

Sharing Control of Dispersed Situated Displays between Nomadic and Residential Users

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ABSTRACT

As the number of public displays in the environment increases, new opportunities open up to improve situated interaction and to enable new kinds of applications. In order to make distributed display resources available to nomadic users, a key issue to address is how control can be dynamically shared between display users. It is important to study how control over a shared display can be acquired, released or shared by nomadic and residential users given their competing demands for display resources.

In this paper, we present a system and a user study investigating these issues in the context of two applications both competing for display resources provided by a deployment of interactive office doorplates. The first application (Hermes II) provides situated note leaving and messaging services whereas the second one (GAUDI) supports user navigating a university department. Office occupants (i. e. residential users) can control whether the navigation application may (temporarily) use their doorplate display (thus giving priority to the navigation needs of nomadic users to the department). We report on findings from a user study, and discuss interface design implications for specifying display control.

Categories and Subject Descriptors

H.5.2 [User Interfaces]: User-Centred Design

General Terms

Management, Experimentation, Human Factors

Keywords

Display sharing, participatory user study, pervasive navigation, interactive doorplates

1. INTRODUCTION

Situated digital displays – i. e. displays physically and (semi-)permanently attached at a specific location – are a popular sight in today’s world. Typical examples include

timetable and announcement displays in airports and public transport stations, building information systems in conference centers and shopping malls, or advertisement screens in public places. A common property of existing systems or display networks is that they restrict (understandably so in many scenarios) the extent to which the display may be appropriated by other users. However, the imposition of such restrictions is unfortunate in some situations; mobile users could substantially benefit from the situated display resources, for example to overcome the size limitations of a mobile phone screen (or lack of a screen) or to share content with others (cf. [11, 18]). While there has been research on shared screen usage, the actual sharing process is usually confined to a single application or display (cf. e. g. [7, 13]).

A more general approach to the problem of sharing situated display resources is to employ an explicit control mechanism, which is independent of a specific application. Control over a display can then be granted to, requested for or obtained by a user or display owner in a flexible way. The display sharing itself can take place in different ways: spatially (e. g. by dividing the screen among a number of users), temporally (e. g. by assigning a time window to a user), or a combination of both (cf. [10]).

In this paper, we present a system that integrates and shares display resources (in the form of a deployment of interactive and digital office doorplate displays) between two applications. The first application (Hermes II) provides situated note leaving and messaging services while the second one (GAUDI) supports visitor navigation in a university department. Office occupants (i. e. residential users) can control whether the navigation application may (temporarily) use their doorplate display (thus giving priority to the navigation needs of nomadic users to the department) through a simple interface enables users to adjust control settings for ‘their’ displays. The system presented has been designed in such a way that only minimal code-based modifications were required to each application.

Based on this system and the findings of a participatory user study investigating the issue of screen control for dispersed situated displays, we discuss implications for the design of interfaces for specifying display control, and illustrate how to realize these within the proposed system. By involving existing users in the re-design and enhancement of an existing device, with its integration into mundane yet im-

portant aspects of everyday working practice, we also begin to gain some insight into, and anticipate, the design relevance of those well known, if poorly understood, processes of ‘domestication’ (how a technology is made ‘at home in a setting’) and ‘innofusion’ (how a technology is adapted to new uses and existing practices are adapted to accommodate the new technology) [6].

2. RELATED WORK

Several research projects have explored how situated displays can be used to support communication, coordination, collaboration, and emergent social behavior. A comprehensive survey of such systems can be found in [12] and [8]. Situated displays vary according to the degree of control that users are given over the information that can be placed, manipulated or taken away. The corresponding spectrum ranges from digital signage systems based on public displays that implement an authoritarian model of control to more or displays, which are fully controlled by their current user (e.g. ATMs). There are a number of systems that fall in-between these two extremes by providing varying degrees of control to their users, such as group displays (e.g. [7]) or interactive doorplates (e.g. [4]).

