A Framework to Guide the Design of Environments Coupling Mobile and Situated Technologies

Benjamin D. Bedwell, BSc. (Hons)

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Abstract

An increasing number of devices are being situated in public spaces yet interactions with such devices are problematic: they tend to be impersonal and subject to social apprehension while devices suitable for specific tasks may be difficult to locate. This thesis considers how one might design for these environments to overcome these issues and deliver engaging user experiences. It proposes the coupling of the interactive features of mobile and situated devices to facilitate personalised interactions with those situated devices. The thesis explores coupling techniques that extend the computational capabilities of the situated device through the addition of the input, output and storage capabilities of the mobile device. Finally it considers how multiple points of coupling can be used to link sequences of interactions with different situated devices providing rich, cohesive experiences across an environment.

The thesis presents a novel framework that builds upon previous work. Existing work is reviewed that links mobiles with single situated displays, and that uses mobiles for mediating exploration of physical spaces to address the lack of work addressing multiple situated devices in public. This review grounds a proposal and elaboration of a core model of interaction within a coupling environment, providing the basis for a design framework. This was supported by the implementation of a test-bed that consisted of six couples in various configurations, underpinned by a software infrastructure.

Formative user studies refined the framework and revealed novel aspects of the user experience for study. It was found that through support for narrative and personal orchestration, coupling environments afford personalised trajectories. By designing for personal trajectories the visitor has a more enjoyable personal experience and seeks to improve the experiences of others. In addition, coupling environments support social experiences; the step-by-step nature of a visitor's trajectory through the coupling environment lends itself to gradually introducing visitors to social coupled interaction and reducing social awkwardness.

Acknowledgements

We live on a placid island of ignorance in the midst of black seas of infinity, and it was not meant that we should voyage far.

H. P. Lovecraft, 1926

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1. Introduction

1.1 Motivation

*This thesis proposes the concept of **coupling** – the combination of the personal mobile device with publicly-situated devices – in order to overcome the lack of personalisation of interaction between those publicly-situated devices and users and a lack of potential-user awareness of/ability to find the situated devices. Combination of these two different types of device also affords new interaction beyond those possible with either type alone.*

Within the last decade, computing has begun to pervade the environment in the form of situated devices (terminals, displays, speakers and so on) and mobile devices (mobile phones, media players, etc.); at the same time the public expectation for personalised computing services beyond the computer room - in shops, schools, museums, galleries, and so on - has increased. A number of overlapping philosophies of research and development that have emerged to service this desire for widespread computing: *ubiquitous computing* (ubicomp[1]) (Weiser, 1991), *pervasive computing* (PvC) (Hansmann et al., 2001) and *ambient intelligence* (AmI) (Ducatel et al., 2001) describe saturation of the environment with computing technology.

Looking at the world around us we see a range of existing situated installations – devices embedded into the environment, e.g. an e-mail terminal at an airport waiting lounge, a photo-printer in an art gallery, etc. These devices are distinct in that they are designed to support the interactions desired in the context in which they are situated. However, the majority of such publicly-situated devices (or *installations*) are also notable for their lack of personalised interaction with their users. Fierce competition for physical space, particularly in environments such as shopping centres, ensures that the location of situated devices such that potential users can find them is also a significant issue.

The increasing adoption of personal mobile computing devices – mobile phones and media players for example – offers a route towards a more personalised form of ubiquitous computing. While the use of situated installations extends the locus of personalised computing from one point to a number of different static locations, use of mobile devices emphasises delivery of personalised services anywhere.

These devices are both:

[1] Henceforth the term 'ubicomp' or ubiquitous computing is used to refer to the spread of

- **identifiable** (the devices have unique hardware addresses and often contain their owners' personal data) potentially replacing the role of the personal ID card; and
- **computational** (they possess one or more of the abilities common to the desktop computer, i.e. input, output and storage) potentially replacing the role of the desktop computer.

Mobile proponents suggest that mobile phones are "what computers have become"[2]. Yet the property of mobility, while itself providing unique interaction opportunities, has requirements that limit mobile devices: freedom from physical constraint (e.g. wires), small size and light weight. A mobile device that is intended to communicate with others must utilise one of a number of wireless interfaces that tend to provide lower bandwidths and less reliability than wired interfaces. A lack of continuous mains-supply places reliance upon batteries for power, and so considerations of power-consumption are introduced as a foil to the use of increased processing power. These limitations have a fundamental impact upon the richness of the computing experience that can be provided by mobile devices in comparison to situated devices such as the desktop computer.

Coupling mobile and situated devices

Situated public devices alone cannot provide personal ubiquitous computing. On the other hand we have accepted that while the mobile device is truly the computer that can be taken "anywhere" it fundamentally fails to provide the computing experience that we have been led to expect by our reliance upon more resourceful situated devices. This thesis proposes and explores a computing design space that addresses the need for personal ubicomp where mobile devices are carried to and *combined* or "coupled" with publicly-situated devices to:

- **facilitate personalised interactions** (as the mobile device identifies its owner and acts as a personal input/output device) with those situated devices, to
- **extend the computational capabilities** of the situated device through the addition of the input, output and storage capabilities of the mobile device, and to
- **link sequences of interactions with different situated devices** providing rich, cohesive computing experiences across an environment

Consider the arrangement shown in Figure 1 below. Here a mobile phone has been combined physically to a publicly-situated projector using a cable.

[2] http://www.nokia.com/press/press-releases/showpressrelease?newsid=1077775 (accessed 22/2/10)

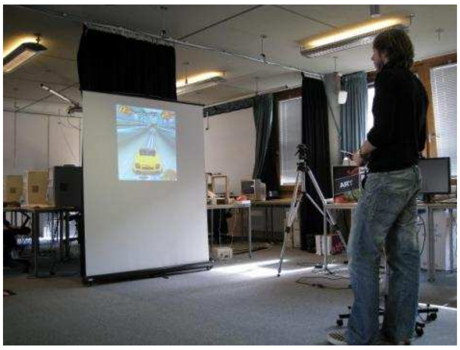


Figure 1 Combining a mobile phone with a situated display to form an operational couple

By coupling the two devices in this way the mobile's visual feedback is shown on the much larger public display, allowing much more comfortable viewing by both the user and bystanders – the interaction may now more easily become a social experience. Furthermore, the public display has become interactive as the mobile device provides a keypad that the user may use to manipulate the public display's output. Additionally, the user might save the results of his interaction at the display to his phone then physically carry them and transfer them to another public display to allow him and other users to share their results.

1.2 Coupling devices

The benefits of combining heterogeneous mobile and situated devices has previously been identified in research, from the Chameleon (Fitzmaurice, 1993, Fitzmaurice and Buxton, 1994) to Dynamo (Izadi et al., 2003), and more recently in the mainstream mobile markets in the form of devices such as the Samsung D900[3] – marketed as a phone with the ability to create and navigate media on a situated display – and applications such as Slide Show Commander[4] which allows a PDA to act as a remote controller of a PowerPoint presentation. These combinations build upon one-off opportunities for a user to combine their mobile device with a device situated into their environment.

This thesis elaborates the concept of the couple, as well as the exploration of environments in which multiple situated devices allow sequences of coupling experiences. Given the current state of computing technology we can now envisage a scenario where a user with a personal mobile device explores an extended physical environment populated with installations (situated devices) and temporarily couples their mobile device with specific installations in order to carry out different steps of a task. Consider how a user might experience this in, for example, a shopping centre:

> *A visitor arrives at a site where a map of the centre is displayed on a table which itself is able to track objects placed on its surface. The visitor places their mobile phone on the map and is able to "look through" the device's screen to the map below. As they slide their mobile across the map, the places of interest are highlighted via overlays on the mobile's screen - these places of interest are determined based on the visitor's profile stored on the mobile. The visitor can specify particular places as desired destinations, and a map annotated with these destinations and routes between them is downloaded to the mobile when the visitor leaves the map. While walking around the centre, the visitor is alerted via their mobile when they are in the vicinity of one of the chosen destinations. At a video shop, their mobile indicates that it can help to quickly identify which aisles are of the greatest interest to the visitor: a list of aisles are sent to the visitor's phone, the visitor chooses an aisle and a nearby digital display indicates via an arrow marked with the visitor's name which way to walk. As the visitor walks past more displays the trail continues until they reach their chosen aisle. Finally, by examining the map stored on their mobile device the visitor learns that there is an interactive*

[3] http://www.samsungmobile.co.uk/mobile/SGH-D900 (accessed 10/12/08)
[4] http://www.pebbles.hcii.cmu.edu/software/slideshow/index.php (accessed 10/12/08)

public display in a neighbouring shop and walks up to it. Using their mobile device to control an avatar they play with other shoppers in a virtual environment on the display for the chance to win a product from the shop. The visitor's actions during the visit update the profile stored on their device for use at future visits and visits to other interactive environments.

This is purely an example of a public space that might host a coupling environment – the thesis does not focus upon shopping centres specifically, but hopes to provide guidance that might be applied to a range of public environments such as museums, city centres, university campuses, and so on

1.2.1 Key design questions

The design questions raised by analysing the scenario may be separated into those relating to the design of the **individual couple**, and those relating to the design of the **environment** containing many couples. Considering the individual couples in the scenario highlights three significant questions that the thesis tackles:

- How can a user combine their mobile device with a particular situated installation and how is this process of coupling understood?
- What interactions are afforded by the resulting couple?
- How might a situated device support coupling with multiple visitors simultaneously, and affect interactions between those visitors?

Beyond the individual couple, the thesis explores how experiences at multiple situated devices spread across an environment might be linked and how these relationships are conveyed to and enforced for the user visiting the environment. If the previous scenario is reconsidered it may be noted that the situated devices made sense as couples when visited in a particular sequence, and that the *coherent sequence* of experiences provided value beyond the experiences at the individual couples. The thesis explores the following questions in order to determine how such coherent experiences might be orchestrated:

- What factors affect how suitable a situated device is for coupling with a user's mobile?
- Should suitability be determined by user or by the system? If the latter, how is the process conveyed to the user?

- How does a user locate a chosen situated device in order to couple their mobile device to it?
- What other entities or aspects of the environment have an impact upon the visitor's exploration of the environment?

1.2.2 Approach

To address such questions a set of couples, chosen to span the couple design space (including those parts currently underdeveloped, according to a review of prior art) are implemented, forming an environment in which more sustained user-experiences of *sequences* of dependent coupled interactions may be undertaken. The couples and environment are iteratively developed over the course of a number of user trials in order to refine the core model upon which they are based. This core model deals with the user-experience at two levels – that of the situated interaction that takes place at an individual **couple**, and that of the exploration of the wider **environment** to create a personal trajectory through the environment.

i. Exploring the couple

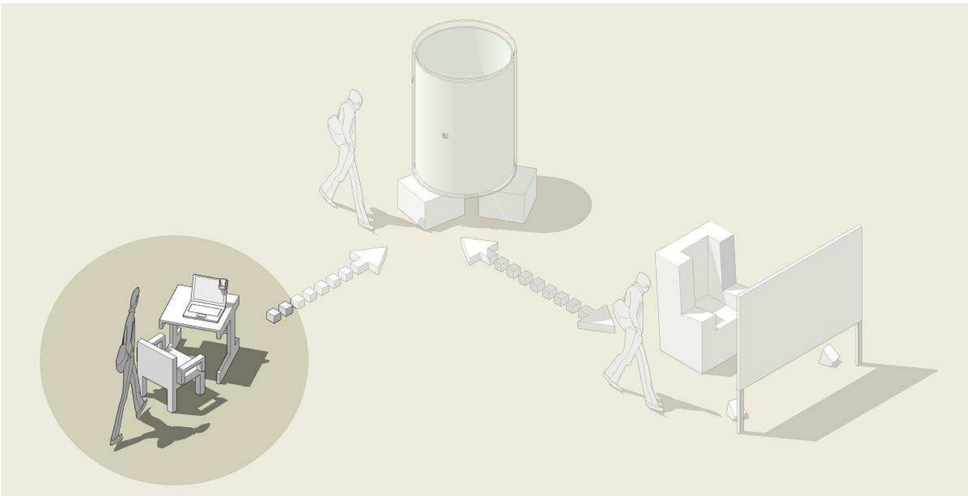


Figure 2 An individual coupling opportunity highlighted within an environment

The thesis work explores the development of a range of novel couples of mobile and situated devices that span the design space. A number of deployments allow observations of how users understand the concept of interacting with an assembly of mobile and situated device, and indeed how the user understands the process of combining the two devices beforehand allowing the refinement of a model of user behaviour at a couple.

Key findings resulting from observation of interaction at the couple relate to the impact of the design of the couple upon the degree to which a visitor's interaction is (or is perceived to be) staged for others:

- **Environment configuration can reduce social awkwardness over the course of the visitor's trajectory:** reducing social awkwardness over the course of a visitor's trajectory increases the chance and extent of visitor engagement, but requires a sympathetic introduction. Four characteristics of coupling environments are identified that reduce social awkwardness to this end.
- **Particular arrangements of a couple encourage beneficial social interactions:** the nature of the input and output channels of a couple, as well as its spatial configuration and physical form each have an effect upon the social interaction at the coupling opportunity: the key design features of a couple that may be tailored to support a range of interactions from personal to group, and momentary to sustained are identified.
- **Couple and coupling environment design may benefit from supporting the need for experience-sharing amongst groups:** the cyclical nature of interaction in the coupling environment naturally facilitates turn-taking within groups given that particular identified barriers to turn-taking are considered and avoided; turn-taking can be enforced through existing social conventions without intervention by the system

ii. Exploring the coupling environment

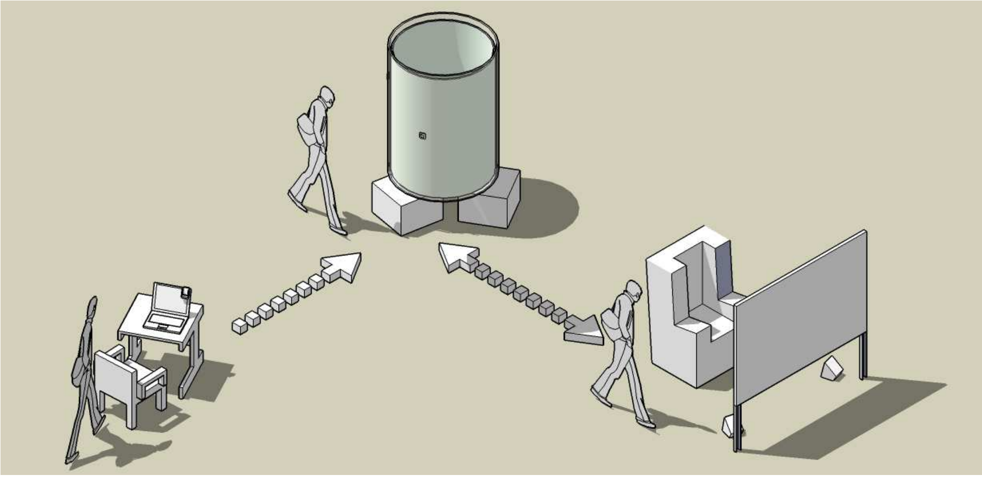


Figure 3 A sequence of couples forming a coupling environment

In addition to consideration of the individual couple, the thesis describes how a set of couples are arranged within an environment and how experiences at each couple are developed that build upon one another to explore - through iterations of the coupling environment - this concept of related and dependent coupling.

