Sociality, Physicality and Spatiality: touching private and public displays

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ABSTRACT
This paper considers two strands of research that each contributes to an understanding of touch-based interaction with private and public displays. The first is based on general frameworks for private device–public display interaction, which is driven by the growing body of work in the area, but focuses on the level of integration of public and private devices and the importance of understanding social setting and bystanders. The second strand is centred on physicality; how different kinds of physical device impact interaction and how modelling of touch-based devices causes particular problems that require notations and formalisms of continuous and bodily interaction.

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, touch interaction, spatial interaction, physicality

1. INTRODUCTION
This position paper is drawing from two strands of work involving studies, models and frameworks for understanding:

(i) interaction with personal devices and public displays

(ii) physicality and spatiality of human interaction

For the first of these we will draw on our own experience and analysis and also from a recent workshop at CHI2008 [15]. For the second we will draw on ongoing studies and formal analysis, and also work of the DEPtH project and its associated Physicality workshops (http://www.physicality.org/).

Our framework for personal device–public display interaction covers various dimensions, but here we will address two in particular: the level of integration between devices and the social setting. Similarly physicality covers many issues, but we will focus on two of these: the issues of space and movement, and bodily interaction with the devices. We are partly presenting some of our work that is relevant to the issue of touch-based interaction with private and public displays, but doing so in the knowledge that our models and frameworks need to be adapted in order to address these emerging technologies.

2. MOVEMENT AND CONTACT
In the context of this workshop there are two obvious kinds of touch (depicted in figure 1):

(i) touching a display in a private device

(ii) touching a public display

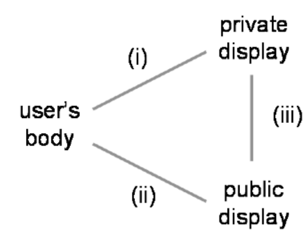


Figure 1. Ways to touch and connect

One of the aspects that emerged from the recent CHI workshop was the ways in which mobile phones could be used to gesture and move in multiple kinds of space:

- body-relative space – For example, using the accelerometers built into some phones.
- walking / absolute space – For example, using GPS tracking or Bluetooth signal strength location techniques.
- screen-relative space – Where the phone is positioned near or on the screen.

One example uses phone with built-in Near Field Communication (NFC) tag readers (like RFID), so an array of tags are placed behind a screen onto which a map and interactive content is projected, and the phone is touched against the display in order to select content [12]. This suggests that, as well as the direct physical touch of a finger (or other part of the body) on a public screen, we should also consider indirect touch using the device itself. This is shown as link (iii) in figure 1. There are other technologies for achieving the same effect including visually tracking the phone or using the phone's camera to detect visual codes (e.g. [14]).

In a public setting there can be several advantages to this form of indirect touch. In a restaurant or busy place personal hygiene may be important, so the act of physically touching a screen that others have also touched or perhaps be dirty may not be acceptable. On the other hand, if the users' hands are expected to be dirty we may not wish them to dirty the screen (greasy fingers in a fish and chip shop!).

In addition, the use of a proxy device effectively creates a very clear minimum granularity for selection. This can be a problem if fine section is needed, but sometimes may be advantageous especially where the tracking mechanism is not accurate and a more direct interaction might encourage incorrect expectations.

This form of proxy interaction does not readily admit straightforward multi-touch interaction as the device itself makes a single point of contact. However, one can imagine various forms of multi-user multi-touch interaction where several users cooperatively use their personal devices. Also in the NFC tag system described above, the user combines touching the phone against the screen with keypad-based interactions. It is easy to imagine systems that combine placing a personal device against a public screen and then simultaneously using a (probably single touch) finger interaction on the device screen whist moving it across the public screen. For example, placing a photograph on a public display where the position is indicated by the device location and finger gestures are used on the device display for sizing and rotating .

3. LEVEL OF INTEGRATION

When considering multi-display interactions, one of the first dimensions to bear in mind is the level of coupling between the public and private displays.

alternative interface (no coupling) – For example, a public display may show the same news feed as is available on a mobile phone. In the Hermes system at Lancaster, small screens are placed beside office door. Visitors leave messages on the doorplate, which the door owner can subsequently read *either* on the door plate itself *or* via a web interface [3].

secondary interface (weak coupling) – The Hermes web interface or its SMS interface can be used to update the display that is subsequently seen by someone at the door. Although both displays are clearly part of a single interaction, they function as two single display systems interacting with a common information store.

coherent interface (strong coupling) – In a public photo display developed as part of the CASIDE project at Lancaster, users can navigate using the phone to find an image and then upload it to the screen, so this feels like a single interaction [4].