Frequently, research has been focusing on a single application running on one or more displays. RoomWizard [13] is a typical example of such a system. It consists of interactive doorplate displays that display room allocation and support the booking of a room. As it was designed to be a single purpose appliance, the system supports only a single application (i.e. room booking). Consequently, it does not implement any control mechanism; users can basically walk up to a screen and interact with it without restrictions.

Another class of systems supports multiple applications oftentimes on a single display but sharing control is left to the people interacting with the system, i.e. to social protocols/turn-taking. The system presented by Huang et al. in [7], for example, provides a number of applications to support group collaboration such as reminders, schedule information or note-leaving/chat tools. In this case, all applications are displayed simultaneously on a single touch-sensitive display, and again no means to share control are provided. McCarthy et al. [11] have introduced three separate systems/applications, where control is tied to the location of the display. Unicast uses a private peripheral screen to display information selected by a specific user, whereas Outcast shows information selected by an office occupant on a doorplate display. Groupcast uses a public situated screen to display information chosen by members of a group.

The analysis of the situated display systems can be organized along two dimensions (Figure 1). On the one hand, the situated displays can be regarded through the set of functions that they are built to provide. Given the challenges related to their development, the situated displays were initially designed to support single applications. It is only recently that the multi-applications systems have started to emerge.

On the other hand, the situated displays can be categorized according to the user-display relationship. Situated displays enable an interesting double perspective with respect to its users, particularly in relation with the content being displayed. Thus, there are users who produce the content being displayed and are usually in control of it, and there are users who are merely spectators or consumers of

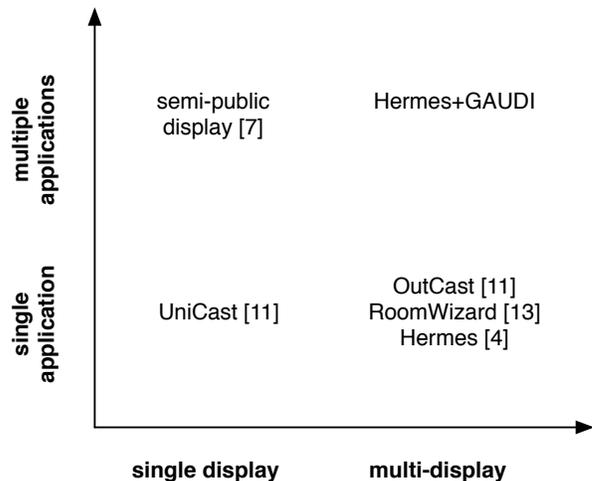


Figure 1: The design space of situated displays can be organised along the number of applications they are meant to support and the number of displays they enable interaction with.

content. We called the former category, first order users and the latter one, second order users. These categories are not necessarily fixed. For instance, the more interactive a situated display is, the more the second order users can become involved in producing the content. Given the inherent feature of public displays, their content is usually accessible to both first and second order users. However, first order users usually have greater control and/or ownership over the displayed content and they usually have access to a larger range of system functionalities or applications, e.g. OutCast [11].

Usually, the relationship between first order users and displays is a well-defined function (each user has control over one and only one display, but has access to all displays), while the interactive public display systems enable a ‘one to one’ relationship between second order users and displays, e.g. they may be able to leave notes but cannot control whether the note will remain visible afterwards. Our study focused on a ‘one to many’ relationship where the second order users interaction with the system has a simultaneous impact on several displays in order to provide navigation support. None of the system discussed above provide a means to explicitly specify preferences for display sharing/control, and few support multiple applications. A generic mechanism/system for sharing control over public or semi-public displays would facilitate the use of display resources in the environment

The relevance of the above distinction between users interacting with public displays is particularly relevant for user studies and prototype development. The study presented in this paper focused exclusively on first order users, e.g. owners of the offices on whose doors the system is displayed. Future work will involve the second order users, e.g. visitors in the building who may benefit from the application providing navigation support.

3. SYSTEM DESIGN

In response to the findings of an earlier user study, we designed a system that enables display owners to share con-



Figure 2: Hermes II doorplate display deployed outside an office with the messaging interface shown on it.

control over their displays and that supports multiple applications. Currently, a messaging/interactive doorplate application (Hermes) and a navigation system (GAUDI) have been implemented. In the following paragraphs we briefly discuss these two systems separately before presenting the architecture we designed to integrate them.