The thesis' key findings from observation of this process revolve around the notion of the *personal trajectory* through the coupling environment:

- **The uniqueness of a personal trajectory is directly related to visitor engagement and exploration of a coupling environment, thus differentiation mechanisms are a necessary design feature:** the infrastructure described in the thesis provides multiple mechanisms to provide unique trajectories for visitors; visitors derive greatest satisfaction from trajectories that are both evidently unique and that they have had a hand in making unique. Mechanisms that restrict visitor choice and conceal choice until goals are met both facilitate personalised trajectories but restriction is detrimental while concealment encourages exploration.
- **The means of shaping one's trajectory must be transparent:** making the causality and boundaries of differentiation mechanisms visible encourages personal progression and the open transfer of knowledge and observation between visitors. Visitors feel a keen sense of ownership over their experiences if the mechanisms by which they can be personalised are clear – in such cases visitors are discouraged from experiencing interactions by proxy. In contrast, visitors to environments where mecha-

nisms for personalisation are absent or unclear prefer to observe others interacting where possible.

- **Orchestration may need to allow the visitor control over pace of exploration:** orchestration by the system should exercise direction when necessary, but tend to offer a greater degree of freedom to the visitor to shape their trajectory as the visitor's sense of social awkwardness decreases; it is also important that the means to legitimise breaks in exploration of the environment are offered as any orchestration approach asserts a basic level of pressure on the visitor to constantly utilise the system.

1.3 Contribution

In practical terms, the contribution of the thesis is as follows:

- A design framework and key considerations, including a basic model of user interaction with an individual couple extended to a broader model of visitor behaviour in an environment with multiple couples. This model of visitor behaviour compliments the development and understanding of the notion of the personal visitor trajectory through a coupling environment and social interactions between visitors in the environment. The framework presents both the benefits of coupling environments with the design features that allow these benefits to be achieved.
- Proposal and development of a software infrastructure that demonstrates the use of the framework, allowing the creation of a test-bed, i.e. a coupling environment consisting of multiple couples. The test-bed supports the discovery of couples by the user, guidance of the user to opportunities and the enforcement of narrative and other contextual dependencies required to ensure a cohesive larger experience.
- Formative user studies with various types of user utilising the test-bed, the observations of which feed back in to and refine the framework, whilst also providing illustrative cases.

At the time of completion of this thesis an overview of the early concepts of the framework had been presented at the “Mobile Interaction with the Real World” workshop at the MobileHCI conference (Bedwell and Koleva, 2007). In addition, reflections on two projects guided by and informing the framework during the course of its development – *Future Garden* (Schnädelbach et al., 2006) and *Anywhere-Somewhere-Everywhere* (Bedwell et al., 2009) - have also been published. An additional paper (a reflection on a further project, *Rivers Baghdad*[5]) is awaiting review.

[5] http://www.riversbaghdad.com (accessed 12/3/10)

1.4 Thesis structure

Chapters 2 and 3 of the thesis form a broad review of relevant prior art. Chapter 2 focuses on the individual couple, first exploring the tangible user-interface (TUI) as a concept encompassing the couple, then the mobile-phone-public-display (MP-PD) concept as a specific example of a couple. This chapter concludes by categorising and discussing existing implementations of couples. Chapter 3 looks beyond the individual couple towards coupling environments and discusses context as a key consideration in the provision of cohesive user experiences of those environments. Initially relevant aspects of user and environmental context are isolated, then existing examples of both mobile and situated devices used to facilitate the exploration of physical environments are discussed.

Chapter 4 proposes a model of user interaction with a couple, extended to include user behaviour within a coupling environment grounded with reference back to the earlier review. A couple design space is proposed, followed by a discussion of the notion of personal visitor trajectories, complimenting the earlier visitor behaviour model. In both cases key design issues are isolated. Chapter 5 instantiates the model proposed in chapter 4 through implementation of six couples, a software infrastructure and three configurations of coupling environment suitable to address the previously raised design issues through user trials. In chapter 6 the software infrastructure is described in detail.

The observation methodology and structure of the user trials are then summarised; following this chapters 7 and 8 focus upon key findings emerging from the observations and development of the software infrastructure and couples. Chapter 7 reflects upon the importance of personalised and diverse trajectories through the coupling environment: how diversity of experience is provided for the user by the system, the necessity of a careful balance between user and system control over the user's trajectory, and accountability and visibility of system control. Chapter 8 discusses the social interactions observed occurring within the coupling environment with a keen focus on the link between social awkwardness and a perception of staging linked to particular couple design choices.

Chapter 9 concludes the thesis, summarising the work carried out and presenting the key findings discussed in chapters 7 and 8. It states the contributions made through the research and also suggests future work.

Part I – Review of the state of research

2. The couple

Raghunath et al classify the combination of mobile devices with situated devices (using the Personal Server (p.46) and synchronisation of PDA with desktop computer as examples) as device symbiosis (Raghunath et al., 2003). Three forms of symbiosis are presented:

- mutualism (all organisms benefit from their relationship to each other);
- commensalism (one organism benefits with minimal cost or benefit to the others); and
- parasitism (the benefits that one organism achieves come at a cost to all others)

The vision of coupling explored in this thesis is founded on *mutualist* symbiosis, whereby both situated and mobile devices benefit from an extension of their capabilities. For example, the situated device in any couple benefits from the ability to identify its user and thus personalise its services, while the mobile device benefits from a richer selection of input and output components.

This first half of the review of relevant prior art explores the individual couple, firstly by considering the couple as a specific form of tangible user-interface (TUI), then the mobile-phone-public-display (MP-PD) assembly as a specific type of couple, as visualised below in Figure 4.

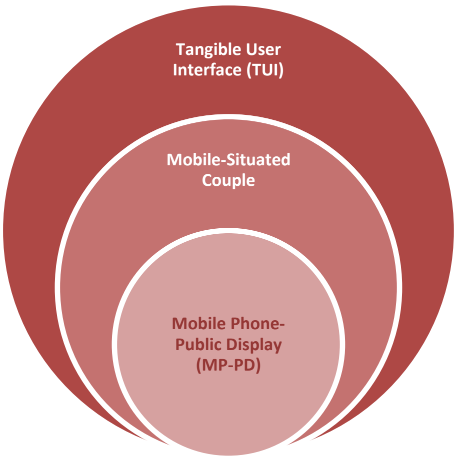


Figure 4 Relations of TUI, couple and mp-pd design space

In both cases there are descriptive frameworks that analyse these design spaces and the relevance of their axes to a mapping of the *couple* design space is discussed. Following this a range of existing device assemblies that are analogous to couples are categorised, referencing their design to the previously identified frameworks.

2.1 Descriptive frameworks

2.1.1 Device assemblies and TUIs

In a couple, both the situated device and the mobile device might be considered a physical input device. Considering the parts of the couple as such, how might interaction between the user and the two devices, or indeed the interaction between the two devices within the couple be described?

There are several fundamental pieces of work that might be of use to a designer considering how to construct an assembly of mobile and situated devices. In (Card et al., 1991, Card et al., 1990), Card et al acknowledge the benefits of and build upon previous explorations of the design space of input devices (including the work by Buxton (Buxton, 1983)). Individual input devices are seen as six-tuples, (M, In, S, R, Out, W) where:

- M is a manipulation operator (all combinations of linear and rotary, absolute and relative, position and force),
- In is the input domain,
- S is the current state of the device,
- R is a resolution function that maps from the input domain set to the output domain set,
- Out is the output domain set, and
- W is a general purpose set of device properties that describe additional aspects of how a device works.

Such a design-space is widely accepted as sufficient for an exhaustive mapping of physical input devices, but is possibly too little focussed upon the interaction afforded by the mapped devices to be of great use in this form to our mapping of the coupling design space, much significant information falling into Card et al's general purpose W attribute. Card et al.'s framework attempts to provide the means to thoroughly consider the design of sensing-based interfaces; an alternative approach to this issue is detailed in (Benford et al., 2005) in which a range of novel sensing-based interfaces are analysed using a framework that considers whether the user's interactions with (in particular movements of) the interfaces are expected, sensed and desired. In comparison to an "ideal" interface design where the expected, sensed and desired interactions precisely overlap (such that all possible interactions are catered for and made use of effectively), real designs are shown on reflection to be more complicated; the framework is shown to reveal interesting design issues where the three types of interactions do not overlap perfectly.

In significant work conducted in the late 1990s and early 2000s, Holmquist, Jacob, Ishii and Ullmer - amongst others – draw on the previous work considering assemblies of devices and champion the concept of TUIs (a term coined in (Ishii and Ullmer, 1997)). The review focuses now on TUI literature, not only because the relationship between the mobile and the situated technology when combined in a couple bear similarities to the physical objects and sensing technologies combined in a TUI system, but also because the literature considers in more detail the *role* of the devices in such combinations, and the reasons for the interactions afforded by combinations. To do so, TUI work also commonly draws upon the work of earlier authors (such as Gibson (Gibson, 1979) and Norman (Norman, 1999, Norman, 1990)) who emphasise the link between the form of device with the interactions that users conceive and the interactions that the device may actually afford. Gibson coined the term “affordance” to describe the actionable properties of an actor’s surroundings; Norman discusses affordances with respect to constraints imposed upon interaction and the mental maps formed by actors before and during interaction.

Holmquist et al in (Holmquist et al., 1999) introduce three categories of computational artifact:

- containers: generic objects used to move information between different devices or platforms;
- tokens: used to access stored information, the nature of which is physically reflected in the token in some way; and
- tools: used to manipulate digital information

The work describes how interaction with tokens can either give access to information associated with those tokens, or create or modify the associations between token and information. Interfaces that give access to a token’s associated information are termed information faucets. The notion of container and tool are highly relevant as roles for the mobile device in a coupling environment. Fishkin reflects on these computational artifacts and TUIs in general, describing not roles but a taxonomy defined by two axes: embodiment and metaphor (Fishkin, 2004). Embodiment refers to the separation between the user’s manipulation of a component of a TUI system and the system’s response to that manipulation, ranging from “full” where the feedback is exhibited by the device being manipulated by the user, to “distant" where the output occurs somewhere away from the user. Metaphor (similar to the classification system proposed in (Underkoffler and Ishii, 1999)) relates to the strength of analogy between interaction with/results of interacting with the TUI and other similar interactions with the real world, i.e. is the TUI used as if it were another real-world object ("metaphor of noun"), or is it used in a way that is like other actions that might be enacted in the real world ("metaphor of verb")? Metaphor ranges from no analogy ("none") to "full" where there is no separation from the user's point of view between the TUI and the real world. Fishkin uses the resulting general taxonomy to explain that there is no particular combination of metaphor and embodiment that is superior to the rest, and to reflect upon the relationships between the cognitive artifacts that play each of Holmquist et al.'s roles.

Gross and Do discuss a number of prototype physical computational components (Gross and Do, 2004) ranging from sensitive floor tiles (PlantTiles) to wooden blocks affording the ability to physically rearrange the structure of sentences (Navigational Blocks (Camarata et al., 2002)). The results of this discussion are suggestions as to concepts for a language to describe TUIs. Physical size, which is referred to later on a number of occasions in the section, is described in terms of:

- Object-size: objects we have an intimate relationship with and that may be manipulated by hand
- Body-size: interaction with which often involves movement or posture
- Room-size: spaces that we inhabit, possibly with others (often a driver for interaction with the TUI)
- City-size: the most public of TUIs - shared with others - where our individual interaction is often exposed for all to see

The tangible interfaces described by Gross and Do clearly vary more broadly in their form than those described by Holmquist et al. Tokens, containers and tools are all considered as portable objects, i.e. object-size, as spatiality is a key concern. Gross and Do discuss three additional scales (body- to city-size) that have little to no potential for movement. While a mobile device by itself sits within the object-size category, in combination with situated technologies the resulting device may be body-size or larger (in fact the Blinkenlights installation, originally deployed at the Haus des Lehrers building at Berlin Alexanderplatz[6] covered the face of the building - 144 windows - a massive increase in scale from a mobile phone

[6] http://blinkenlights.net/blinkenlights (accessed 22/2/10)

display). It is clear that the range of size possible in coupled interaction is more analagous to that suggested by Gross and Do.

These classifications of scale may also be discussed in relation to both PARC's original ubicomp artifacts - the tabs, pads and boards - which Weiser in (Weiser, 1991) describes as:

- Tabs: inch-scale (that approximate active Post-It notes);
- Pads: foot-scale (like a sheet of paper); and
- Boards: yard-scale (the equivalent of a blackboard or bulletin board).

These ubicomp artifacts are clearly intended as objects to be situated in or carried around environments and hence do not extend beyond Gross and Do's body-size scale towards room- or city-size, but do offer an extension to the definitions of object- and body-size. Authors such as Ballagas et al. in (Ballagas et al., 2006) draw analogies between the PARC tabs and mobile phones, placing mobiles at inch-scale; a 'pad' (for which we might use a desktop computer display, an Internet tablet, or laptop as an example) however seems to fall uncomfortably at the meeting point between object- and body-size: such devices are obviously portable and manipulable but tend to be several if not more times larger (in terms of volume or screen size) than mobile phones and as such favour more situated applications. It may be suggested that the distinction lies in how movement of the device tends to be integrated into the interaction: a mobile phone or similar-sized computational artifact can be moved precisely and comfortably by hand and thus has clear potential as a personal spatial input device, i.e. the object is manipulated in-hand; a foot-scale device on the other hand does not comfortably afford use as a precise spatial input device - it is more suited as a sensor for spatial input from another smaller device or localised movements of its owner, i.e. the object is manipulated in situ. Yard-scale and body-size seem relatively analogous and describe an object that - as a whole - cannot typically be manipulated in-hand, but that reacts to more general movements of the user or to other devices as input.

