic deployment of new user interface configurations at runtime.

DisplayManager object classes can be downloaded and instantiated during runtime by a DisplayDevice application (i.e. they do not have to be on the class path when the Java VM is started) as long as they implement the DisplayManager interface. This is in order to support the dynamic deployment of new or modified user interfaces and functionality at runtime.

A DisplayManager downloads, instantiates and manages DisplayPanel objects in the same way that a DisplayDevice application controls DisplayManagers. The primary advantage of this design is that the system does not have to be stopped, redeployed and restarted when a new user interface layout (DisplayManager) or user interface component (DisplayPanel) is developed, or when an owner decides to change the layout or functionality provided by his or her door display.

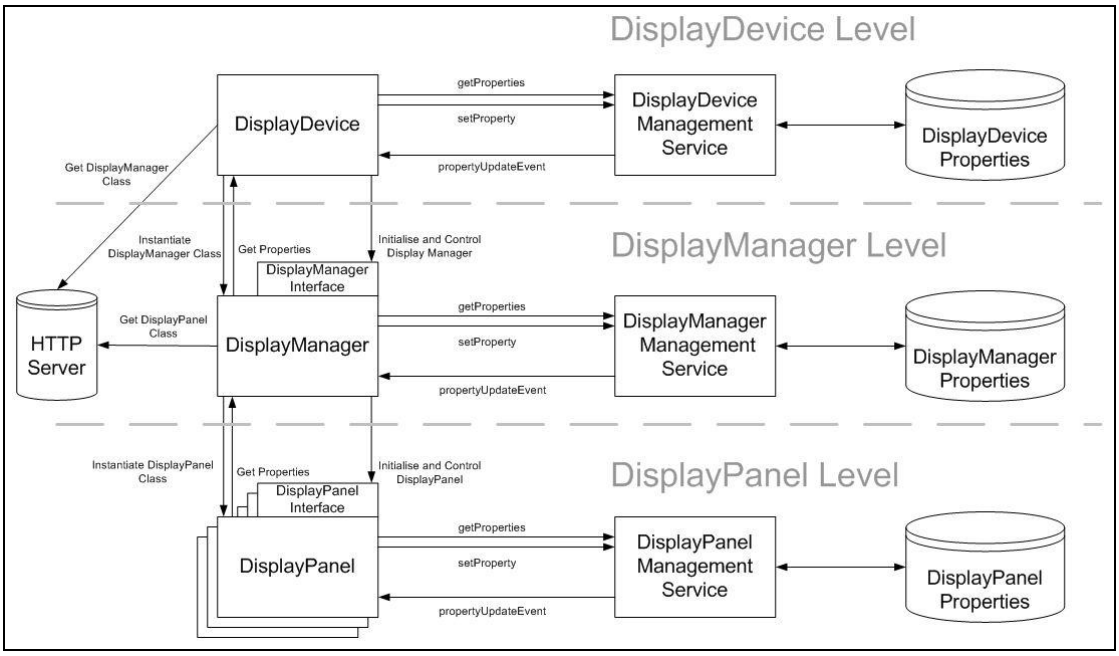

Figure J-7: Display Manager Proposed Architecture

J.5.1 Analysis

The proposed redesign of the Hermes software architecture provides key advantages over the original Hermes architecture. Firstly, as object classes are downloaded and instantiated during runtime, large sections of the application running at an office can be automatically updated (managed by the Management Services at each level). For example, to deploy an updated user interface component (DisplayPanel), the system administrator only has to copy the appropriate class files to the HTTP Server (Figure J-7) and modify the configuration for a door display using the DisplayManager Management Service, the Management Services will then trigger the appropriate DisplayManager objects which will then download and instantiate the new DisplayPanel object.

Additionally, this architecture allows for far more flexible and configurable user interfaces to be developed and (easily) deployed on door displays (with different sized screens) as the layout of user interfaces can be modified by switching to a different DisplayManager at any point. This feature will be a definite advantage if the new door displays provide larger screens and increased processing power, perhaps allowing the displaying of web pages, streaming of video etc.

It would also be possible to implement the architecture shown in Figure J-7, to some extent, using a web browser and HTML pages including a technology such as JavaScript for control. For example, the DisplayDevice could be represented as a web browser, the DisplayManager could be a web page using frames (or even tables) to form a layout and the

DisplayPanel components could be represented using individual web pages. The two approaches each have different advantages, for example the HTML-based approach would be far easier to implement while the Java approach would give fine-grained control an inherent flexibility at each level.

J.6 Summary

This appendix commenced by describing an experiment designed to investigate requirements for potential display and user interface configurations. This uncovered several important issues such as a preference among the participants for a compact seven inch wide screen format display. Next, a cultural probe based user study intended help uncover additional requirements for the forthcoming Hermes 2 system. This study received a relatively poor response but demonstrated that paper-based messaging activities existed in the new Computing building. Following this, existing work carried out for the forthcoming deployment of Hermes 2 door displays was presented, including the design of the door display hardware configuration and associated housings. The final part of this appendix discussed a proposed software architecture for the forthcoming Hermes 2 system in order to help support dynamic updating of software components and configuration of user interfaces for door displays.