3.1 Situated Messaging

The Hermes system provides services revolving around an interactive doorplate metaphor [4]. It has been extensively evaluated and has been continuously refined during several extended deployment phases. The Hermes I system was deployed outside ten offices for approximately 27 months. The positive feedback from the Hermes I system has stimulated the development of a second generation system, Hermes II. This system will support full video conferencing in addition to the asynchronous messaging facilities provided by the original. The deployment of Hermes II will also be more substantial than the original with over 40 displays across two floors of Lancaster’s Computing Department building. Figure 2 shows an early prototype of a Hermes II doorplate unit deployed outside an office and its user interface.

The office owner (i.e. residential user) associated with a Hermes doorplate can dynamically specify a message to appear on his or her doorplate. A message can be set by directly interacting with the unit or remotely through a web-based interface, e-mail or SMS. Furthermore, visitors to the office (i.e. nomadic users) may leave messages for the office owner by scribbling a message on the doorplates touch sensitive screen. These messages can then be viewed by the office owner via a web-based interface or e-mail. During the deployment of Hermes I over 5500 messages were set by doorplate owners and over 750 messages were set by visitors.

Technically, the system is based on a client-server architecture. The displays (clients) run a Java-based application that connects to a web server to retrieve and post messages. The server also provides a web-based interface for office occupants to specify various preferences. Additionally, it incorporates a GSM-bridge for sending and receiving SMS and MMS.

3.2 Pervasive navigation support

Unlike traditional guides [2], the pervasive navigation system GAUDI provides individual navigation support through situated displays [9]. A user can enter a target location through a portal display (see Figure 3), which triggers the computation of a route from her current location to the tar-



Figure 3: Portal display of the navigation system: a user specifies the target location by touching the portrait of the person she wishes to be guided to.

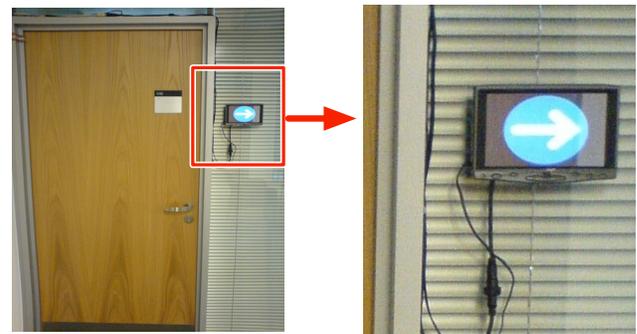


Figure 4: A Hermes doorplate display outside an office showing an arrow for navigation support (enlarged on the right).

get location. This route is then labeled in a geometrical world model and broadcast to all available displays in that area. In addition, an adaptable presentation is sent out that contains rules enabling individual displays to adapt the generic presentation to their individual location (see [9]).

As a result all available displays show arrows pointing towards the target location to support way finding in unknown areas. These arrows are shown for a certain amount of time (depending on the length of the route), or until the user indicates her arrival at the target location by touching the display nearest to the goal. Figure 4 shows an arrow rendered on a Hermes doorplate display.

The GAUDI system borrows concepts from client-server architectures by computing the route and the generic presentation on a central server. However, since clients individually adapt this information to their location, the system also incorporates some facets of a decentralized architecture. All components are implemented in Java and presentations are generated in SMIL and/or HTML.

3.3 Integration

The primary goal in designing an integrating architecture was to introduce components that provide means to manage

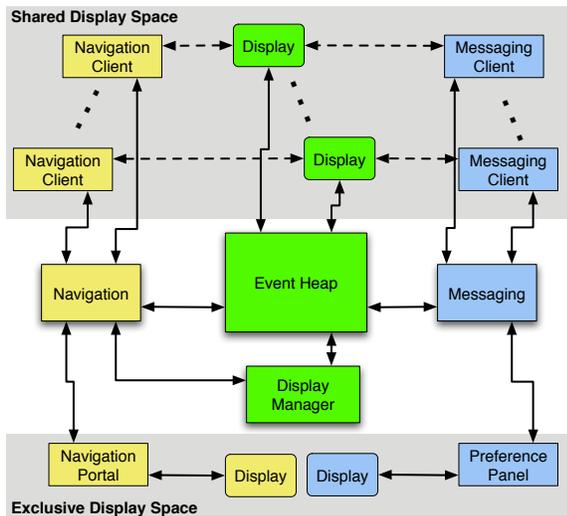


Figure 5: System architecture integrating Hermes, GAUDI and display control.

