Public Displays and Private Devices: a design space analysis

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ABSTRACT
This paper offers a reflection on the design space capturing interaction between private devices and public displays. Our aim is to map out the broad territory rather than present a specific interaction technique or application. The analysis of the design space covers (i) the range of possible interactions according with the number of devices vs. displays involved in the interaction, (ii) the type of the devices identified in terms of size and purpose, (iii) social context and audience characterised through number of participants and level of audience's participation, (iv) levels of conflict between participants and audience in terms of content and pace, (v) spatial context in terms of levels of publicness and extent to which displays are part of the environment, and (vi) multiple device interaction described in terms of time-space matrix, and levels of coupling between public and private displays.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces – *graphical user interfaces, interaction styles.*

General Terms
Design, Human Factors

Keywords
public displays, private devices, design space.

1. INTRODUCTION
Our public places are increasingly being invaded by displays. Many of these have been with us for some time, but are proliferating as display costs fall: tiny screens on ATMs and chip-and-pin, TV-sized displays on tourist information touchscreens, and larger displays showing football matches in the pub or news and advertising in airport departure lounges. In addition, vast screens are becoming increasingly common not just at special venue such as stadia or pop concerts to display close-ups of singers to a large audience, but also in public squares and shopping centres such as Manchester's 'Big Screen' in the UK.

The smaller end of this spectrum are mostly time-shared public terminals; largely sharing the same usability and design issues as applications on individual PCs with the main difference being the need for instant 'walk up and use' learnability. With a few exceptions, the larger end of this spectrum are dominated by broadcast-style media, sometimes 'tuned' to the place, but with no potential for user interaction or control.

In this paper we investigate some of the interaction challenges and opportunities when these large displays become interactive. In particular we will look at the way in which small personal devices, such as mobile phones, can be used to enable these interactions. Our aim is to map out the broad territory rather than present a specific interaction technique or application.

The meeting of small public devices and large public displays creates challenges from fine-grained interactions such as text entry, to application-level issues of navigation and content. In addition, the public nature of these displays means we have to consider issues of public policy and control of content.

2. THE WIDER AREA
As a simplification we could say that traditional single user interface design and research is focused on the individual using devices and displays which are, at least during the period of interaction, under their sole control and often 'ownership'. In contrast CSCW has focused particularly at groups, which are to some extent known (and accountable) to one another whether because they are part of a work group in an organisation, are friends or family or some self-selecting group such as a chat room or domain-based bulletin board.

Arguably bulletin boards with their loafers and active participants take us into similar territory to public display as individuals influence what a large group see. One crucial difference in that loafers at an internet discussion deliberately choose to do this, whether passers-by at a shopping mall are there to shop not explicitly to see the contents of a display … although at the point they stop to watch do indeed step into a similar role to the loafer.

We are interested also in the device use and control/input devices may be individual (as in the mobile phone or your desktop mouse), group (as in a whiteboard marker in a meeting room) or public (as with the giant chess pieces in a public square). Figure 1 plots various areas of interaction along individual–public dimensions for control/input devices and displays.

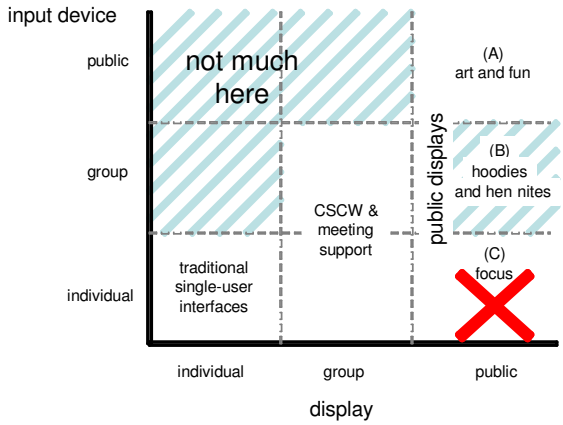

Fig. 1. **Space of device and display possibilities**

Whilst it may be interesting to ponder for artistic purposes, there doesn't seem to be any immediate examples or potential applications for input devices that are more public than the displays they control. One could imagine an Internet café providing Bluetooth keyboards to allow easier interaction with applications on your PDA or phone, however in this case whilst not owned by the individual, the keyboard would, for the duration of the interaction, be in a sense 'personal'. So, the top left of the diagram is empty.

At the bottom left we have individual devices interacting with individual displays – as noted above the purview of traditional single-user interaction.