In (Ullmer and Ishii, 2000), Ullmer and Ishii discuss the physicality of TUIs as promoting collaborative co-located interactions in comparison to traditional GUI computer interaction. Gross and Do imply an increased support for collaborative interaction through the increased scale of interfaces possible in tangible computing, an effect also noted by other authors such as Izadi et al. (Izadi et al., 2002) who explore the use of large displays for shared interactions; many of the instances of coupling reviewed later such as Dynamo (Izadi et al., 2003), TexTales (Ananny et al., 2003), Plasma Posters (Carter et al., 2004) and so on, consist of collaborative interaction with a shared piece of situated technology. Brignull et al discuss how larger technologies not only afford collaborative tasks but also tempt users into interaction by making the interaction more visible (Brignull, 2005, Brignull and Rogers, 2003).

In Ullmer's thesis (Ullmer, 2002), TUIs are divided into three categories:

- interactive surfaces (where the user manipulates physical objects upon a planar surface),
- constructive assemblies (where users interconnect modular elements) and
- tokens+constraint (physical constraints that limit the manipulation of tokens once they are associated)

An analogy may be drawn between these three types of TUI constructs and potential mobile/situated device couples. The previously discussed framework by Card et al. contains a notion of a composition operator which maps the output domain of one device to the input domain of another. Three types of composition operators are described:

1. merge (where a cross-product of input and output is useful),
2. layout (where the coupled devices are collocated) and
3. connect (where the output of the first device is the input of the second device).

This vocabulary to describe the combination of input and output domains is clearly relevant when discussing the types of combination that might occur in a TUI system.

Given that the use of physical constraints can, as discussed at length in (Ullmer et al., 2005), simplify both the interpretation of the combined device and help to minimise errors in interactions with that device, there are very few existing instances of coupling where the couple is a physically constraining relationship: the majority are purely operational couples that occur via wireless pairings between the devices.

2.1.2 The mobile-phone to public display (MP-PD) design space

Of the different specific types of combination of mobile and situated device possible, the most studied thus far is the mobile phone and public display couple. In this emerging research area there have been several attempts to chart the design space; a selection of these is reviewed below.

In (Ballagas et al., 2006) Ballagas et al attempt to outline a design space for the mobile phone as an input device for interactions with situated displays. The work builds on Foley et al.'s desktop-GUI theory (Foley et al., 1984), suggesting three particularly important sub-tasks of their proposed system that are equally relevant to MP-PD couples:

- position;
- orient;
- select.

In an MP-PD couple, the mobile is equivalent to the mouse as the input device, affording these three sub-tasks. Text input, quantification and path specification - three other GUI tasks isolated by Foley at al. - are also suggested as tasks that transfer to MP-PD couples, but which are too trivial to address in the paper; text input and quantification can be achieved via keypad input, or by combinations or position, orient and select tasks, while the path specification task is merely an extention of position. In order to illustrate and map the increased diversity of the mobile as input device over the mouse, four other attributes are suggested by Ballagas et al. as necessary to describe an MP-PD couple:

1. dimensionality (up to 3 dimensions);
2. environmental feedback (continuous or discrete);
3. measurement (relative or absolute); and
4. interaction style (direct or indirect).

The authors evaluate a number of existing MP-PD couples, placing them in a matrix created using these four attributes as axes. The design space of Card et al (Card et al., 1991, Card et al., 1990) is referenced as an exhaustive mapping of input device design, yet it is noted that mobile phones as input devices in MP-PD require a more focussed consideration of attributes such as feedback. Ballagas et al.'s evaluation using their own matrix reveals areas of over- and under-exploration in the MP-PD design space, in particular (although not explicitly identified in the paper) a lack of exploration of 3D spatial input. Of note the design space also considers the mobile and situated devices as input and output devices respectively, without considering how these roles may be reversed or shared. Scale is also only addressed as a brief discussion point.

Dix and Sas in (Dix and Sas, 2008) attempt an overview of the key issues that a design space of MP-PD couples should address, defining the scope of the design space as being the interaction between private (as opposed to public- and group-) input devices and public (as opposed to private- or group-) displays. Six key issues are raised:

1. Physical size (poppyseed-scale, tab-scale, pad-scale, board-scale, perch-scale);
2. Input device use (selection/pointing, text input, storage, user ID, display ID, content ID, sensing, interaction/display surface);
3. Social context (witting/unwitting participants and/or witting/unwitting bystanders);
4. Participant-audience conflicts (conflicts of content, conflicts of pace);
5. Spatial context; and
6. Multiple device interaction.

With regards to physical size, Dix and Sas revisit Weiser's tab-pad-board scale and extend both ends, adding poppyseed-scale and perch-scale, suggested examples of the two being individual LEDs and concert displays/building fronts respectively.

The authors consider eight types of interaction with the mobile device in the MP-PD couple that include and extend those discussed by Ballagas et al. Of interest are storage, the various identification uses and sensing which are novel additions. Although content identification and display identification are essentially specific applications of Ballagas et al.'s (and indeed Dix and Sas' own) selection task, the purposes that the tasks serve are significant enough to warrant discussion. The need for identification of content and devices respectively arises from the fact that:

1. situated technology may present a broader and deeper range of content than that possible on a mobile device, and this content is likely to have come from sources other than the user viewing it (assuming the situated technology is public), thus the content is likely to be mixed and unfamiliar, unlike that found on the user's own device;
2. in a public environment both situated and mobile technology proliferates and it may not be clear which devices are available for use or which devices are being used.

User identification becomes necessary if personalised services are desired from a public situated technology. As most mobile devices are personal objects (i.e. they typically have one fixed owner) they are essentially a badge of identification. Storage arises from the ability for mobile devices to collect, create and transfer content anywhere in an environment, and it may be observed that a mobile with storage ability is essentially analogous to Holmquist et al.'s container TUI component. A key observation that can be drawn from Dix and Sas' set of tasks is that the authors consider coupling environments rather than simply individual couples: storage implies that there is a desire to move content between multiple devices; device identification implies that there are multiple (not all suitable) opportunities to couple; user identification implies that there are multiple mobile devices attempting to couple. Garzotto and Paolini talk in a similar manner of couples providing “more durable user experiences that span over time and space” (Garzotto and Paolini, 2008).

Dix and Sas expand Ballagas et al’s text input role of the mobile to a more general interaction/display surface role, encompassing the mobile’s capability for input such as key-presses and other button/switch-based interaction as well as touch-screen interaction in its own right. This potential appears to be overlooked as obvious or trivial in all design-space literature reviewed.

Social context is another aspect of the MP-PD design space overlooked to a significant extent by the other literature reviewed here. The authors suggest three relationships between visitors and the MP-PD couple:

- participant
    - witting participant - actively engaged with the system doing some form of input/interaction;
    - unwitting participant - triggers sensors to have some effect, but does not know it;
- bystander
    - witting bystander - sees the screen and realises interaction is occurring;
    - unwitting bystander - sees the screen but does not realise interaction is occurring; and
- passer-by - may know screen is there, but does not watch or interact with it

These three types of visitor relationship are related to Brignull and Rogers’ three activity spaces presented in an earlier work (Brignull and Rogers, 2003): peripheral awareness space (which passers-by inhabit), focal awareness space (which bystanders inhabit) and direct interaction space (inhabited by participants). There are interesting implications raised by Dix and Sas regarding effects upon interaction or beneficial adaptations to interaction for different combinations of these types of user and audience. While systems such as Dynamo are stated as examples of multi-participant/no audience interactions, i.e. CSCW systems, where interaction is on the whole mutually beneficial, the authors suggest that when there are both active participants and witting bystanders there is a chance of conflict between the two. Potential conflicts are divided by the contentious aspect, namely:

- Conflicts of content
- Conflicts of pace

Conflicts of content may occur when multiple participants are interacting with one public display at different paces causing a confusing mixture of content and interactive feedback components to be visible simultaneously. More obviously, different content may be desired by different participants and different content may be interesting for any bystanders in comparison to that desired by the participants. Conflicts of pace occur due to the different speeds at which multiple participants interact, or the different rates at which an audience may enjoy watching the interaction in comparison to the speed at which the participants wish to interact. An implicit emphasis is placed by the authors here on the enjoyment that public displays may bring to an audience, and the extent to which that benefit may outweigh the benefits gained by tailoring the interaction entirely for the participants.

In (Reeves et al., 2005) Reeves et al. consider the social impact of the user's interactions with an interface in public as a spectacle. The work provides a taxonomy in which public interfaces are classified using two axes, defining the extent to which both the user's manipulations of the interface and the results of those manipulations are revealed to the public. Application of the taxonomy to existing examples of public interfaces reveals four categories of design: "secretive", "expressive", "magical" and "suspenseful". The taxonomy suggests, like Brignull & Rogers and Dix & Sas, that public interfaces may draw an audience of potential users, but indicates that this may impact upon the use of the interface by the current user, demonstrating that in some situations – for example where the interface is available for all to use - it may be beneficial for both the feedback of the interactions and the manipulations of the user to be revealed so that bystanders may learn how to use to the interface, while in others – for example where a sense of mystique needs to be created – the 'performance' of the user may be hidden and only the feedback revealed. This is subtly different from Dix & Sas's distinction between witting and unwitting bystanders, and indicates that a witting bystander might see the interface and realise that interaction is occurring but be unaware of who is interacting with it and how.

In (Garzotto and Paolini, 2008), Garzotto and Paolini present a conceptual framework for mobile-phone and public display combined interaction. Significantly, Garzotto and Paolini consider explicitly the locus of interaction in their design space: the mobile as control interaction type is sub-categorised into mobile as pointer and mobile as locus of interaction types, drawing a distinction between the channel through which interaction feedback is delivered (the public display and the mobile respectively). An interaction of the former sub-type is that made possible in the C-Blink system (Miyaoku et al., 2004) whereby the movement of the mobile phone maps directly to the movement of a cursor on the public display which can then interact with other on-screen content. In mobile as pointer interactions, the user's visual attention is focussed purely upon the public display; when the mobile is the locus of interaction, the user's attention must shift between the two devices, first to provide control input (to the mobile) then to experience feedback (from the public display). The content display channel is divided into public display only and both mobile and public display. This emphasises the limitation of the scope to the public display as output, suggesting that the display channel may not be mobile only. Content display channel is not necessarily analogous to the feedback display channel, where feedback to interaction may clearly be mobile only - Garzotto and Paolini's space does not concern itself with this.

Interestingly, Garzotto and Paolini's design space is a rarity in its consideration of the content flow in a couple. When content is pushed to or pulled from the user's mobile, the system is clearly the dominant partner in the interaction, whereas when the user pushes content from or pulls content to their mobile they are dominant and control the pace of interaction. There is a link between the mechanism of content flow and Dix and Sas' conflicts of interaction: Dix and Sas' conflicts assume that there is a balance of control amongst participants (and possibly bystanders) that may be skewed; Garzotto and Paolini briefly consider this under the dimension of social interaction, suggesting that one user may inhibit others in multi-user interaction, yet also introduce the system as an additional actor, complicating this balance significantly, as each user must compete for control with not just other users, but also with the system itself.

Pham et al describe a coupling approach to situated computing similar to that of Want et al's Personal Server (Want et al., 2002a, Want et al., 2002b), delegating tasks to situated technologies surrounding the user when beneficial, while otherwise using the user's own mobile as the computational device (Pham et al., 2000). The authors consider display tasks in particular, naming their display delegation approach Small Screen/Composite Device (SS/CD), hence the inclusion of the work in the category of MP-PD concepts. There is a more explicit consideration by Pham et al of the possibility for resource contention among multiple users in comparison to the literature previously discussed in this section. There is also a consideration of the balance of control over decision-making in the SS/CD system. The Personal Server (p.46) decides on behalf of the user how to delegate computing tasks, there is no apparent notion of choice by the user beyond deciding which devices to move towards; the SS/CD system on the other hand determines a system choice regarding the most suitable output device, then lists all possible choices for the user with the system choice prioritised - in this way the user makes the final decision over which display device to use. This mechanism for specifying attention overcomes the potential difficulty faced by the Personal Server of needing to specify the target of a wireless coupling attempt by reintroducing an explicit coupling step. Finally, SS/CD recognises the potential of the mobile device to act as an additional control device to the situated device determined to be the main display.

Pham et al propose three interaction models that map the level of delegation of control from mobile to situated device in a couple:

- Abdicative;
- Cooperative; and
- Exclusive

In an abdicative couple the mobile device delegates all control to the situated device, resulting in the situated device being used for all input and output in the interaction until the couple is broken. Use of the Personal Server (disregarding the jog-dial) is an example of abdicative coupling, where the Personal Server is simply a means of initiating interaction at a suitable situated device. In a cooperative couple control is shared between mobile and situated device such that input components of both the mobile and the situated device can be used. Slide Show Commander is an example of a cooperative couple; in this case the user can manipulate and annotate a PowerPoint presentation through a mobile interface that is a simplified version of that of a desktop computer, but the user can also use the mouse and keyboard of the computer to which the mobile is coupled to perform more complex (or indeed the same) actions on the presentation. In an exclusive couple only the mobile device can be used to control the interaction, the situated device playing the role of output component only. The Chameleon provides an example of an exclusive couple, where spatial manipulation of the mobile device is the only form of control. While wireless mouse cursor control via mobile and representation of the application control interface on mobile cannot occur in an abdicative couple, either may be feasible in either cooperative or exclusive coupling. They represent levels on a more continuous scale of possible control in a couple where any control is retained by the mobile device.

2.2 Examples of implemented couples

In comparison to the few serious attempts to map the coupling design space, there is a much larger body of work demonstrating real implementations of couples, and studies of these. Even so, the vast majority of these implemented couples consist of wireless connections between mobile and situated devices, and of mobile-phone to public display combinations. A significant distinction emerging while reviewing this literature is that of varying potential cardinalities and heterogeneities of couples. Of those examples found, only a minority consist of more than one situated device between which the user can move their mobile device, and none of these explore extensively the possibility of heterogeneity amongst the situated devices.