control over displays. In addition, we tried to minimize the alterations to the existing systems (Hermes and GAUDI). Figure 5 shows the resulting architecture. On the left side, the navigation system is shown, the middle part illustrates the components dealing with display control, and Hermes is shown on the right side.

The navigation system consists of a number of clients associated with individual shared displays and a central component (Navigation), which computes routes and adaptable presentations. Additionally, there is a portal component, which provides an interface for specifying the target location (on a dedicated display – see Figure 3).

The messaging system is also composed of a number of clients associated with individual displays (i.e. doorplates), which are connected to messaging server (Messaging). Furthermore, there is Preference Panel that allows office occupants to specify e.g. what message should appear on their doorplate. This Panel is accessed through a web browser i.e. using the display attached to the users workstation.

Control over shared displays is managed by a display manager that directly connects to instances of a process manager (ProMan) running on each display (not shown in the figure). ProMan runs in the background and can dynamically switch between different applications, i.e. messaging and navigation clients.

A central event heap [14] ties all the components together. Displays periodically push heart beat events onto the heap, which the Display Manager uses to detect the addition or removal of displays. Control related events are also pushed onto the event heap. The Display Manager is listening for that type of event as well, and uses the information contained in that event to adjust the control settings for the display related to the event.

For example, a doorplate owner may put up an important message that she wants to be visible at all times (i.e. and that she does not want to be replaced by navigation-related information). In such a case, she may decide to stop sharing her display (by setting the display sharing preferences to zero - see Figure 6), and a corresponding event will be generated and will be put onto the heap. Upon receiving

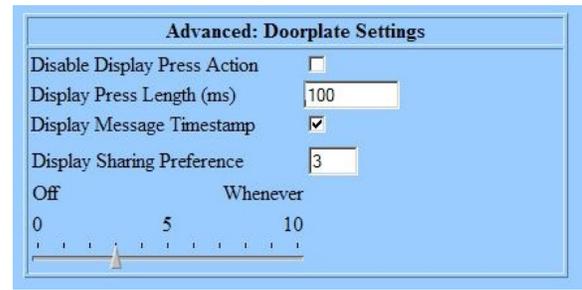


Figure 6: Interface provided for display owners to set display sharing and control preferences (bottom of panel).

it, the Display Manager will instruct the process manager on that display to switch to the messaging client – possibly hiding the output of the navigation client. It will also notify the Navigation component about the change. When it is no longer necessary to display the message, the residential user can again change the control settings for her doorplate and thus allow the navigation application to use it again (by moving the slider shown in Figure 6 to ten). This will in turn generate another control event on the event heap, which will then propagate to the Display Manager and navigation application, enabling the latter one to use this particular display again.

4. A STUDY ON DISPLAY CONTROL

In order to gain insights into the extent to which Hermes owners would be prepared to share their displays for the purpose of assisting the navigation of visitors to the department, we have carried out a questionnaire based study. In the following paragraphs, we will provide a qualitative analysis of the resulting findings. The nine participants involved in the study at this stage were all owners of Hermes I displays (with ownership ranging from over two years to approximately two months). We would argue that these previous owners are in a significantly better position to provide an informed response than those without.

4.1 Goals

The main goals of the questionnaire were to inform the design of Hermes II by gaining initial insights into the variance that users would show in the extent to which they wished to control the sharing of their office door display this would in turn enable us to gauge whether a one size fits all approach would be suitable when building the systems GUI or whether a degree of personalization or tailorability should be supported (but with the potential cost of increased complexity in the user interface). We also wished to gain insights into the preference of participants regarding four possible approaches for displaying navigation arrows on the display of the Hermes II door unit. Furthermore, we have been involving users in every stage of the development of the system and we intend to continue this participatory design approach [15].