In the centre we have CSCW and in particular meeting support systems, such as Colab that proliferated in the late 1980's early 1990s (Stefik, 1987), sometimes using group devices (e.g. the electronic whiteboard marker or central plinth), sometimes individual. Some more recent situated display work fall into this area. For example, the Dynamo system (Izadi, 2003). uses individual USB pen drives to store personal information, but this is accessed and shared by plugging them into a shared display and manipulated through a number of common wireless keyboards and mice. This has been trialled in a UK sixth form common room (16-18 year old students). In this sort of circumstance social protocols dominate and few access or other external controls are needed.

The right hand side of the diagram represents different forms of public display interactions.

At the top right (marked A), we have interaction through public devices. Existing applications that we know of in this area are all in an arts/entertainment. In the Regrets project small (public) booths were used to collect regrets from passers by which were then displayed in Cambridge Market Square (Mulfinger, 2005). In this space are also sensing technologies (again largely for arts/entertainment purposes), for example in the Metamorphosis installation cameras were used to sense movement in the Lancaster University underpass and these influenced the movements of a butterfly on a multi-screen projection [[http://www.thepooch.com/Events/metamorphosis.htm]].

The middle right (B) represents interaction with public displays through group devices. It is labelled "hoodies and hen nites" to represent the fact that there are groups in public spaces who may wish to interact with each other. However, the slot has also been hashed out as it seems likely that most group interactions with public displays will either be using the individuals' in the group own devices, or solely through public devices. Knowing this (and if such interactions want to be encouraged or channelled) it is possible to design public devices especially for this kind of group use. For example, in previous work we have proposed the 'Hopscotch Keyboard' (Fig. 2) large letters painted on the ground or on a special mat which can be used to type messages for a public display (Dix, 2004). This would clearly not be the most ergonomic way or efficient text entry device, but was proposed partly thinking of groups of friends typing transient messages to one another in a public space (perhaps outdoors, or in a club).

Finally in the bottom right of Figure 1, we have the area that is the focus of the workshop and this paper.

Fig. 2. **Envisionment of a hopscotch-style virtual keyboard to enter text into a public display**

3. UNDERSTANDING THE DESIGN SPACE

3.1 Physical size

Weiser's seminal article on ubiquitous computing describes three sizes of screen: the inch-scale or tab, the foot-scale or pad, and the yard-scale or board (Weiser, 1991). Public displays at the yard scale are common in public places: advertising or showing departure times at airports and foot scale devices are common for touch screens, typically where the device is used by one person at a time. Inch scale is less common, but the Hermes I & II office door units at Lancaster are exactly this size.

In addition to these scales the examples have included larger and smaller scales. Following Wesier's use of imperial measurements, we have called these **perch** and **poppyseed** scale. These are slightly archaic measures with the perch being five and half yards or 16 ½ feet and the poppyseed one twelfth of an inch.

The large displays at pop concerts and in town centres are perch scale with projected display even larger. In the underpass at Lancaster we have used projected displays the size of 3 double decker pusses side by side, but, for example, at the Queen's diamond jubilee the whole of the front of Buckingham palace became a display.

Finally at the poppyseed scale, at Lancaster we have developed FireFly, individually controllable LEDs that enable the creation of ad hoc displays consisting of thousands of semi-independent elements, each of which is only a fraction of an inch across.

3.2 Interaction device uses

Personal device can be used for a variety of purposes, some of these are similar to those on a standard desktop display, but some very different.

selection or pointing – Mobile phones have been used as a substitute for an optical mouse, or tracked based on their display..

text input – When you text a message to a display or use the appropriate HID profile..

personal memory/storage – The Dynamo system used personal USB sticks to hold MP3 or other fields for sharing with school friends. Similarly in the Lancaster climbing-wall display, images were uploaded and downloaded from mobile phones.

personal identification – Bluetooth tracking or RFID tags can be used to say *who* is interacting with the display, sometimes very direct as you touch the phone to the display,, at other times more just that a person is in the vicinity. Personal identification can be used as a surrogate for personal memory, as in the Satchel system where personal devices stored links to network accessible material (Lamming, Eldridge, Flynn, Jones & Pendlebury, 2000). Where this is used in this mode however the identification needs to also carry any authentication information necessary to access the remote resource.