The proxy interactions in the previous section are an extreme form of coherence as the two displays are not just digitally, but physically brought together. More commonly coherent interaction involves using the personal device for input and maybe some personal feedback. Controlled experiments on distributing interfaces over public and private devices have confirmed more widespread deployment experience. They have shown that the impact of combining the public and private displays can indeed increase interaction efficiency in terms of task-completion time, and also increase satisfaction in terms of perceived ease of use and speed [10]. However, the qualitative analysis of these experiments revealed that switching of attention could be problematic.

4. SETTING AND AUDIENCE

Public displays by definition are in public spaces where there are likely to be other people around as well as those directly interacting: some watching the display, others totally unaware of its existence.

Urban artistic performances, such as street theatre, similarly include members of the public with various levels of engagement and an analysis of these events [6] divided people into several categories: performers, witting and unwitting participants and witting and unwitting bystanders. In non-artistic setting there is no '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 occurring

witting bystander – sees the screen and realises interaction is occurring

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

These categories clearly allow many possibilities. Figure 2 looks at some of these combinations, focusing on active/witting participants and "bystanders" (this general heading includes unwitting and witting bystanders and passers-by). Here are some of the issues that can arise in each combination.

		audience	
		no bystanders	some bystanders
active participants	none	turn off display?	standard broadcast
	1	individual multi-display	public/ individual conflicts?
	2 or more	collaborative or interfering?	ditto + are group themselves part of 'display'

Figure 2. Interactions between participants and audience on public screens

The above table can be interpreted 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 a particular system 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 crucial, but in some case the dynamics is significant – it is the fact that the use of a particular display moves between situations that can be important.

In particular we may want to encourage people to use a public display, what Brignull and Rogers [2] call the 'honeypot effect', enticing people from being passers-by to being active participants.

If active participants are seen to be actively interacting with a public interface, then this may encourage bystanders to (a) become aware that the display is interactive, i.e. move from being an unwitting to a witting bystander and (b) be encouraged to interact themselves, i.e. transition from witting bystander to participant.

To encourage these transitions, interactions (ii) and (iii) from figure 1 are particularly important. However, even individual interaction with a personal display (link (i) in figure 1), while in a sense is still 'private', in that others cannot see the display, is nonetheless 'public', in that others may see that the individual is interacting. For example, the active participant may be standing in a pose that suggests interaction with the screen or may be shifting gaze to and from the personal device and public display. Depending on the balance between privacy and desire to engage bystanders, fine choices of interface design may be able to subtly change the 'performance' of using the device.

5. PHYSICALITY OF DEVICES

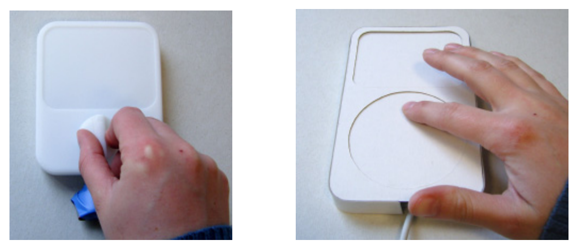
Two of the authors are product designers, part of a research group attempting to create a suite of systems for the development of computer embedded products sympathetic to the designer’s mindset and methods. In particular they have been using low-tech keyboard emulation boxes called IE Units alongside software building blocks allowing rapid prototyping without electronics or programming skills. [8]. There are a number of other groups working in this area including Phidgets [11], DTools [13], and Switcharoo [1], although these mostly come from a computing or electronics background. The IE system has been used to empirically measure the performance of real products against physical and virtual prototypes and this research found that the link between the physical act of holding a product and interaction was more marked than has previously been understood [8].

In the context of touch-based interaction one particular series of experiments was most interesting. Mobile phone prototypes were produced at various levels of fidelity: from a real handset with solely the display rendered on screen to a completely screen-based emulation. For the purpose of the experiments, the separate screen was intended as an emulation of an 'on device' screen but in the context of this position paper, it effectively became a personal device interaction with a larger (although private) display. Instead of a smooth change in user responses to the gradually less physical prototype, a sharp change was observed. The 'break point' was reached when the keyboard became smooth (paper over a soft keypad). While an emulated keyboard is not the same as a touch-based screen, still this suggests the physical impact of not having tactile elements is significant to interactive experience.