4.2 Method

The questionnaire given to participants contained 3 main sections – with one section relating to the work described in this paper. This section of the questionnaire comprised

16 questions exploring user attitude towards the additional navigational functionality to be supported by the Hermes system. This attitude was further broken down in two main dimensions: (1) the owners' preference towards different forms of visualizing the Hermes display while providing navigational support, and (2) the owners control over the content being displayed.

Each question had responses based on a 5-point Likert scale and included a blank field for comments. Participants were given the choice of answering questions on their own or with additional explanation from one of the papers authors.

4.3 Participants

The participants included three secretaries, three lecturers in computer science, one professor of computer science, one research fellow (with a background in sociology but also with a reasonable level of technical expertise) and one research assistant. All the secretaries were female while all other participants were male.

4.4 Results

The study revealed a number of interesting findings which are detailed below. Please note that when providing quantitative analysis based on the Likert scale, a response of Strongly Disagree has the value of 1 while a response of Strongly Agree has the value of 5. Despite the apparent simplicity of this approach there are some important and complex issues unearthed in this study, for the design concern with display control also uncovers deeper issues connected to 'control' more generally, ideas about privacy, access to shared resources and notions about the rights and obligations involved in 'community' membership. As far as the re-design of the system is concerned the study revealed a number of interesting findings that are detailed below.

All participants responded with 'Agree' or 'Strongly Agree' to the initial question of whether or not they would be "generally happy for my Hermes display to be used to support the navigation system" (Mean = 4.67). One single user expressed concerns about system stability and predictability once the added functionality is in place.

Participants had concerns about having the navigation icon occluding his/her public message (Mean = 3.3). This was presented as 'approach 1' and an example is shown in Figure 7(a). In general, participants were concerned about the prospect of this approach hiding their public messages, especially those of a time sensitive nature, such as "gone for coffee back in 10 min" as one participant commented.

Participants favored more the idea of occluding the 'note taking interface' of their display (Mean = 4.3). This was 'approach 2' and an example is shown in Figure 7(b). However, again there was some concern given over the removal of the 'note-leaving interface'. One participant commented that a visitor could "always still leave a note on my door" (i.e. using a piece of paper) but then went on to comment that he would prefer a small button to be made available to still allow visitors to leave notes.

The third approach presented to participants involved using the entire display for the navigation arrow (Figure 7(c)). This visualization form received little interest (Mean = 3.0). The general response of participants to this approach was concern over the impact on the public message display and the note-leaving interface and a strong preference for control over when this approach could be used. Interestingly, one

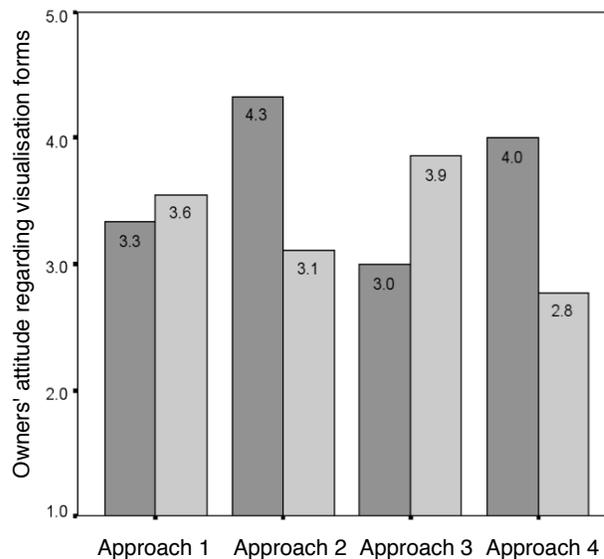


Figure 8: Owners' preferences for different forms of visualising navigational aids supported by door display (dark bars), and control over them (light bars).

participant has her office on the same corridor as a fire exit and mentioned that in the event of a fire alarm she would be more than happy to have the entire display used to show the navigation arrow pointing to the fire exit.