display identification – In an environment with many displays, there needs to be some way to know which display a user is addressing. In some cases (e.g. touch screen) this is implicit in the way in which interaction is performed. However, in other cases there may need to be more explicit identification, especially when using personal devices. This may use the same technology as for personal identification– if the display knows that I am near it then my device can know it is near the display. However, this does depend on the location technology being precise enough (e.g. Hermes II initial tests have revealed that when standing in the right location up to 15 displays may be within Bluetooth range when 'searching for Bluetooth devices' using a Bluetooth capable mobile phone). The camera on the phone has also been used for this purpose, using visual codes to label the screens.

content identification – A special case of selection is simply to record "what am I seeing now". In the case of displays with a single pane of content, this can be accomplished by relating time-stamped display identification to a schedule of display content. In other cases panes or specific content may need to be selected.

bespoke sensing – Location sensing, accelerometers to give device orientation, and other techniques may be used to give more application-specific input.

display/interaction surface – A phone or PDA is a display surface in its own right, either mirroring in some way a public display or independently (browsing a device for an image to upload).

3.3 Social context and audience

By definition pubic spaces are likely to have people in them, some interacting with the display, some watching it, some totally unaware of its existence.

There are some parallels with urban artistic performances, such as street theatre, that include members of the public. An analysis of these events (Dix, Sheridan, Reeves, Benford & O'Malley, 2005), divided people into three categories: performers (the actor/street performer), participants (members of the public who in some way affect the performance) and bystanders (general public not 'part of' the performance). The latter two categories are also divided into whether they are 'witting' or unwitting'. An 'unwitting' performer is one which in some way riggers a sensor, is filmed or in some other way is part of the performance but just does not realise it. A witting performer is one who has knowingly joined in. Similarly a witting bystander is one who knows that a performance is happening (the audience) whereas an unwitting bystander may simply see someone doing something odd in the street and not realise it is a performance.

In non-artistic setting there is not a performer, but we do find the other categories:

unwitting participant – triggers sensors to have some effect, but does not know it

participant – actively engaged with the system doing some form of input/interaction

unwitting bystander – sees the screen but does not realise interaction is occuring

witting bystander – sees the screen and realises interaction is occurring

passer-by – may know screen is there, but does not watch or interact with it

Looking at an individual they may move between these categories, indeed the critical aspect of what Brignull and Rogers (2003) call the 'honeypot effect' is in enticing people from being passers-by to being active participants.

These categories clearly allow many combinations. Figure 3 looks at some of these combinations, focusing on unwitting participants and bystanders (grouping unwitting and witting bystanders and passers-by under a general heading of 'bystanders"),

		audience	
		no bystanders	bystanders
active participants	none	(a) turn off display?	(b) standard broadcast
	1	(c) individual multi-display	(d) public/ individual conflicts?
	2 or more	(e) collaborative or (f) interfering?	(g) ditto + are group themselves part of 'display'

Fig. 3. **Interactions between participants and audience on public screens**

The figure can be read in two ways (i) as a set of possibilities of a particular system, *what may happen* and (ii) at any particular moment *what is happening*. So for a system it may allow multiple active participants and an audience but at a specific moment there may be one or no participants, or no audience. Often it is the momentary situation (ii) that is most important, but in some case

the dynamics, it is the fact that the use of a particular display moves between situations that can be important.

Situation (a) is effectively a display for no-one, but public displays can be major power drain and source of light pollution, so it is a far from an insignificant issue.

Situation (b) is standard broadcast style public displays with no interaction, but may be showing the results of previous, asynchronous interactions of kind (c) or (d).

In (c) we have effectively single-user multi-display interaction where there are interesting issues such as how to choose between small-private displays and larger-displays for interaction (e.g., Gostner 2005), but these issues are dealt with adequately elsewhere.

Case (e) and to some extent (f) are fairly standard groupware/CSCW situations. The Dynamo school experiments are effectively in this category. In addition, personal devices may be used for individual working while engaged in group interaction.

Situations (c) and (e) have real interaction, but are not really 'public' if there are no bystanders and no interference, more social space interaction. However, if the system allows others configurations, say (f) or bystanders (d/g), engaged participants may not notice the change in situation, so inadvertently do private things in a public setting.

In larger-scale public displays participants may not even be aware of each other, so interference (f) may become a serious issue. One set of solutions is to borrow the techniques of groupware systems and expose individual interactions in order to allow social protocols to emerge. More fundamentally, if individual interactions make substantial use of screen space then it may not be possible to have more than a small number of simultaneous participants. In such case personal devices are not only useful for protecting privacy, but effectively allow the available screen real estate to 'scale' with the number of active participants.