For ease of review, based on a reconsideration of the frameworks from the previous section the examples are split into five categories:

1. For spatial control: here the movement of the mobile and thus spatial relationship between mobile and situated device affords control;
    a. Chameleon
    b. C-Blink
    c. Virtual Graffiti
    d. MobiSpray
2. For selection: the mobile is used as a means of selecting a choice;
    a. Hermes
    b. Snap and Grab
    c. QR code
    d. Touch and Interact
    e. ContentCascade
    f. Disc-O-Share
3. For data input: the keypad, buttons or touch-screen of the mobile is used to allow data input;
    a. TxtBoard
    b. TexTales
    c. Plasma Posters
    d. Blinkenlights
4. For transfer: the storage capability of the mobile is used to allow data to be transferred to or between situated devices;

   a. Dynamo
   b. Pick and Drop
5. For alternative output: the personal output of the mobile provides an alternative channel for output from the public situated device.
   a. Pebbles
   b. Total Recall
   c. MobiDiC
   d. Rotating Compass
   e. UbiCicero
   f. Modigliani's House

There are a few reviewed systems - in particular UbiCicero - where the mobile takes on multiple roles; in these cases the alternative roles are also discussed. These categories simply group similar systems to provide a general degree of coherence to their review; for now the categories are briefly clarified as follows:

Significantly, the data input category is well-populated; although text input is stated as a role for the mobile by Ballagas et al (Ballagas et al., 2006), Dix and Sas (Dix and Sas, 2008) and data input as a role by Garzotto and Paolini (Garzotto and Paolini, 2008) the role is considered by these as almost too trivial to discuss since data input is the most conventional use for a mobile. The data input category defines a broader role than text input alone, a role closer to that of Dix and Sas' interaction/display surface, i.e. the use of the mobile's buttons and other input components to create content or otherwise control interaction. The large number of systems utilising the mobile in a couple in this more conventional manner (there are a growing number of examples beyond those reviewed below) reflects firstly the ease with which such a system can be created (the mobile simply needs to forward keystrokes and other inputs to a situated device) and the ease with which end-users can adopt and interact with such a system due to their familiarity with the means of interaction.

The spatial control role is most closely analogous to Garzotto and Paolini's mobile-as-control role, incorporating a range of spatially-reliant tasks of other frameworks, particularly Ballagas et al's position, orient and path specification. Here the ability of the user to manipulate the mobile in space is taken advantage of as a form of controlling input. In a good number of systems that fall into this category, the mobile naturally replaces the conventional desktop mouse as a means of controlling interaction occurring on the situated device. There are however examples of tasks that utilise the additional freedom of the mobile over a mouse (3D vs. 2D), e.g. the Chameleon, used to control a view in 3D space. TUI literature, e.g. the spatial relationship-task mappings from Ullmer et al's Token+Constraint framework (Ullmer et al., 2005), is particularly relevant to descriptions of these systems as much of said literature focusses on the spatial relationship between objects. Of interest with spatial input roles is how the spatial input is sensed by the system - unlike data input which is easily conveyed between the coupled devices, spatial input and selection may be sensed by a situated device in a variety of (in most cases non-robust) ways, e.g. using computer vision as is the case with C-Blink (Miyaoku et al., 2004) and others.

Selection represents a role by which the mobile is used to indicate a choice. Although a user may easily make a choice via a mobile's keypad such a process is covered in the data input category - the selection category includes systems that utilise mechanisms other than this to afford indication by the user. Systems that use spatial relationships to make a selection might be included as these do not utilise movement per se. A distinction that may be drawn between selection and spatial control is that selection is a discrete process whereas spatial control describes a continuous process where the spatial relationship between mobile and situated device changes constantly over time. Systems that afford spatial control may naturally also afford selection, utilising this distinction to afford the two different control tasks, e.g. interpreting movement of a mobile as spatial control and stasis (or indeed a keypress or other discrete signal) as a sign that the user wishes to make a selection. The selection role incorporates Ballagas et al's selection task and the selection/pointing role of Dix and Sas.

The transfer role encompasses interaction that allows a mobile to be used as a container (in the manner defined in (Holmquist et al., 1999)) to physically move content from one situated device or location to another. Systems that support the transfer of content between the mobile and one situated device only are not included, e.g. ContentCascade (Raj et al., 2004) is designed to support the transfer of content from situated device to mobile and to explore a mechanism to do so; while transfer occurs the system was not designed to propagate the content from situated device to situated device through an environment in the same manner as Dynamo (Izadi et al., 2003) or Pick and Drop (Rekimoto, 1997). Beyond Holmquist et al's container computational artifact, Dix and Sas also proposed a storage role for the mobile that implies the transfer of content out of situ using the mobile.

The final category, alternative output, includes those systems in which the mobile offers an additional altered output to that of the situated device. Although many systems utilise output channels on both mobile and situated device, e.g. for visualisation of controls and for interaction feedback respectively, only the systems where the potential for personal or private alternative output channels via the mobile is taken advantage of are included. Pebbles (Myers et al., 1998) is a clear example of such a system where a user's mobile offers a personalised view of a shared environment visualised on the situated public display. Dix and Sas include such a role as an interpretation of their interaction/display surface role, while Garzotto and Paolini tangentially address the role in their consideration of the content display channel where it was suggested that both mobile and situated device might produce output.

2.2.1 Mobile for spatial control

i. The Chameleon

The Chameleon (Fitzmaurice, 1993, Fitzmaurice and Buxton, 1994) is a mobile device tethered to a physical space. The mobile is spatially-aware and provides an augmented view of the physical space, allowing a user to look through the mobile display to see digital information overlaid onto the space (creating a *situated information space*) depending upon the position and orientation of the mobile in the space; Fitzmaurice and Buxton term this egocentric spatial relationship between mobile and physical space as "eye-in-hand".

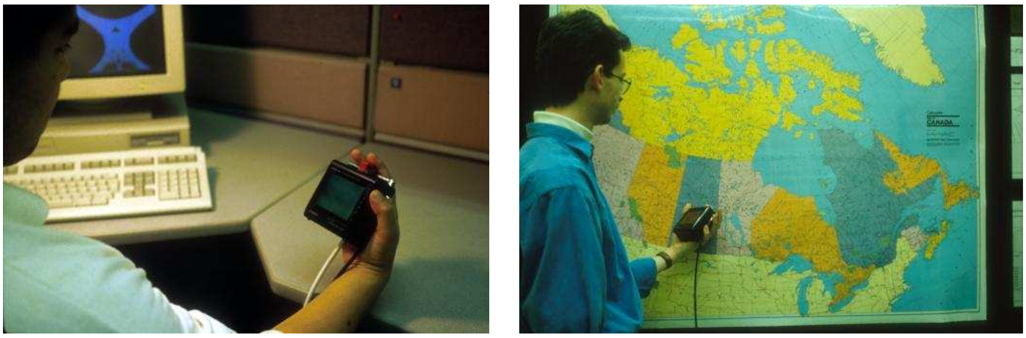


Figure 5 Chameleon used with desktop computer (left) and to create 'active map' (right)

While a situated information space need not involve a coupling between the mobile and a situated device (an informationally-augmented map, for example, requires no situated technology), Fitzmaurice outlines a scenario where the Chameleon is coupled to a fax machine in order to visualise the digital information associated with the various processes that the situated device supports, e.g. a list of contacts (Fitzmaurice, 1993). He continues to discuss a second scenario - an augmented library - illustrating an alternative form of coupling between the Chameleon and situated devices in which the situated devices (in this case small situated displays) are used to draw attention to useful physical resources (book shelves) which can then be explored in more detail through the Chameleon. Given the five categories, the Chameleon is significant in its illustration of the mobile in a spatial control role, where an alternative view is altered by spatially manipulating the mobile; the mobile is the locus of interaction, with the majority of feedback (depending upon the scenario of use) originating from the mobile; the Chameleon does also provide an alternative output to a situated technology, implicitly in the case of the fax machine scenario offering a personalised view (contacts that are relevant to you), yet the emphasis here is not explicitly on providing a personal view.

The Chameleon is significant in its use of all three dimensions of a physical space; the mobile can be moved across a surface, e.g. a situated display, but can also be moved around a 3D device to gain an augmented view of a situated device from all angles. There is a lack of implemented mobiles as 3D spatial control components in a couple; this is partly due to a lack of application - the majority of use-cases proposed for the Chameleon, for example, concern augmentation of non-computational artifacts - but also due to the difficulty with which such a couple is implemented.

The following three more recent examples of spatially-controlled couples attempt to provide more lightweight 2D spatial control; two of these systems (C-Blink and Virtual Graffiti) do rely on the situated device for spatial tracking even in these fewer dimensions.

ii. C-Blink

The C-Blink tracking system described in (Miyaoku et al., 2004) involves the visual tracking of a rapidly blinking light source (a mobile phone's display) by a situated camera; the situated camera relays the tracking information to a situated computer which processes the information and moves a cursor on a situated public display accordingly, thus allowing a direct mapping of a user's movement of their mobile in front of the public display to the movement of a cursor on that public display. A user is given the option of grabbing content from the display by targeting the content then briefly altering the hue of the visual signal (via keypress), thus issuing the grab signal; a user is also provided with an opportunity to push ("pitch") content to the display by issuing a third visual signal. Miyaoku et al discuss the use of C-Blink with multiple situated devices for affording transfer between those devices, comparing such a system to Rekimoto's Pick and Drop.

C-Blink may be implemented using a standard (situated) web-cam and large display and mainstream mobile phone, in clear contrast to a number of other tracking-based couples that rely upon the modification of the mobile phone by the addition of laser, RFID, UWB, or other radio emitters. Also, the developers focussed upon reducing the size and complexity of any client-side application; processing does not occur on the mobile, thus one mobile client application is suitable for coupling with any number of different situated devices.

iii. Virtual Graffiti

Virtual Graffiti is a demonstrator application described in (Kray and Rohs, 2007) implemented to explore a client-less alternative approach to that of Miyaoku et al's C-Blink. The system utilises visual markers adopted from the reacTIVision computer vision framework[7]; a user captures a marker by photographing it with their mobile phone, then displays the photograph of the captured marker on their mobile phone display. A camera is situated near to the public display so that when a user holds their mobile phone in front of the situated display the situated camera can recognise and track the captured marker displayed on the user's mobile phone display. As with C-Blink, the tracking information is then processed by a situated computer to map the movement of the mobile to the movement of a cursor on the public display. In the case of Virtual Graffiti, different markers captured by the users affect the output of the public display in different ways, most simply by allowing paths to be drawn on the display in different colours (Figure 6).

[7] http://sourceforge.net/projects/reactivision (accessed 22/2/10)

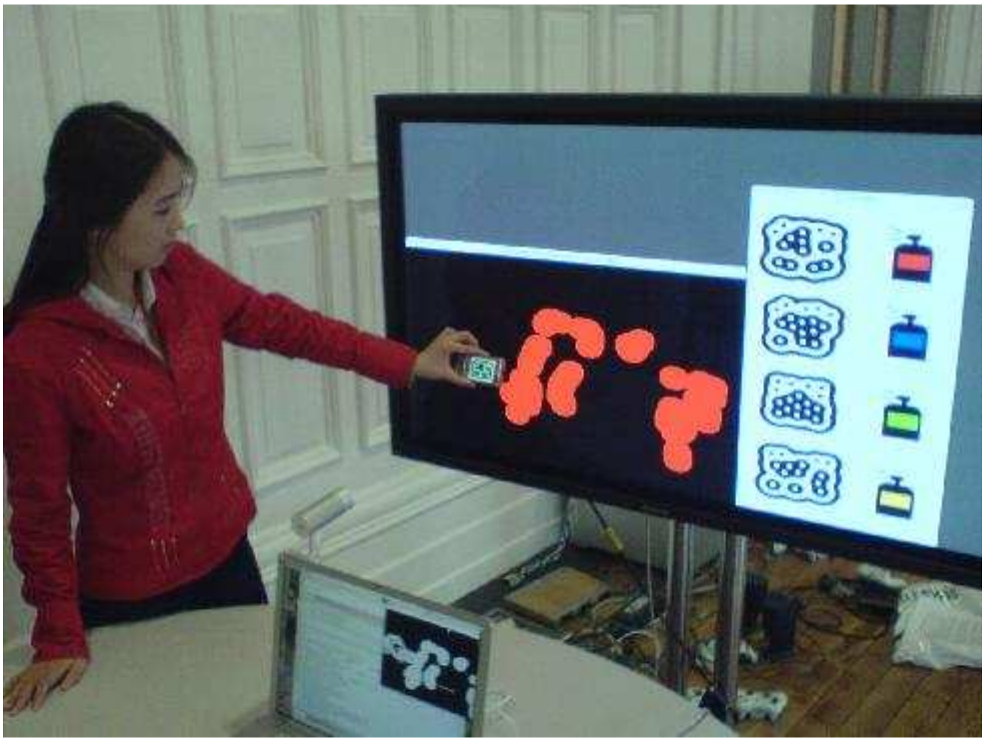


Figure 6 Virtual Graffiti being used

At no point in the coupled interaction between user, mobile and situated devices is any software installation required on the mobile device, thus the potential to couple with the situated device is not limited by the varying software environments of different mobile phones in comparison to the, albeit fairly forgiving, requirement of C-Blink for mobile Java runtime capability.

iv. MobiSpray

MobiSpray[8], a system created by Jürgen Scheible, allows a user to couple a mobile device with an in-built motion sensor to a situated projector to allow the user to “paint” onto public surfaces. The gestures of the user (interpreted in terms of roll and pitch) are translated into two-dimensional movements of a cursor on the projected display; keypresses by the user on the mobile indicate whether or not the user wishes to paint at the current cursor location. MobiSpray is an interesting alternative to vision-based spatially-aware couples such as Virtual Graffiti; all motion sensing takes place on the mobile device yet the processing of the information produced from that sensing takes place on the situated device, thus offloading complexity to the device most suited. The implication of this difference is that MobiSpray is robust and perfectly usable on current mobile phones (with the caveat that the phone must include

[8] http://mobispray.com/ (accessed 27/1/10)

a motion sensor, an example being the Nokia N95[9]). As currently implemented, the MobiSpray system supports only one user (the "artist") who stages the painting process for an audience; the surfaces used for public performances have varied in size, yet all are larger than body-scale.

In all cases of spatial control by mobile reviewed here the interaction between user and couple is synchronous and the mapping of mobile manipulation to feedback from the situated displays is continuous. Feedback is via the situated component of the couple and is visual. Virtual Graffiti is one of two systems reviewed that can support multiple users simultaneously, although this feature arises coincidentally rather than through intention of the designers; witting bystanders may easily become participants due to the simplicity of the coupling process. Such a trivial transition is not possible in the other reviewed systems due to the need to install client software on the mobile phone before coupling. One can imagine, although again this is not discussed in the related literature, that multiple users may also use their own Chameleons simultaneously to afford a personalised, private view into the same information space. The nature of cursor control means that mechanisms to avoid contention between multiple users would need to be designed and implemented for C-Blink, e.g. support for multiple personal cursors at the situated display, or turn-taking, in order to avoid conflict for control of one public cursor.