In section 3, we noted that experiments on distributing information between public and private displays could lead to problems related to switching of attention [10]. The participants in these experiments were young (average age 30), but for older users switching attention between hand-held devices and distant screens (e.g. remote control and TV) can be difficult and for some people may even require changing spectacles. Even feeling for buttons such as cursor keys can be problematic for older users and so what may appear to be a 'heads-up' interaction actually involves switching visual attention. While this sounds like any form of multi-device interaction with displays is more problematic for older users, it can also be seen as an opportunity for touch-based interaction as the gains of subtle tactile feedback often disappear. Speculating, larger touch-based devices for interacting with remote displays may have advantages in this context, not just for public displays but also in the home.

We have in addition been involved in formally modelling the nature of physical interaction. In particular we take a stance where we separately model the device's physical states and interaction effectively 'unplugged', i.e. totally ignoring any digital functionality and then as a separate exercise, map this to digital behaviour [7]. We have modelled a variety of consumer devices using separate state transition networks (STNs) to model the physical and digital/logical aspects of the devices. While many devices have quite complex mappings, there are some simple devices, such as some light switches, where there is a one-to-one correspondence between physical device states and logical states (in the case of the light switch electricity flowing). These simple mappings, which we call *exposed state* devices, are particularly easy to understand as the device itself physically encodes everything.

This technique has been applied to device prototypes within the product design setting using IE units. Alternative physical devices have been developed for the same digital functionality – a media player. Figure 3 shows two of these devices: (i) is a dial with exposed state and (ii) is touchpad. The latter is of course similar to many touch-based personal devices.



(i) dial (ii) touchpad

Figure 3. Physical prototypes

The raw physical model of the touchpad is in fact trivial – there is no visual (or tactile) difference between states in the device itself. In addition, while your finger moves over the surface, there is no intrinsic haptic feedback as it traverses critical regions (in this case changing menu selection on the media player). As with mouse-based interaction, users have to use their imagination in order to construct the virtual world behind the device. It is perhaps odd that touch-based interaction, which, on the one hand, is far more physical than pressing keys, on the other hand, it has less tactile feedback.

6. MODELS AND ARCHITECTURE

So far there appears to be little systematic modelling or user interface architecture for interactions between personal devices and public displays, although there is certainly interest in the area.

In the *single* device modelling above, we chose STNs to model the physical device as these are well understood in computing science and even used in end-user documentation. However, we were aware from previous work on status–event interaction that a purely discrete notation would have limitations [5]. Indeed this has turned out to be the case and detailed analysis of even simple switches requires such extensions to describe the 'bounce' found when one initially tries out the switch to see which ways it moves.

Again even in simple switches, we have found that a thorough analysis really requires, at least simplified, modelling of the human body, in particular the forces exerted by a finger. This is even more important for touch-based devices as the device itself is stateless and the trajectory of interaction is driven by the sensing of the body alone. This is also evident in the explicit role of the human body in figure 1.

For UI architecture, there are various models for multi-user and multi-modal systems, which should be useful as they already deal with multiple input streams and non-standard inputs such as gestures. However, for public screen interactions there are also many issues relating to security and trust that need to be reflected in the architecture. Whereas in a 'normal' application, all the devices are typically owned by the user, with public displays, there are multiple 'owners' and many stakeholders.

7. SUMMARY

In this position paper, we have considered several aspects of two strands of work focused on interaction with public displays using personal devices and on the issue of physicality in design.

We have seen that 'touching' in such contexts may include mediated touch using the device itself, potentially powerful in certain types of public place. This form of proxy interaction entails a high degree of coupling between devices, although other forms exist involving either pure heads-up interaction with fingers on a personal device or interactions dividing visual attention between personal device and public screen.

An understanding of 'audience' is also important; both bystanders watching the screen and passers-by, whom we might wish to attract. So, whilst in some situations we may wish to have unobtrusive interactions in order to preserve privacy, in others, more expansive gestures may be appropriate in order to create a form of ad hoc 'performance'.

Finally, we considered the modelling of physical devices and saw how effective modelling of touch-based interaction is likely to require both notations for continuous phenomena and also modelling of aspects of the human body.

These various factors from the two strands do not yet make a single coherent view of touch-based interaction with multiple devices. However, there are threads of integration, notably the way all the topic covered inform or are informed by the different relationship sin figure 1. While this is still a developing area, we believe both the separate strands and the emerging threads between them offer initial insights.

8. ACKNOWLEDGMENTS

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