It is in situations (d) and (g) where potentially some of the most 'public' issues come into play. In urban spaces such as a large shopping centre or city-centre square, there may be many hundreds of people noticing or actively watching a public display. Imagine a participant were interacting using their mobile phone as a control device, navigating menus or links on the public screen. If the system were not designed with this in mind the effect would be at very least unprofessional. It may be we deliberately design the system so that watching these interactions is part of the audience's viewing experience – however the critical thing is that in such systems there is an audience experience as well as a participant interaction and that both have to be considered during design. As in (f) the use of personal devices by active participants can reduce the potential for interference, as 'uninteresting' parts of the interaction can be offloaded from the public display onto the personal devices.

In (d) and (g) issues of wittingness come into play. If bystanders are aware that what they are seeing is the effects of someone else interacting with the screen then this may make the effects more comprehensible (although not necessarily more enjoyable). Alternatively we may design a system so that participants are deliberately not aware that interaction is occurring. Even if the bystander is aware that interaction is occurring, they may not be aware *who* is doing the interaction. Indeed for privacy reasons this may be a deliberate feature of the system. However, where the participants are obvious (e.g. collaborative group interactions (g)), then this might become part of the 'performance'.

3.4 Participant–Audience Conflicts

We have mentioned conflicts between the audience and the active participants; these are of two kinds: conflicts of content and conflicts of pace.

3.4.1 Conflict of Content

In traditional single-user interfaces the content displayed targets a single individual. In collaborative interfaces, the attention shifts to groups and the presentation of material of shared interest. But with public displays, not only is the screen real estate a fixed resource but also, the potential 'users' are not necessarily cooperating! Interaction with public displays will generate a combination of individual exchanges, group exchanges and more community effects, all potentially 'competing' for the same screen real estate and even physical space.

Even the earliest synchronous groupware with large displays (e.g. Colab (Stefik et al. 1987)) faced problems such as contention between multiple cursors. However, because they mainly focused on cooperating groups, conflicts could be managed socially. This is also reflected in more recent work on collaborative use of situated displays (e.g. Dynamo). In small public displays such as touch-screens, proximity can determine a temporary 'owner' or owning group, but larger public displays require systems and interaction mechanisms that either resolve or avoid conflicts. Furthermore, in groupware, feedthrough, where one person's actions are visible to others, is normally a desirable feature (Dix, 1994) in contrast to the situation in large public displays.

There are three forms of content conflict: (i) conflict between the use of the screen for displaying content and for displaying interactive feedback (menus, etc.) (ii) conflict between different users wanting specific content (iii) conflict between the particular requirements of an individual and maintaining a content stream that is intelligible, useful and engaging for bystanders.

3.4.2 Conflict of Pace

In 'traditional' desktop systems changes happen when the user does things; hence the pace is controlled by the user (or strictly the slower of user and system!). If the user wants time to think the system patiently waits. This is not the case in groupware and other sorts of open systems due to external events created by group members or environmental factors. However, remote groupware applications can still provide user control by using each person's display to throttle the impact of everyone else's interactions (Ramduny & Dix, 2002).

Pace control in public displays is more problematic as the content may be responding to other users, context, broadcast streams etc. Furthermore, there may be many users, some explicitly 'connected', but others simply viewers; so a single user may not be able to take control of the screen.

There are two kinds of pace conflict: (i) users cannot always have things when they want due to other users requests (c.f. content conflict), the playing of media, etc. (ii) users cannot speed-up, slow-down, stop or replay the flow of information because of the audience.

3.5 Spatial context

The spaces in which screens are placed is also critical and may vary in its level of 'publicness':

fully public – The underpass and the Wray display are both in public places open to anyone, as is the case with many large city-centre displays, airport displays etc.

semi-public – The Hermes units are installed in the corridors outside offices. These are in some way open to everyone, but in fact only people with 'legitimate' purposes (or illegitimate ones!) are likely to be there

semi-private – The climbing wall display, by its placement, makes it only available to climbers! Similarly some of our own systems such as SPAM (a system for use in the office of a care home for ex-mental patients) operate in environments where only close members of a work group are normally present.

The displays also vary in the extent to which they are 'part of' their environment:

no coupling – Many public displays merely show news feeds or related content.

weak coupling – The Wray village display shows information pertinent to Wray, but not the particular location within Wray.

close coupling – The Hermes units show content related to the particular office.

dynamic coupling – Where the display takes into account the dynamic context of the environment – e.g. the underpass reacting to passing cars.