2.2.2 Mobile for selection

i. Hermes

Hermes is an iteratively developed network of situated displays deployed in Lancaster University. In the initial iteration (the Hermes door-plate system) as described in (Cheverst et al., 2003), the system allowed owner of a room to which the small display was attached to display a message, and the visitors to the room to leave messages for the owner. The owner could update the display directly or remotely using a web interface or via SMS, allowing the information to be delivered to the location without need for the author to be on location. Only the owner's content would be displayed, while the visitors' messages would be received then held invisibly. A second iteration afforded the ability to push images to the situated display via MMS, thus allowing remote posting from the visitors' perspective, not just the owner's. In this iteration a subset of the images left by visitors was displayed and thus the situated display device's size was increased to accommodate the richer information being displayed. The third

[9] http://europe.nokia.com/phones/n95 (accessed 22/2/10)

iteration (the Hermes photo display) extended the system to allow Bluetooth to be used by visitors as a means of pushing information, as well as allowing a visitor to pull an image from the display to their mobile by touching the screen to select an image, then selecting their mobile device from a list of those devices found by the display in a Bluetooth device search. The second and third iterations are presented in (Cheverst et al., 2005a, Cheverst et al., 2005b). The initial iterations explore asynchronous interaction, limited as such by the nature of the message passing mechanisms (SMS, MMS, e-mail, etc.) used to push to and pull from the situated devices. The implementation of the pulling process also limits the couple to one mobile-one display as two users cannot touch the display simultaneously.

Later work with Hermes explores responses to these limitations and later iterations allow multiple concurrent mobile couples as selections on the situated display are made using the mobile as either:

1. a means of controlling a personal cursor on the situated display, or
2. a means of visualising a private copy of the situated display

rather than through tangible interaction with the situated display. Additionally, the interaction is also synchronous as individual key-presses are communicated instantly (to allow instant response by the situated display). These advantages come at the cost of requiring use of mobile client applications; in all earlier implementations the Hermes system does not require the user to install any software on their mobile device.

The CASIDE project[10], of which Hermes is one research prototype, aims to explore how the deployment of situated displays can foster community. Hermes achieves this at two levels: the initial prototypes allow location to be populated with information, i.e. a means is provided for content to be dropped at and picked up from a location, thus changing a place into a point of interest where people visit to consume content or leave content to be consumed. Asynchronous communication between people can thus be encouraged and supported. With the addition of the mobile clients, Hermes also supports co-located synchronous collaboration between users as users may discuss and influence one another's interaction at the same screen. As such asynchronous communication between users was encouraged during the initial iterations of Hermes (where users did not need to spend much time at the situated displays) and co-located collaboration between users was encouraged by the later mobile-client-based iterations (where users needed to spend time at a display).

[10] http://www.caside.lancs.ac.uk/ (accessed 22/2/10)

ii. Snap and Grab

Snap and Grab, discussed in (Maunder et al., 2007, Maunder et al., 2008) explicitly addresses Hermes' reliance upon either:

1. the need for users to touch the situated display as a means of creating the couple between mobile and display, or
2. the need for mobile clients

to allow information to be pulled to the mobile. As with Hermes, the situated device of Snap and Grab is a public display, used to display a selection of user-generated content. In contrast to Hermes, Snap and Grab requires users to take a photograph of the content that they wish to save to their mobile and push that back to the situated display. The display attempts to match the image to any of the images that it is currently displaying and if a match is found sends any associated bundles of content back to the device that made the initial request. All parts of this process occur via standard Bluetooth actions and thus while no client software is needed there is also no need for any physical interaction between user and situated display, meaning that multiple users can couple their mobile to the situated display concurrently.

iii. QR code MP-PD interaction

In work by Jin et al (specifically (Jin et al., 2006)), a mobile device is used to reserve part of a situated resource. In the use-case presented, a wall with three potential workspaces is situated in public. While not being used, each portion of the wall is simply overlaid with a projected QR code[11]; when one of the codes is photographed using a mobile equipped with a client application, the application decodes information that can be used to create a wireless couple with a situated computer and projector which then extend the mobile's display onto that portion of the wall, providing the user with a large workspace in which they can manipulate content from their mobile device with convenience. The system as such represents a means for users to select and utilise portions of a situated public resource as opposed to the selection of content. However, the authors propose an extension to this functionality to allow content transfer amongst distributed similar public workspaces: in addition to displaying a code to allow coupling, unused workspaces also display "public" content, allowing users to drag content from their personal workspaces to these unused workspaces to leave content behind. The system represents an archetypal example of the use of situated, larger display technologies to overcome the increasing difficulty with which rich information can be ma-

[11] http://www.denso-wave.com/qrcode/index-e.html (accessed 22/2/10)

nipulated on small screens, and of the use of situated public spaces to allow content to be added to and transferred between physical locations.

iv. Touch and Interact

Hardy and Rukzio present Touch and Interact(Hardy and Rukzio, 2008), a system for transfer of content amongst situated displays. The system is presented as an improvement upon Pick and Drop (discussed as an example of transfer) whereby the mobile phone replaces the specialised pen device as a means of selecting and moving content between different devices. It as an example of an alternative means of selection, whereby a selection is specified literally by touching it rather than pointing. Touch and Interact is implemented using NFC (Near Field Communication[12]) enabled mobile phones and situated displays underlaid with a matrix of NFC tags which allows the mobile phones to determine which part of the display they are being held over; while the mobile is held over a position, extra information regarding the content displayed at that position is displayed on the mobile's display, providing a private higher-detail view of that content. The keypad of the mobile may be used to select the content being "touched" and trigger transfer of that content to the mobile from the display. In a reverse operation content may be pushed onto the situated display by choosing content on the mobile device then touching a destination position on the situated display with the mobile device.

The results of prototype trials by Hardy and Rukzio reveal that Touch and Interact-style interaction with a display is comparable qualitatively and quantitatively to manual touch-screen interaction for simple tasks (e.g. selection) and in addition supports more complex tasks that become difficult through manual interaction, such as the use of tools to manipulate content. This benefit arises from the secondary feedback channels (display, audio and haptics) provided by the mobile phone; in the case of the picture board prototype discussed by the authors the situated display shows the content while the mobile display indicates the currently selected tool and its potential effect upon the content, while haptic feedback is used to draw the user's attention to the mobile device. The Virtual Graffiti system (p.32) offered the potential for similar secondary feedback - having taken a photo of a marker to select a paint colour from a palette that photograph remained on the mobile's screen, yet the marker did not relate intuitively to the action the mobile then afforded, thus the feature did not aid the user. The mobile display is intended to be read by machine, not by the user. The mobile

[12] http://www.nfc-forum.org/aboutnfc/ (accessed 22/2/10)

feedback provided by Touch and Interact is targeted at the user and is unimportant to the system itself.

v. ContentCascade

While these systems allowed a user to actively specify one of a number of choices being output by a situated device, ContentCascade (Raj et al., 2004) explores a passive selection mechanism. The system affords transfer of selected content from a situated display (which alternates the content being displayed) to a mobile, but selection of content is determined by the situated display depending upon the length of time that a mobile device is proximate or "hovering". A hover detection threshold is set: a user with a mobile that remains within Bluetooth range of the situated display for this length of time is deemed to be interested and thus selects the currently displayed content. Once a selection is implicitly made in this way the situated display transfers a general piece of meta-data relating to the content (e.g. a short textual description that may serve as a simple reminder of what the user has seen); after a subsequent period of sustained interest the user is deemed to have made a more concrete selection, thus a more detailed piece of meta-data is pushed to the mobile (e.g. an image slideshow); the process continues with richer meta-data "cascaded" to the user's mobile as the period of interest lengthens. The lack of direct interaction between a user and a Content-Cascade display and the intangible nature of the couple formed allows multiple users to be supported concurrently. Interaction is continuous but passive. The user's mobile is used to review content that has been selected later, rather than necessarily being used as instantaneous feedback to the interaction with the situated display.

Much of Raj et al's discussion concerns the possible differences between users regarding the behaviour that signals interest in (and thus selection of) displayed content; a mistaken passive information push to an uninterested user's mobile device may be, as the authors concede, considered intrusive. While an increasingly common tool of marketers, Bluecasting - the indiscriminate dissemination of adverts via Bluetooth - as implemented by providers such as Filter[13] initially received some negative reactions for this reason. In October 2007 the UK Information Commisioner's Office removed Bluecasting from the list of marketing methods that require recipient opt-in[14], thus explicitly legalising bluecasting to remove previous ambiguity on the matter, yet with a strong caveat that steps are taken to reduce as best as possi-

[13] http://www.bluecasting.com/ (accessed 22/2/10)
[14] New guidelines omitting Bluetooth can be found at http://www.ico.gov.uk/upload/documents/library/privacy_and_electronic/detailed_specialist_guides/guidance_part_1_for_marketers_v3.1_081007.pdf (accessed 22/2/10)

ble the chance to intrude. As Bluetooth technology stands currently, mobile users either make their devices discoverable or non-discoverable, thus receiving or not receiving every Bluetooth request that is aimed at them - there is no passive process of discrimination as there is when actively selecting (as per Hermes or Snap and Grab). ContentCascade points towards potential mechanisms for this passive selection of content and services. As Raj et al state, different users will hover at a poster for more or less time before becoming interested (or disinterested as the case may be), and may express interest more concretely through other gestures beyond simply hovering; these behavioural cues and the heterogeneity of them are raised as interesting research areas in their literature.

vi. Disc-O-Share

Disc-O-Share utilises not just the proximity of a user's mobile to the situated device to control selection (as with ContentCascade) but also the proximity of one coupled user's mobile to another (Kray et al., 2008). While ContentCascade essentially determined whether the user's mobile was within a certain proximity (Bluetooth's maximum range) for a certain amount of time, Disc-O-Share defines three spatial proximity regions (distal, outer proximal and inner proximal) surrounding each mobile within a certain proximity of the situated device (a situated camera) and affords different interactional possibilities amongst the mobiles in the camera's proximity depending upon the extent to which the mobiles' proximal areas overlap each other's.

Figure 7 Disc-O-Share interaction with proximity regions highlighted

Of the two applications implemented by Kray et al, the photo-sharing application best exemplifies the mechanism: one user offers a photograph by entering their mobile into the proximity of the situated camera; another user moves their mobile into the first's outer proximal region and is presented with a thumbnail of the photo being offered; the second user signals their selection of that photo by moving their mobile closer and into the inner proximal region of the first mobile. Transfer occurs, but the second user changes their mind and withdraws their mobile into the distal region of the first, signalling their desire to cancel the transfer. In the case of Disc-O-Share (as presented in the literature) the situated device simply mediates the interaction between the mobiles; multiple concurrently coupled users are required for any coupled interaction, and the resulting interaction is continuous and synchronous.

Disc-O-Share makes more intuitive aspects of wireless collaboration between users. Most significantly creating spatial relationships to signal transfer reduces issues with reconciliation of device and device identity; both Hermes and Snap and Grab rely upon a user - at some point - choosing one of the devices being coupled from a list of nearby Bluetooth devices, a task that is not always trivial or intuitive unless the devices are clearly and uniquely named. The physical, spatial task of moving one's mobile near to a target mobile device was seen as intuitive and uncomplicated by test subjects of Kray et al. The process also takes the locus of interaction beyond the mobile interface (to which it is limited in the case of Hermes, for example) into the physical space surrounding the devices thus naturally encouraging group collaboration rather than a purely mobile-GUI-based interaction that instead encourages focus on individual devices. The additional step whereby a preview is shown of any content being offered (when a mobile is moved into another's outer proximal region) was also seen is beneficial over standard Bluetooth sending; this increase in steps in the process of selection, as with ContentCascade, gives an increased perception of control on behalf of the mobile user. Interestingly, Disc-O-Share varies from the previously-reviewed systems in that the main output component is the user's mobile, providing personal feedback on the interaction. Output from a situated projector to support the interaction (visually marking the proximity regions of each mobile) is explored, but is not found to drastically improve the usability of the system.

2.2.3 Mobile for data input

i. TxtBoard

The TxtBoard artefact represents a means for mobile users to leave messages created on their mobiles at a location for public display via SMS(O'hara et al., 2004).

Figure 8 TxtBoard display

The situated display is intentionally unobstrusive, being well-integrated and situated in a central high-traffic location in order to receive attention as opposed to drawing or demanding attention through large size. The interaction supported by TxtBoard (asynchronous and discrete) encourages brief at-a-glance behaviours rather than sustained interaction, thus enhancing existing processes in the home rather than interrupting or altering them – TxtBoard shares this intention with the similar Hermes@Home system (Lagoudakis et al., 2006), a domestic implementation of Hermes; this aim is in contrast to that of the other systems reviewed in this section that aim to bring new forms of interaction to spaces, altering the behaviour of inhabitants in or visitors to those spaces. While the system practically supports use by users beyond the family occupying the house in which the TxtBoard is situated, the device is coupled to by only the family group during its deployment. The system supports individual rather than multiple concurrent couples and feedback is discrete and serves to disseminate only the most recent text input by a mobile user, thus raising the possibility that messages intended for a particular recipient or set of recipients may be “overwritten” before they are seen; a mechanism is provided by the situated display for the replay of previous messages, yet the fact that the situated display is not seen as a means of trivial message passing appears to have reduced the pace of coupling and thus assured to an extent that messages persist for long enough on the display to avoid the need for use of the replay mechanism.

ii. TexTales

Ananny et al present TexTales, a system consisting of a situated projector and computer to which mobile phones could send SMSes(Ananny et al., 2003). The projector created a large (room-scale, beyond the body-scale situated devices of Plasma Posters reviewed later on) public display on the floor of an outdoor area central to a housing community and displayed a selection of photographs taken and selected previously by members of the community. SMSes sent to the display would be displayed as comments to the photographs, the senders specifying which photograph via the SMS. The location and scale of TexTales were chosen to draw the attention of passers-by, seeking to encourage passers-by to stop and interact, not simply fill pauses. TexTales saw use by multiple users - essentially concurrent coupling although couples were transient - thus responsibility for text added to the display was often ambiguous and accountability was distributed amongst the audience. Here concurrent coupling (rather than solitary) means that accountability may be diluted and thus exploratory interaction encouraged.

iii. Plasma Posters

Plasma Posters are introduced as situated public displays that present content created and sent to the display via email by users (Churchill et al., 2004). The authors deployed a network of Plasma Posters around a workplace, maintaining their operation over a period of two years, aiming to increase a sense of community amongst the workers. Interaction with the situated displays is limited largely to viewing as there is no functionality implemented to allow editing on-location. Carter et al describe an extension of the system to allow “graffiti” to be added to the displays via a mobile device in order to explore the effect of this new ability to edit on-location on the established behaviour of users with the displays (Carter et al., 2004).