The fourth approach presented to participants involved using the notion of a semi-transparent navigation icon shown on 'top of' the standard Hermes UI (Figure 7(d)). This approach was generally well received by participants (Mean = 4.0) but some did mention concern over the visibility/salience of the navigation arrow when using this approach. Given the fact that this approach does not come at the cost of temporary disabling Hermes functionality (contrary to the other three approaches) participants commented that the issue of control was less important if this approach was adopted - "not so important because use not affected".

There appears to be an inverse relationship between the preference for a particular approach and a user's need to practice control over it (cf. Figure 8). Thus, the more satisfied users are with the way, in which navigational support¹ is visualized on the doorplate display the less they need to exercise control over it. Indeed there appears to be a significant negative correlation between the preference for each of the visualisation forms and the amount of control the user would like to have over their deployment ($r(33) = -0.41$, $p < 0.05$) (two missing data).

The remaining questions were concerned with control and notification in general (see Figure 9). Usually users are less interested to provide permission (Mean = 2.6) or to be informed (Mean = 2.8) when the system is about to be used for navigational support. Similarly, they discard the option of providing limitation of display usage for navigation support (both in percent of time (Mean = 2.5) and number of times per day (Mean = 2.3)).

¹which basically constitutes an additional functionality on top of the messaging, which is primarily benefiting others rather than the display owner

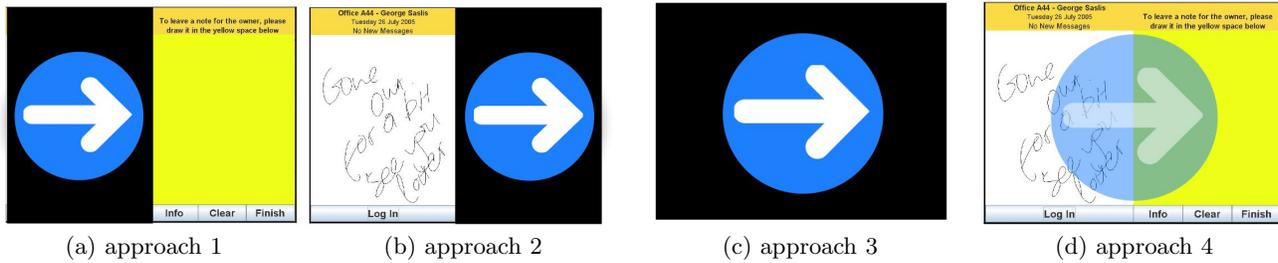


Figure 7: Four possibilities to visualize the navigational aid: (a) Overlaying the note leaving area, (b) overlaying the public message area, (c) full screen display (hiding both note leaving and public message area), and (d) transparent full screen overlay.

This attitude is triggered by users seeing the interactions with Hermes, required by these control options, as unnecessary interruptions. As one of the subjects noted “There are already too many interruptions in life!”. Another participant pointed out that once she agreed with the navigation support provided by Hermes, she would not like to be bothered with these specifications any more: “It should be all or nothing”.

The only two aspects regarding Hermes control which were generally favoured by the subjects are related to occasional users’ interaction with Hermes. One pertains to a system requiring the users to touch the display for canceling the navigation and thus remove all instructions being shown on available displays in the environment (Mean = 4.0). This is not surprising, since it will ensure the promptest regain of system control over the entire display area by his/her owner. The second preference was expressed less strongly (Mean = 3.6). It refers to allowing visitors to interact with the office display in order to request support for another navigational task, e. g. looking for another office or for the exit.

In general study participants did not show any preference with respect to accessing system logs regarding Hermes patterns of usage while providing navigational support (Mean = 3.3). The example shown to participants is depicted in Figure 10).

5. DISCUSSION

Given that all participants responded in a positive manner to the notion of letting their display be used as part of a situated display navigation system, we will continue with the final development and deployment of the system. The main observations resulting from our participatory design study consist of identifying both the consistencies and inconsistencies in users’ preferences. The former pertains to the different ways of visualizing navigation support. They will directly inform the design of the system and will be further investigated and implemented. The latter refers to user control over the system and requires careful consideration.