The tighter forms of coupling tend to require some model of the location and visibility of the display in the environment. Sometimes this is done in a bespoke manner, for example the Wray display. However, more explicit meta-descriptions can be used and this was the case in the navigation experiments where the system knows the location of each screen and hence can plan set of route signs to a particular location.

3.6 Multiple device interactions

If you are writing an SMS on our phone while also watching a film in the cinema this is not a multi-device system, but two single device systems. To be an interesting multi-device system they must in some way interact or have some level of interconnection. Of course, you may be texting about the film, or even texting to a number displayed on an advert, so we may need to draw the boundaries a little wider to see all the interactions.

Given this, we can use the time/space matrix, familiar from its use in CSCW (Johansen, 1988) in order to ask when and where interactions with two different devices take place. Figure 4 shows this with some examples in each.

	Same Time / Synchronous	Different Time / Asynchronous
Same Place / Local	climbing wall: phone+display	Hermes: write + read message
Different Place / Remote	SMS to Hermes door display	Wray, upload image from web

Fig. 4. **Time/space Matrix for multiple devices**

Although more than one display is used in each of the time–space categories, some certainly do not 'feel' like multi-device systems, especially the remote or asynchronous systems. Just like there are various levels of coupling with the environment, there are various levels of coupling between the public and private displays.

alternative interface (no coupling) – A public display may show the same news feed as is available on a mobile phone, or in Hermes it was possible to read door messages from a web interface

secondary interface (weak coupling) – The Hermes web interface or SMS interface could be used to update the display that was subsequently seen by someone at the door. Both displays are clearly part of a single interaction, but the sense is of two single display systems interacting with a common information store.

coherent interface (strong coupling) – In the climbing wall display, as you navigate the phone to find an image, then upload it to the screen it feels like a single interaction.

It is worth looking more closely at the synchronous/local cell, as this is where we expect most (but as navigation shows not all) coherent multi-display interaction to occur. In the case of interactions combining public and personal displays, because the personal device is carried around, it is easy to do eyes-up/eyes-down interactions where the two displays are really used nearly simultaneously (or at least as fast as you can move your eyes).

4. EXPLORING THE DESIGN SPACE

From early in our work in eCampus, we realised that the interaction between public displays and personal devices was a fruitful one. Indeed many of the issues in this paper were present in our early discussions in the area (Dix, 2005). This analysis of the design space, which we have refined in this paper is being used to drive research as we deliberately create scenarios and prototypes to fill in points in the design space.

Our previous work on situated displays had already dealt with smaller displays where the interactions were either individual or with a group. So the area to the bottom right of Figure 10 (situations d&f) was of particular interest – issues of audience and how to deal with conflicts between audience experience and personal interaction. As we have discussed in section 3.4, there are two main kinds of conflict:

conflicts of content – is the material one person wants to see appropriate for others

conflicts of pace – if the material is acceptable to both the same timing may not be

So, the design challenge is how to use the presence of a personal device to eliminate or mitigate some of these conflicts. Box 1 shows an early scenario exploring one potential conflict where an interacting participant wishes to select a news item and see it, and how to avoid this being unacceptable for a non-interacting viewer.

In section 3.6 we saw that active participants could be individual or collaborating, and that bystanders could be witting (aware they were seeing an interaction) or unwitting. The scenario in Box 1 is a case where the interaction is individual and the bystander unwitting even though the display was actually affected by the interaction. One could imagine other situations where there was no change whatsoever in the public display, but only in the person one. Figure 5 shows a refinement of the audience-experience part of the design space taking into account these distinctions. Note, we are not distinguishing cases of individual or collaborative participant in the case of unwitting bystanders as the issues appear similar.

<table>
<tr><td></td><td>Witting Bystander</td><td colspan="2">Unwitting Bystander</td></tr>
<tr><td>Individual Participant</td><td>(A)</td><td rowspan="2">(C) public display affected but bystander unaware</td><td rowspan="2">(D) public display not affected. only personal display</td></tr>
<tr><td>Collaborating Participants</td><td>(B)</td></tr>
</table>

Fig. 5. **Subdivision of audience experience design space**

Following from detailed scearions (like that in Box 1), over the past year we have systematically constructed prototypes and systems at various stages of development that explore each of the boxes (A) to (D)..

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