An initial observation is that the Plasma Posters received sustained regular attention from potential users, with behaviour similar to that of the TxtBoard family. As with TxtBoard, the potential users of the system are related and already participate in social communication via email; Plasma Posters provide a means of information “staging” similar to yet on a greater scale than that of TxtBoard, i.e. allowing a user to share or disseminate information to a wider audience than would normally be deemed acceptable by messaging systems such as email or SMS. The implications of the extension of Plasma Posters to incorporate the mobile as an authoring tool remains fairly undiscussed by Carter et al; instead findings from trials of the extended system seem to present a greater desire by users to use the mobile as a means of capturing content and discussion from the situated displays for review elsewhere later. Unlike

TxtBoard and TexTales where there are no other data input devices nearby, the apparent lack of use of the mobile authoring capability is unsurprising given the ease with which the Plasma Posters are updated via nearby PCs (in comparison to the unwieldy process of entering text via a mobile device); the clear advantage of mobile devices is the ability to capture and transfer the previously authored content.

iv. Blinkenlights

In extreme contrast to those systems reviewed thus far even the large TexTales situated display is dwarfed by the situated displays produced throughout the Blinkenlights project[15]. As of this review three major installations have been presented publically as part of the projects, beginning with the original deployment at the Haus des Lehrers building in Berlin[16] in September 2001, followed by "Arcade"[17] at Tower T2 of the Bibliothèque Nationale de France in October 2002 and finally "Stereoscope"[18] at Toronto City Hall in October 2008. In each case the project organisers utilised an entire building façade, placing a centrally-controlled array of lights in the windows of the building to create a 2-colour matrix display of 144, 520 and then 960 "pixels". Such displays may be considered city-scale - clearly a class apart from the room-scale display of TexTales.

Figure 9 Blinkenlights situated display used for Pong

[15] http://www.blinkenlights.net/ (accessed 22/2/10)
[16] http://www.blinkenlights.net/blinkenlights (accessed 22/2/10)
[17] http://www.blinkenlights.net/arcade (accessed 22/2/10)
[18] http://www.blinkenlights.net/stereoscope (accessed 22/2/10)

Particularly in the case of Stereoscope, the Blinkenlights displays have been opened to the public to allow public authoring, with submissions of pixel art and animations screened, selected and displayed. Of immediate interest to this thesis is a particularly compelling form of interaction with the public displays - that of coupling with mobile phones for synchronous, continuous interaction with the displays. Bystanders were able to connect their mobile phones to the display by calling a specific phone number, and then (if a free player slot was available) could control their avatar on the display using the mobile's keypad; two users could couple at any one time to play the Blinkenlights' version of Pong (and in the latter two iterations additional classic games). Interestingly, the sheer scale of the situated display in combination with the huge and varied audience of the installations appears to have (from video interviews of participants) rendered the actual player of the game relatively anonymous; the effect of the user upon the display is also transient, feedback occurring only while a user is actually connected to the installation with all trace disappearing when the couple is broken, thus a user may cleanly and quickly disassociate themselves from responsibility for the couple.

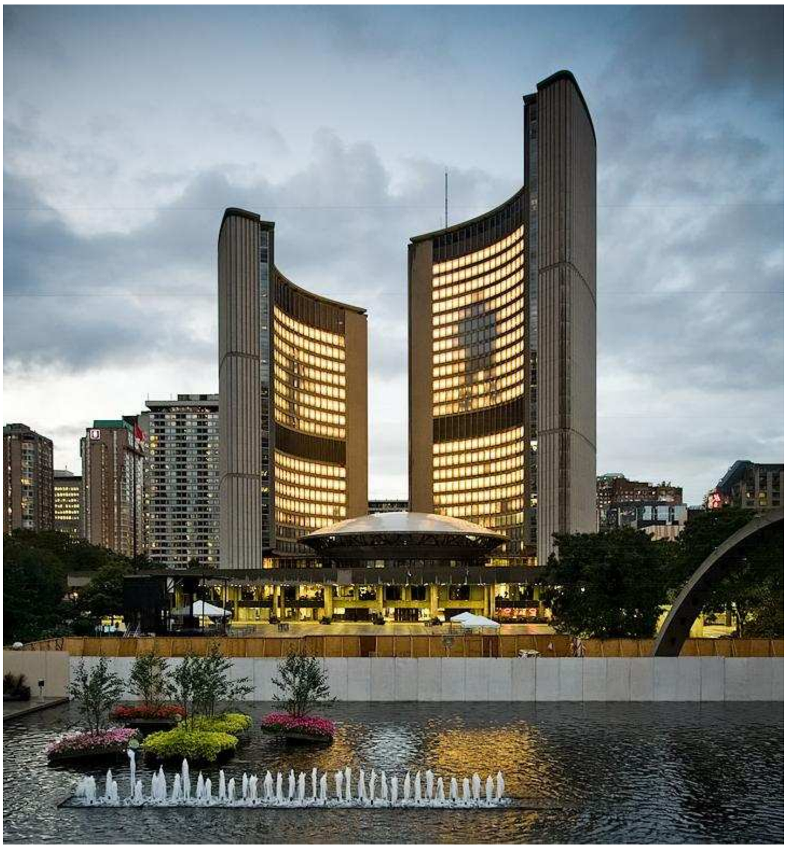


Figure 10 Blinkenlights Stereoscope situated display

Blinkenlights demonstrates the use of the text input capabilities of the mobile device as a means of control rather than for traditional content creation; essentially either type of system is manipulating a data view, yet interactions with Blinkenlights and the results of those interactions are momentary. Polar Defense utilises the mobile phone in a similar manner yet allowing larger teams of users to play together simultaneously via SMS, mobile web-browser or via voice commands (Finke et al., 2008). Like Blinkenlights the installation was deployed in a public space where visitors that were not necessarily familiar with one another would congregate, thus the game is deliberately slower and asynchronous, allowing both for the latency of SMS and for a degree of anonymity to be afforded given the smaller scale and relative closeness of the installation (more comparable to TexTales' display) in comparison to that of the Blinkenlights installations. Key observations made by the authors concern this provision of ambiguity: asynchronous control is suggested as the key aspect of the system for encouraging successful public engagement with the display, with SMS allowing "covert" involvement.

2.2.4 Mobile for transfer

i. Personal Server

The Personal Server, introduced in concept in (Want et al., 2002a) and discussed in more detail in (Want et al., 2002b), is proposed as a means like Internet Suspend/Resume(Kozuch and Satyanarayanan, 2002) of utilising the most convenient and capable of surrounding technologies (both mobile and situated) for tasks, but with the use of a tangible mobile device and without the aim of transferring the same workspace between devices. In an approach closer to that alluded to in the previous paragraph, it is assumed that the applications and services available on different situated devices are those suited to their context and thus the only information carried via the Personal Server is the user's own metadata and the content with which they wish to work, both of which can be transferred to the application devices via the Personal Server. Literally carrying this information is additionally seen as a means of circumventing possible issues with latency/downtime and privacy that may occur when attempting to access data over a wider network. Want et al suggest that use of the Personal Server thus renders the surrounding technology as "scrap", used opportunistically.

The Personal Server has no available computational power beyond that required to wirelessly couple with and transfer content to surrounding devices, and can take no user input except through a simple jog dial or provide direct output of any sort. The authors' stress that the Personal Server is not a replacement for current mobile devices - after all it does not have its own display - but that it is simply a means of linking technologies without reliance upon a wide communication network. Indeed Want et al point out that there are a range of services that the Personal Server could afford that do not require a display, e.g. coupling to restaurant computers automatically while the user walks by in order to create a list of choices for the user on a display later on when they are actually hungry and choosing a restaurant. True as this may be it is no justification for requiring a user to carry an additional separate display-less mobile device (equal in size to a deck of playing cards) in addition to their existing mobile devices. The Personal Server is a key step in the progression towards coupling, exemplifying the potential of the mobile device for coherently linking multiple situated devices to afford effective, personally relevant computing, by acting as a container for personal data and as a form of identification.

There is an additional issue for debate in Want et al's thesis which is that a wireless interface between the Personal Server and the situated technology is fundamentally superior to a tangible interface due to matters of convenience. It is stated that the need to create a physical couple is "troublesome" and that the Personal Server benefits from a lack of an "explicit connection step". This may be true in some cases, yet it is widely accepted that tangibility is an aid to cognition as the use of physical constraints makes explicit and limits interactional possibilities (Ullmer, 2002, Norman, 1991, Zhang and Norman, 1994). For example, in a room with multiple displays and multiple users, each with a Personal Server, the contention for and distribution of situated resources becomes complex; as per Bellotti et al's question of address for sensing systems (Bellotti et al., 2002): how does a user address one particular device and how do they know that it is addressable? Given physical sockets on each addressable device, it is a trivial task to indicate which device the user intends to address (by choosing which device to plug their Personal Server into) and it is immediately clear to a potential user whether or not the situated device has the capacity currently to be addressed (whether there are unused sockets available). In fact the situation in which users must choose which device to couple their Personal Server to never arises in the literature, and the authors state that wireless coupling between the Personal Server and a situated device is lengthy - between 10 and 20 seconds - a shortcoming that they accept, rendering the coupling step potentially lengthy and difficult to understand.

ii. Dynamo

Dynamo is an interactive table-top system, described in (Izadi et al., 2003) by Izadi et al. As many groupware systems and interactive public surfaces do, Dynamo allows multiple simultaneous users to control personal cursors on the shared display and thus collaboratively manipulate displayed content. Interaction between a user and the situated display is synchronous and continuous and of course feedback via the display is public. The display itself (of the implementations discussed in the reviewed work) is comparable in scale to that of TexTales, i.e. beyond body-scale, thus inviting group participation rather than a split between audience and participant. Of particular interest within the scope of this thesis is the content transfer aspect of the system. Dynamo aims to mimic a traditional meeting space metaphor, by allowing content to be physically carried to the surface, then laid out for the group to view together; as such the developers provide two mechanisms for transfer of documents to and from the situated display: base interaction points and mobile interaction points. A base interaction point allows portable storage devices to be coupled with the situated display - doing so allows users do move content from a representation of the storage device on the situated display to the situated display (and vice versa): portable storage devices in this context are analogous to personal content sources and sinks. A mobile interaction point on the other hand allows portable computation devices such as laptops to be coupled to the situated display; in this way the devices can be used as personal control devices in addition to a source/sink for content. The keyboard of a personal laptop can be used to edit content on the shared display in a way that would be difficult (or obtrusive for other users) via the situated display alone. It is not clear whether control using a smaller mobile device such as a phone or PDA would offer much benefit to a group collaborative process using Dynamo - support is provided for the coupling of PDAs to the display via mobile interaction points, allowing content to be created and annotated using the device’s stylus or keypad, yet interaction of this sort is supported more effectively via coupling with mice and keyboards (also possible using base interaction points). More attractive is the use of mobile devices as content sources/sinks to transfer content between such situated devices, or to disseminate content amongst similarly coupled users. A particularly compelling extension of this, as suggested by the authors, is the transfer of identity information so that aspects of the public display may be personalised during coupling; given the fact that mobile computational devices are usually more personal and unique to an owner (e.g. a person will usually have one and only one mobile phone) and are usually carried on their person for much of the day in comparison to more disposable portable memory devices, the mobile device serves well as a form of identification. In later work tabletop arrangements of the situated display are explored in order to more closely relate to the shared meeting table metaphor (Izadi et al., 2005). In these latter iterations the distinction between base interaction points and mobile interaction points are clarified somewhat by referring instead to interaction points where control devices (mice, keyboards or laptops) can be coupled and a device hub to which portable storage can be coupled.

iii. Pick and Drop

Pick and Drop is a much earlier system (Rekimoto, 1997), intended less for supporting group collaboration (although this is discussed as a potential application in the reviewed work) and more for personal convenience, similar to the Personal Server and Internet Suspend/Resume systems which allow a user to easily move content that they are currently working with from one situated device to another to take advantage of the device most suited to the current process. Rekimoto discusses the abstract and unwieldy nature of existing mechanisms to achieve a similar work-flow such as file transfer over a network, suggesting that physical transfer of content is more intuitive; he balances this suggestion with the caveat that for such a mechanism to be intuitive the pick and drop process must be rapid and uncomplicated. Pick and Drop thus uses a pen-style device that is associated with a unique id that can be read by a situated display; upon touching the pen to a piece of content on a display the content is associated with the pen, then a touch to a second display signals transfer of the content associated with the pen to that second display. Naturally the situated devices need to be networked in order to allow both to access the content. The author avoids literal transfer of the content via the pen device due to the form-factor changes that this would necessitate (at the time of writing); more than a decade on Pick and Drop-style transfer between un-networked situated devices using such a small device is eminently more feasible given the extent of miniaturisation over the years. Now portable memory devices and many mobile devices support the transfer of a collection of content; typically the integration of the transfer process into a workflow is not as lightweight as that described by Rekimoto, yet mobile devices have clearly become capable of transfer of working state, as demonstrated by Dynamo and Personal Server.