With respect to different forms of visualizing the navigational support, there are two approaches which consistently met users’ preferences: the navigation arrow occupying the “note taking interface” or the semi-transparent navigation arrow in the background of the entire display (see Figure 9). This is understandable since both these approaches do not occlude the area of Hermes display, which is for the exclusive use of the display owner (i. e. where they post their own messages to be seen by visitors).

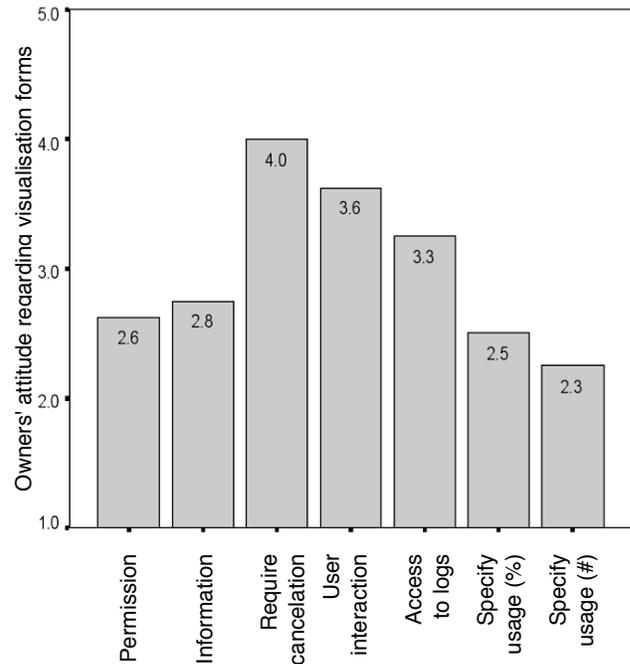


Figure 9: Owners’ control over door display while providing navigational support.

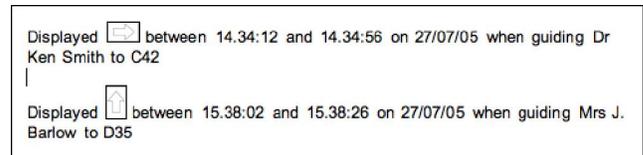


Figure 10: Example of Hermes log providing information regarding the usage for navigational support.

The approach involving a solid arrow occupying the entire screen (i. e. the one which is currently implemented in the system) was the least preferred. Given the sample size, the difference in users' preferences does not appear significant and therefore the two preferred approaches need to be investigated further.

In particular, we will now proceed to carry out studies with the transparent arrow design (approach 4) in order to check whether the navigation arrow can be made sufficiently salient for a range of visitor's to use (including visitor's with less than perfect vision). Should this approach prove to be satisfactory in practice then (based on feedback from participants) the extent to which control needs to be provided (e. g. concerning under what circumstances a door display may be appropriated by the navigation system) could be minimized and hopefully this should help maintain the system's easy to use nature. However, the use of transparent overlays may be less suitable when more complex content has to be displayed (e. g. annotated arrows or maps of the local area), the number of concurrent application increases, or if direct interaction is necessary.

An alternative to taking full control over a display is to share it by subdividing it into two (or more) regions or sub-displays. While these could be treated as distinct displays, there are some issues that result from this approach (cf. [10]). Display sharing could also occur on a temporal basis. For example, users could agree on a schedule for who is in control when, or display owners could define time slots for when they are willing/unwilling to give up control. This approach could also be combined with the one investigated in our user study, or with simultaneous screen sharing. However, the idea of specifying time-based constraints of this type was met with little enthusiasm by the participants of the study.

With respect to the owners' desire to exert control over the door displays, and in particular over the content being displayed, the inconsistency between users' preferences was clearly the most relevant aspect. For example, the idea of providing visitors with means to interact with the display for starting a new navigation task elicited both positive (e. g. "no major problems with this") and negative reactions (e. g. "I dont want people fiddling with my display"). Attitudes regarding the access to Hermes log also varied considerably from "this would be a very good feature" to "I don't think I' care".