2.2.5 Mobile for alternative output

i. Pebbles

The aim of the Pebbles project[19] at Carnegie Mellon University is to explore how mobile devices can be combined interactively with other devices (both mobile and situated). Throughout the project several different software systems have been developed; (Myers et al., 1998) presents the first versions of Remote Commander and PebblesDraw which emulate keyboard/mouse controls in Windows via PDAs and control of a drawing program via PDA respectively. More significantly, the two applications allow multiple users to couple PDAs to the same PC and work together in the same application on that PC. In the case of Remote

[19] http://www.pebbles.hcii.cmu.edu/ (accessed 5/8/08)

Commander, the single existing cursor on the situated display is controlled by users via their PDA in turns; PebblesDraw provides a personal cursor for each coupled user on the situated display so that multiple users may interact with the situated display concurrently. In these early iterations of the applications the mobile device serves purely as a means of input to the couple yet in the following years of the Pebbles project the authors create a new application, Slideshow Commander (Myers, 2001), that builds upon their experiences with the use of Remote Commander with Microsoft PowerPoint; Slideshow Commander is more specific than Remote Commander, affording extended interaction only with PowerPoint, rather than with every desktop PC application. The key addition is the use of the mobile as a secondary private feedback channel, allowing the user to view additional information beyond that displayed on the situated public display; in the case of Slideshow Commander the public display shows the current slide in the presentation while the mobile display allows the user to view annotations of the slide, a timer and a list of all slides in the presentation. While other systems reviewed thus far commonly utilise the mobile for personal input, few use the mobile for personal output; this is largely due to a consensus that installation of client software on the mobile is too complicated a process, thus rendering personal output infeasible. Slideshow Commander, amongst a handful of others such as Disc-O-Share illustrate that there are compelling reasons to explore the use of mobile devices beyond personal input. An interesting additional observation regarding such systems is that this personal feedback clearly separates the coupled user from bystanders; in systems where the mobile affords personal input the participant clearly has an elevated status over the bystander, yet the two share feedback - one is not better informed than the other - yet this is not true of users of Slideshow Commander, Disc-O-Share and other personal output systems, where the participant is the recipient of additional information over that provided for public consumption.

ii. Total Recall

Holmquist et al present Total Recall (Holmquist et al., 2003). The system utilises commercial technology in which a standard whiteboard is fitted with spatial sensors that track pens used to annotate the board surface; movements of the pens are recorded so that all annotations are therefore recorded in both time and space. Total Recall extends this commercial implementation to allow the annotations to be replayed using a PDA coupled to the whiteboard; the PDA is tracked as it is moved over the surface so that it may afford a view (by looking through the PDA display) of the annotations at the positions they were made. Total Recall assumes firstly that the annotations are more meaningful when replayed in the context in which they were made - the whiteboard - rather than on a separate computer screen. Secondly the system acknowledges that the whiteboard is a contentious resource, thus annotations that are valuable to some may be edited or removed by others to whom they are less valuable. As it is described in the cited paper, Total Recall allows one mobile to be coupled to the whiteboard at a time so that users must take turns in replaying annotations; a significant suggestion made by one trial user of the system is that the annotations be disseminated to the mobiles of all bystanders so that multiple users may couple simultaneously. Indeed, users might avoid the conflicts this could cause (with multiple users attempting to move their mobiles over the same surface) by using more than one situated display mirroring the original annotations. Total Recall is particularly interesting as it allows the mobile owner to not just view a specific part of the public content that is interesting, but also a specific time in the life of the content that was interesting, i.e. the mobile provides a personal viewpoint that is variable in both space and time.

iii. MobiDiC

Presented by Müller et al, MobiDiC is a system allowing the coupling of mobile phones to public situated displays to support navigation (Müller et al., 2008). The system is interesting for several reasons. In particular, due to its use in navigation rather than for a purely situated interaction (unlike other systems reviewed thus far) MobiDiC emphasises the role of the mobile rather than that of the situated device; almost all of the user interaction is with the mobile alone - coupling plays only a small part in the entire interaction. MobiDiC is an additional example of the combination of mobile and situated devices for additional forms of output; in this case the authors aim to extend the work of Beeharee et al (Beeharee and Steed, 2006) - which finds that on the one hand photographic trails provide an intuitive guidance mechanism for mobile users, yet the overview provided by maps also play a significant role in correcting navigational errors and disambiguation - by providing both photographic trails (on the mobile) and maps (on situated displays). The system requires that a user couples their mobile with one of a number of public displays situated throughout a city; the user chooses a destination and the situated device constructs a photographic trail client application which is transferred to the mobile. The user can then step through the photographs on the trail as they walk, following the path to their destination. Each path is constructed so that it passes one or more of the other situated displays; when a user nears a situated display the display alters (from advertisements) to a map of the remaining route for that particular user, allowing them to gain an overview of the area. Key to the discussion at this stage of the review is the reasoning behind the use both mobile and situated devices for this task: Beeharee et al found that while maps did play a useful role in navigation (as borne out by thousands of years of history) the wide range of techniques developed to allow the display of maps on mobile displays did not tend to alleviate the fact that the display is simply too small to provide the detail desired by many users. Situated displays on the other hand may be much larger - as large as, if not larger, than paper-based traditional maps. In practice, the users of Müller et al's system used the situated displays very infrequently: this is partly due to issues in their deployment, but also partly due to the overriding focus of the user on either the mobile's interface or on the environment (while trying to spot the landmarks pictured in the photographs). This hand-off of user focus from device to device is an issue not yet raised in the other works reviewed (except briefly through haptic feedback to draw the user's attention to the mobile in Touch and Interact), and for which there is no provision in MobiDiC - the system relies on the users noticing the situated displays of their own accord.

iv. Rotating Compass

Rotating Compass is a system combining mobile phones and situated projectors to enhance navigation in buildings (Rukzio et al., 2005). Using the mobile, a user specifies an intended destination which is disseminated to devices situated at navigation decision-points within the environment. As the user then walks through the environment the situated devices scan for the user's mobile; at the same time all situated projectors display large compasses on the floor at the different decision points in the environment. The compasses highlight one exit from their junction, then another, and so on, cycling through all possible exits regularly. When the user approaches a junction, the situated device at that junction polls the user's mobile every time it highlights the exit that the user should take. In response the mobile vibrates, allowing the user to "feel" the correct exit without having to look at their mobile. The system can support many users simultaneously as the output of the situated projectors is public and generic; personal feedback occurs instead via the mobile device. This personal feedback is also highly private as it is tangible rather than visual and thus cannot be observed by bystanders. In user trials the authors found that the Rotating Compass system afforded more rapid navigation than navigation systems built upon maps, photographs or other visual cues; it may be suggested that there is no need for the user to reconcile a visual model with the real environment, thus pauses do not need to be taken to pay attention to the mobile. Feedback from the mobile in relation to the public display is highly synchronised and continuous, correct timing clearly being crucial to the effectiveness of the system.

v. UbiCicero

Ciavarella and Paternò introduce a mobile guide application: Cicero (Ciavarella and Paternò, 2004). This original application runs on PDAs and utilises communication with infrared beacons situated around the museum to update the mobile display to indicate to the user where they are and to allow the user to trigger multimedia relevant to their surroundings. Of greater interest are the developments made to Cicero to create a new system name UbiCicero (Ghiani et al., 2008). In this later system, the IR beacons are replaced with active RFID tags and social games are added to the museum to enhance learning. The games are displayed on a number of public situated displays in order to a) encourage discussion amongst visitors, and b) to extend the input and output capabilities of the mobile devices. Each situated display in the museum can have one of several states: when no mobiles are coupled visitors who do not have a mobile can use the screen's own keyboard and mouse to view museum content; when one mobile is coupled the situated display can be used to view rich content related to a personal game which the user plays through their mobile's keypad/touch-screen; when many mobiles are coupled the situated display shows the progress of a collaborative/competitive team game controlled by all of the players via their mobiles. The large screen can also serve as a means of locating other players by visualising maps of other visitors' locations. The affordance of suitable interaction for both group social games and individual private games is achieved through differing delegations of the output between the mobile and the situated displays: a private game allows input and feedback regarding the results of any answers given by a player on the player's mobile display, thus a bystander can only see how the player's game is progressing with difficulty. A social game uses both mobile and situated displays as channels for feedback of the game's progress.

vi. Modigliani's House

Modigliani's House is an interactive museum exhibition developed as a demonstrator for Garzotto and Paolini's mobile-phone to situated display coupling framework (Garzotto and Paolini, 2008). In order to demonstrate the mobile phone as identification device, input device and feedback channel the authors deploy a number of different situated displays that can be activated and controlled via a visitor's mobile phone, allowing the visitor to choose to view certain content, have content recommended, and capture content. Any content captured from a situated display to a mobile can be replayed either on the mobile or on one of several other public displays situated in the café attached to the museum. In all cases input takes place only through the mobile device, while output is split between the mobiles and situated devices. Interestingly, even though the mobile devices are used as personal output devices, only one visitor may control a situated display at a time; a mechanism implemented by the authors to allow social interaction with the situated displays affords one user control over the situated display and over audio streamed from the situated device to multiple nearby mobile devices, thus one user controls the coupled interactions but many users may enjoy synchronised feedback, such as an audio story, from the couple. Also significant is the authors' consideration of the merit of interaction installations in comparison to non-interactive artefacts in the exhibition: interactive exhibits are not deemed superior and so the authors aim to integrate the situated devices into the environment well, hiding them in many cases until the visitors intend to use them. Mobiles are used as triggers to uncover these hidden situated devices when necessary. The authors describe how dynamic lighting is used to create "contextual hooks" that draw visitors' attention to exhibits at the most suitable moment. In this way, Modigliani's House illustrates particularly well a need that has seen little discussion in the work reviewed so far, i.e. the location of situated devices in an environment that supports many different couples. The description of Modigliani's House implicitly suggests that in multiple-couple environments certain situated resources are suitable in certain contexts, while being unsuitable in others. As such a visitor's journey through these environments may need to be mediated such that their attention is directed to contextually-suitable situated devices; Garzotto and Paolini's contextual hooks are one means to such an end, MobiDiC's use of photographs to guide from situated display to situated display is another.

3. The coupling environment

So far little discussion has been seen in the literature regarding the coupling *environment*, by which the wider context is referred to in which a user has opportunities to couple their mobile with many different situated devices in different locations. The mobile is potentially a gateway to situated resources, coherently linking multiple situated devices to afford effective, personally-relevant computing, by acting as a container for personal data and as a form of identification; now literature pertinent to the role which the mobile device assumes while decoupled is presented.

If a system has knowledge of and can understand a wider context, logic can be implemented in order to adapt the services provided to be more relevant to the users who interact in locations and with desires that are equally heterogeneous. Within a coupling environment mobile and situated devices are able to communicate and share contextual information; knowledge of context shared between mobile and situated devices enables two processes:

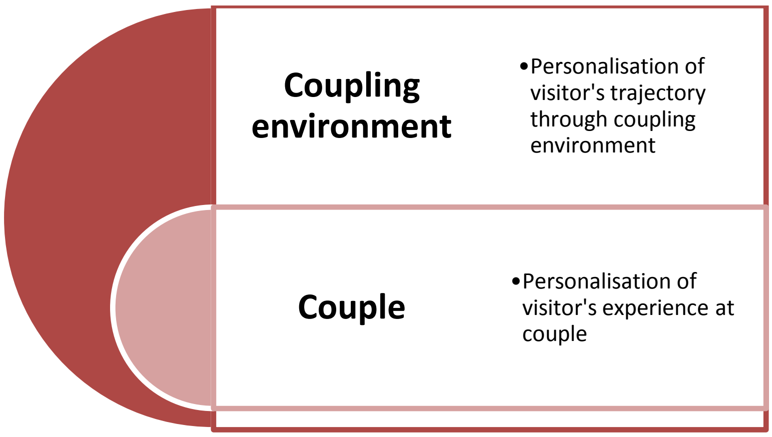


Figure 11 Contextual personalisation at the level of the couple and the coupling environment

At the level of an individual couple, the knowledge of context allows interaction with a situated device to become personally-relevant (as a bank card allows personalised interaction with a generic ATM); at a higher level, knowledge of context allows the personalised exploration of environments to discover and choose amongst the opportunities to couple with many situated devices, and to link sequences of these opportunities coherently.

Consider, for example, the following scenario assuming that both mobile and situated device may freely share and monitor context:

> *A user wishes to catch a bus to their house from the city centre. They do not want to use their mobile network to query for bus times as data rates are too high; they have stored this preference in their mobile. However, their mobile can determine its general location from its current cell ID, and has the locations of several public displays stored in its mapping software database, thus the mobile prepares to direct its owner to use one of these displays to access the required travel data. The phone determines the closest set of displays and provides the user with a choice. The user picks one particular display then the user's mobile displays a set of photographic directions. Once the user has followed these and reached the area of the display, the display looks up and filters the bus data and offers the user a choice of bus times and departure locations, ranked by distance and waiting time. The user makes a choice which is transferred to their mobile after which the mobile provides directions from the access point to the bus-stop. The user sends a text-message to their partner letting them know when they will be home. Once at the bus-stop, the user pairs their mobile to the bus-stop's Bluetooth access point, which pushes a notification to the user's mobile when the bus is nearby.*

In this situation the user makes use of the mobile for selection (choosing from the displayed timetables) and transfer (taking away chosen pieces of information), but in addition the mobile provides the public display with detailed user context that it could not sense otherwise (in this case the user's schedule and preferred language) in order to personalise the interaction. In addition the use of spatial context, along with user choice allowed judgements to be made about which situated devices were most suitable for the visitor, and for the process of navigating to those situated devices to be mediated. Context allows the entire experience to be *orchestrated* by the user and system such that it is personally-relevant and coherent. In this chapter literature is explored that relates to this orchestration.

The process of *user modelling* refers to "analyzing a user's interaction with a system and … developing cognitive models that aid in the design of user interfaces and interaction mechanisms" (Jaimes, 2010), thus encompassing the description of a user and/or their behaviour in the form of a model, and notions of how those models can be used to adapt the user's environment to afford desirable interactions. User modelling forms the basis for many recommender or personalised systems such as ILEX (discussed in section 3.1) and those reviewed in section 3.2. There is a large and established body of work on personalisation and user modelling (also considering adaptation in public environments, e.g. (Wang et al., 2009, Zancanaro et al., 2009)) and a complete review of this literature is beyond the scope of this thesis. Instead, only significant pieces of literature (with regards to the discussion of coupling) continue to be pulled out in the remainder this chapter, demonstrating firstly key pieces of literature *describing* aspects of context that support the orchestration of the user experience in the coupling environment, then work illustrating examples of how this orchestration has been achieved by existing systems.

3.1 Describing context

Contextual attributes and entities

Schilit et al divide contextual information into three categories (Schilit et al., 1994, Schilit and Theimer, 1994):

1. Computing Context - network connectivity, bandwidth, and nearby resources such as printers, displays, or workstations.
2. User Context - the user's profile, location, nearby people, and current social situation.
3. Physical Context - lighting, noise level, traffic conditions, temperature.

In such a view of context, the distinction amongst contextual variables lies with the scope to which they apply. Revisiting the scenario described previously, aspects of user, computing and physical context and the dependence of the interaction that occurs upon them can be isolated. The user's mobile has knowledge of computing context to the extent that it is aware of the location of computational resources (mobile phone network, wifi access points, Bluetooth access points) and of the costs/bandwidths associated with the use of those resources. The device is also aware of user context in terms of its owner's location, preferences and the goal that the owner is attempting to achieve. Regarding physical context, the mobile can derive knowledge of the traffic around the city and thus alert the owner to the presence of the desired transport services.

O'Grady et al propose five categories of context from the point-of-view of the mobile user (O'Grady et al., 2007), extending those of Schilit et al. The latter's computing context is subcategorised into the host device profile (i.e. the computational profile of the owner's mobile), the surrounding electronic resources (i.e. other computational devices) and the network environment (the connections between the computational devices). This subcategorisation emphasises the practical issues considered by O'Grady et al, i.e. the significant impact of the heterogeneous nature of the computational context upon the experience of multimedia through mobile devices.

In addition to the contextual attributes suggested by Schilit et al and O'Grady et al which are linked to the type of contextual entity, Baldauf et al suggest a range of key contextual attributes common across all entities (Baldauf et al., 2007):

- identity (each entity has a unique identity),
- location (an entity's position, co-location, proximity etc.),
- status (temperature and lightning for a room, processes running currently on a device etc.) and
- time (the entity's activity history).

While these attributes are general, the base attribute in each case affords derivation of richer contextual information, e.g. an absolute position of an entity allows spatial relations between that entity and other entities to be derived, while the combination of position with time allows the spatial behaviour of an entity to be derived. Contextual attributes are rarely treated in isolation; the majority of their potential arises from their specific combination for the task at hand.