The interaction with the combined navigation and messaging system can certainly be classified as a complex 'situated action' [17]. There is an entire array of factors potentially contributing to the users diverse and often diverging attitudes, pertaining to both user and task. These aspects could be job-related: people in secretarial jobs, for example, might have more visitors than people in academic ones, which is an aspect that could shape different expectations regarding control over the display. Further aspect influencing user attitude could be related to the level of technical expertise, age or personality (e. g. control, territoriality, ownership, and privacy).

In our study, we limited our investigation to displays for which it is clear who holds ownership over them and hence who has the last word in terms of control. This is not true for all displays: group displays (cf. e. g. [7]), public displays (cf. e. g. [5]) or ambient displays (cf. e. g. [16]) have a more complicated ownership structure. As a result, there might

be a need for more sophisticated control handling mechanisms, e. g. by direct negotiation or through an organizational procedure.

Based on the comments and responses we obtained from the participants of the study, it is clear that further studies are required, e. g. longitudinal studies investigating the actual use of the system once it is fully deployed. Furthermore, it became apparent that a single simple user interface to adjust control preferences might not meet the divergent requirements of different users. Additionally, we identified a substantial number of factors influencing the willingness of people to give up control.

A promising way to address this issue may be the use of learning mechanisms that automate decisions after a training period (cf. e. g. [3, 1]). Technically, the clear separation of display control from application logic facilitates the implementation of more complex control mechanisms while requiring little to no change to existing applications. More specifically, the event heap is well suited to sustain a learning algorithm to proactively set the control preferences according to a users needs.

6. FUTURE WORK

The research in the area of supporting multiple applications through public displays has just started to emerge and the challenges that it faces requires considerable further work. In the medium term, we will focus on the evaluation of the system combining Hermes and GAUDI, e. g. longitudinal studies on the final deployed version. We will extract and study future patterns of usage, and also look into different device configurations: the deployment of one integral system providing both functionalities or of two separate displays, each pertaining to a single application.

In preparation for the initial department-wide deployment, we are currently preparing a short term user study with a working prototype of the navigation system in order to refine its interface and system design. One issue we are investigating in this context is how nomadic users will want to exert control over displays, i. e. through explicit invocation of a meta-level control GUI or implicitly, for example using proximity sensors. In addition, the system components explicitly dealing with display control will enable us to investigate different approaches and interfaces to specify control preferences. For example, the use of learning algorithms is a promising approach to create an interface that is both simple and powerful enough to adjust display control according to the users needs. Such an approach could be easily realized with the display control system presented in this paper.

Another aspect we want to explore in more depth is the adaptation of navigation support to the number and configuration of displays available during the guidance task. For example, the system could display more complex instructions such as a small overview map with a highlighted route in areas where only a small number of displays is available. Ideally, this behaviour should be dynamic so that when an office owner disables her display for use by the navigation application, the instructions on other nearby displays would automatically change to take this fact into account. The event-based architecture used to integrate Hermes and GAUDI (see Figure 5) is well suited to realise this dynamic adaptation in the future.

7. CONCLUSION

In this paper, we have investigated the issue of sharing control of dispersed situated displays. We introduced a system for handling display control in a flexible way, which uses a generic heap to exchange control events and to integrate different applications. Using this system, we integrated two applications (a pervasive navigation support tool and a situated messaging system) with minimal modifications to them. Office occupants (i. e. residential users) can control whether the navigation application may (temporarily) use their door-plate display (thus giving priority to the navigation needs of nomadic users to the department) through a simple interface enables residential users to adjust control settings for ‘their’ displays.

In order to assess the validity of our approach and the feasibility of the system design, we conducted a participatory user study with previous long-term users of the messaging system. The results show that users are keen to adjust control settings for the shared use of situated displays but we also observed considerable differences in terms of how they would like to do so. Not only does the way in which the screen is shared (temporally, spatially, transparent overlay) influence their preferences but there are also individual differences. These findings highlight the need for further investigations on control issues and the design of configurable interface for setting control preferences.

8. ACKNOWLEDGMENTS

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