Chalmers (along with an increasing amount of more recent user modelling literature) promotes the inclusion of history into a definition of context, stating that history or time as an additional dimension of context is a significant and common consideration in everyday activities (Chalmers, 2004). Specifically, he builds upon Dreyfus' three modes of activity - breakdown, analysis and contemplation (Dreyfus, 1990) - which he refers to as an "ongoing 'feedback loop' of activity, interpretation and understanding" (in addition to self-presentation) to propose that not only does context consist of the history of one's own actions but also the interrelation of one's actions with the actions of others. We act in the world based upon what we have achieved and learnt previously, and what we observe of others. Chalmers refers to the George Square system developed during the Equator project[20] as an example of use of historical context; this system is reviewed later in the section.

Oberlander et al discuss coherent sequences of interactions suggesting that coherence amongst interactions, like a natural conversation, depends upon a number of factors not least of which is, as Chalmers echoes, a consideration of past actions (Oberlander et al., 1997). The authors utilise the Intelligent Labelling Explorer (ILEX) hypermedia system (Hitzeman et al., 1997) to demonstrate how a user's history of interaction can be used to alter future interactions; Oberlander et al make a key suggestion regarding the implementation of historical awareness in context-aware systems: the authors claim that a consensus amongst designers of hypermedia systems is that if a user revisits a resource then they expect to interact with that resource in the same manner again, i.e. the interaction is repetitive. Instead, they propose that interaction should mirror more closely human conversation in which a topic would

[20] http://www.equator.ac.uk/ (accessed 22/2/10)

be discussed in a different manner if it was revisited later - it is likely that the speakers would have had experiences in the meantime (e.g. conversations with others) which would affect the second conversation, i.e. the speakers would restate their new opinion, not simply repeat what they had said previously. As an example, Oberlander et al discuss how a description of a jewellery exhibit may make reference to a number of other exhibits in order to illustrate a comparison of different styles of jewellery design; if a visitor has not yet seen these other exhibits then the references will mean little, thus on the first visit to the original exhibit the description is shortened to avoid making the references. If the visitor then visits the other exhibits and returns to the original piece of jewellery, the description will be extended to make a comparison to those other exhibits viewed by the visitor, providing them with an extended yet cohesive experience.

Formation of context

Turning for now from the question of what context is, the review considers briefly how contextual information is formed, or acquired from a situation. Baldauf et al suggest five layers involved in the retrieval, processing and presentation of context (Baldauf et al., 2007):

1. sensors,
2. raw data retrieval,
3. pre-processing,
4. storage/management and
5. application.

The first two levels refer to the acquisition of context; pre-processing of this 'raw' context results in a model or perspective of context relevant to a particular application, storage/management distributes contextual information to the components of a system where it is useful, while application of the information might then take place subsequent to these earlier processes. The review focuses now on the first two of Baldauf et al's layers.

Discussing pervasive systems in general, Indulska & Sutton categorise sensors into three types(Indulska and Sutton, 2003):

1. physical (microphones, cameras, switches, etc.),
2. virtual (sensing virtual events such as page views, etc.) and
3. logical (derived sensing, combining context from other sources to form a conclusion).

Despite a limited scope for physical sensing on mobile devices, there is significant potential for virtual and logical sensing in a network of situated and mobile devices, a mutually beneficial distribution of context amongst mobile and situated devices offering a greater degree of context-awareness to all devices.

In his doctoral thesis Chen discusses three approaches to the formation of context from a perspective of system design (Chen, 2004), one of which is acquisition from a context server. The acquisition of context from a context server represents the most computationally-light approach to context formation by a mobile device. In such an approach context-sensitivity may be provided even to devices that have no sensing capabilities and offloads context acquisition/processing to resource-rich devices. Such an approach mirrors a key tenet of ubiquitous computing by delegating the process (in this case context formation) to the devices in the environment most capable to perform the process. The Me-Centric Domain Server architecture, described conceptually and technically in (Hp and Perich, 2002), aims to abstract the processes of acquisition and storage/management from those devices aiming to use the context. Entities within specific environments are monitored using sensors situated within the environment, with a common yet extensive model of context defined using general rules which can be queried by client devices as and when necessary depending upon their desired application. A knowledge of the context model (and, practically-speaking, a knowledge of the interface with the Me-Centric Domain server) on behalf of the client device is necessary, yet no overhead is required by those devices for the maintenance or compilation of the model.

In a coupling environment there are two sets of devices - mobile and situated - through which context can be formed and interaction can be contextualised. It has been suggested and seen in previous example scenarios that mobiles utilise or present contextual information that can only be provided by other devices. Issues with middleware on mobile devices due to resource constraints lead to a more pressing need for access to logical results of a distributed sensor network. Use of a context server is often highly desirable for mobile devices as they can contribute where possible yet the majority of resource intensive processes (retrieval, pre-processing, storage/management) are delegated to other dedicated devices; integrity and security of the contextual information can also be thus assured to a greater degree. Context relating to a particular entity, e.g. a mobile user, may also then be accessed easily by other entities. Situated devices afford a wider range of physical sensing, the results of which may be stored in and disseminated by a context server.

3.2 Utilising context

As noted in the introduction to this chapter, context might be utilised to create coherent, personally-relevant experiences in the coupling environment, a process occurring both at the level of the individual couple and in the coupling environment. The review now briefly covers personalisation of the coupled experience before focussing on the orchestration of the broader experience of the coupling environment.

3.2.1 Context at the couple-level

Initially two examples of systems that utilise context to adapt the interaction while the mobile is coupled with a situated resource are considered. In both cases the information presented by the surrounding resources is contextualised, being adapted depending upon which user is near to the situated devices; presentation of the information is contextually-triggered, occurring only when the users are near.

The first system is BluScreen (Karam et al., 2007, Sharifi et al., 2006). In this case the extent of context used is minimal, limited to particularly useful aspects of user context; situated displays continuously search for users (user entities), determining the location of users according to whether or not their mobiles' Bluetooth radios can be detected, their identity according to the Bluetooth address of the detected radio, and the history of interaction with the user. The situated displays attempt to display adverts when a user is near enough to view them (i.e. when user location is determined to be within a particular proximity, in this case close enough to be detected via Bluetooth is deemed to be close enough for the user to view), i.e. the adverts are triggered by locational context, and the content of the adverts is personalised according to the adverts that have previously been seen by the users. In the case of BluScreen, the system deems that a repeated advert is of no value to the user, thus the system aims to display only new content to a user, using interaction history as a guide, much as Oberlander et al's ILEX did. The system aims to avoid the use of user context beyond that which can be derived either from previous interaction or sensed without interaction with the user (for example to request user preferences).

As Sharifi et al and Karam et al did regarding BluScreen, Narayanaswami et al suggest that situated displays are more capable than mobiles for the display of visual adverts (Narayanaswami et al., 2008). Narayanaswami et al draw upon the notion of device symbiosis (Raghunath et al., 2003) to discuss symbiotic advertising via a prototype system named

Celadon. In comparison to BluScreen, Celadon utilises similar attributes of user context, i.e. location and interaction history, to trigger and personalise adverts on situated displays respectively, yet the system also makes use of explicitly specified user preferences by referring to the activities of the user in the past. The interaction history used to derive these preferences is necessarily more extensive than the history utilised by BluScreen (simply which adverts have previously been shown when the user was near), consisting of previous interactions made by the user with the services being advertised, e.g. transactions made with vendors.

Celadon aims to provide the user with suitable content based upon previous interactions whereas BluScreen assumes that the most suitable content is the content that the user has not seen before rather than that which is similar to what has previously been preferred. In both cases, the systems assume that the user has either made their own way to the situations where the interaction with the situated displays occurs, with contextual information used to make the resulting interaction as suitable as possible for the situation into which the user has walked. These systems are examples of an extension of purely mobile context-aware systems to take advantage, opportunistically, of situated technology for presentation through coupling. The mobile acts purely as a means of identifying the user, providing the situated devices with a means of linking the relevant components of a global user history and preference repository to a particular user. The systems do not provide much of an extension to the interaction afforded by other identification tokens such as bank or identity cards save that their presence can be detected passively rather than requiring the owner to present the token to the situated device.

Of particular significance is a lack of examples of a wider use of context to personalise coupled interaction. If those couple-based systems reviewed in the previous chapter are considered only minor evidence may be seen that context has been used to adapt the interaction that occurs when the mobile is coupled with a situated device. Naturally, locational context on a micro-scale affects those couples that utilise spatial relations between mobile and situated device: C-Blink (p.31), for example, utilises "locational context" to affect the behaviour of the cursor on the situated display, while in Disc-O-Share (p.40) the locational context of multiple mobiles coupled with a situated device influenced the interaction. Knowledge of user identity is utilised at a superficial level in Hermes, where the user is greeted upon coupling. In a more extensive manner, user identity and interactional history personalises the output and behaviour of the Dynamo (p.47) situated display. There is also evidence of contextual adaptation in couples that afford feedback through the user's mobile device, i.e. where the mobile device is used as an alternative output, e.g. Pebbles (p.49) provides a view of content that is personalised for the user via their mobile device by discriminating amongst different user identities. Total Recall (p.50) is an interesting comparison to these two systems as the view provided by the mobile is personal, yet it is not personalised based upon contextual information, instead the user can alter their view independently of the view provided to other users.

3.2.2 Context while exploring the environment

One of the most obvious of observations to be made of the coupled systems reviewed is the lack of multiple opportunities for coupling combined in any one environment. As stated previously, there is the possibility that such opportunities will proliferate so that in a local environment there may be many. Reconsider the scenario at the start of this chapter: it is clear that a variety of contextual information is used in this scenario, ranging from user preferences to location. There is a cycle of choice (of a particular public display), movement (to the chosen display), personalised coupled interaction (with the display), choice (of a particular bus-stop), movement (to the chosen bus-stop) and personalised coupled interaction (with the Bluetooth point at the bus-stop) in action.

Hornecker et al. discuss entry points (introduced in (Kirsh, 2001)) and access points: design features that invite use and afford use respectively (Hornecker et al., 2007). In Hornecker et al.'s view of the definition, entry points are considered as contexts in which users are enticed into starting an interaction with a system; in the scope of coupling, entry point is a useful term to describe the situation where a visitor has discovered a situated device, e.g. when the visitor in the scenario learns of the public displays with which they may interact. Discovering an entry point does not however guarantee that interaction is actually possible, e.g. discovering a public situated technology does not necessarily mean that it would be wise to couple with the device, and the authors refer to Brignull's thesis in which entry points (in the context of public displays) are seen as either open or closed referring to whether or not they provide both entry and access, or deny access respectively (Brignull, 2005). A key objective of the use of context in this scenario is not just to personalise coupled interaction but to create and link a sequence of suitable couples cohesively, i.e. to ensure that the situated technologies are open or closed at the times that afford the most meaningful coupled interaction. The mobile and environment cooperate to determine and allow the visitor to discover a sequence of personally-relevant couples using a variety of information, including device capabilities (remembering that mobile devices are heterogeneous), user intentions, the locations of technology and the locations of other resources, amongst others. From here on this cyclical process is described as *exploration*. From the example scenario the observation has been made that an entry point may well be dislocated from a corresponding access point to the same coupling opportunity: the user learns of the location of the bus-stop while themselves located at the wifi point, thus this location (or context) is the entry point as they have become aware of and have formed the intention to interact with the bus-stop here; the user only begins interaction with the bus-stop via Bluetooth when they reach the bus-stop, thus the access point is both dislocated spatially and temporally from the entry point. Exploration of a coupling environment may therefore be summarised as 1) choice of - or entry point to - the next suitable coupling opportunity from those opportunities visible in a representation of current context, followed by 2) conception of a route bridging the gap between entry and access point to the chosen coupling opportunity, and 3) the mediation of the traversal of that route.

Both mobile and situated technologies may play a part in supporting both choice and movement aspects of exploration. The review continues first to regard context-aware systems that aim to achieve cycles of exploration and interaction using the mobile device to mediate exploration.

i. Mobile-mediated exploration

There is a well-known collection of context-aware systems that support exploration that are based upon map overviews of the environment. The Cyberguide (Abowd et al., 1997) is commonly cited as one of the earliest examples of an implemented context-aware mobile guide. In the Cyberguide system a mobile device provides a map overview of an environment - this overview alters depending upon user context centring upon the mobile's present location (analogous to its owner's location) and altering in scale to attempt to display both the user and the user's destination. Context beyond the user's location and the user's choice of destination is not used, thus the mobile simply presents context (the user's location, the surrounding architecture, the locations of surrounding situated resources and simple descriptions of these resources) in order to allow the user to choose the next resource with which they wish to interact, then supports the process of movement to the choice by continuously representing an overview of the user's physical context. No explicit guidance to the chosen resource is given and no attempt is made on behalf of the system to influence the choice of the user: all context represented is objective. The authors discuss the possibility for the inclusion of more subjective context, in particular reviews of resources by other users, in future iterations of the system. Also of note is the fact that Cyberguide, like the other systems here, do not link *couples*, but instead link situated resources. The guide developed by Simcock et al (Simcock et al., 2003) is very similar to Cyberguide, representing an overview of the environment to the exploring visitor, centred on their location, showing the relative locations of particular situated resources near to the visitor; as with Cyberguide, media is triggered on the mobile device when it detects that it is within a certain proximity of these situated 'hot-spots': the mobile acts more as a means of viewing an information space, as in the first use case of the Chameleon discussed previously.

As part of the HIPS project[21], Oppermann & Sprecht present Hippie (Oppermann and Specht, 1999), a mobile guide that extends the concept implemented Cyberguide. Hippie supports behaviour similar to that of Cyberguide whereby user choice allows the mobile to guide the user to a particular location, where these locations are contextual triggers, triggering the display of information (related to the trigger location) on the mobile device. Locations may also act as contextual triggers without having been specified as a destination by a user beforehand, thus contextually triggered information can be stumbled upon in a more opportunistic manner, as with Simcock et al's guide. The major extension provided by Hippie is the personalisation of the representation of context, i.e. the suggestion or revelation of points-of-interest, based upon the visitor's history of interaction and explicitly specified user interests. If a point-of-interest is deemed particularly relevant to the visitor according to these aspects of context then it may be advertised to the visitor as the starting point of a smaller tour of points-of-interest that share the common interesting feature, i.e. providing both an experience at that location and a lure to the next, related experience. This system differs from the other systems reviewed thus far in that some degree of control over the exploration is retained by the system; while the visitor is still free to move as they wish within the environment certain points-of-interest are promoted more than others by the mobile. The system utilises this control to attempt to provide visitors with a more relevant and coherent sequence of experiences within the environment. There is very brief discussion of the potential for obstruction of the visitor experience through over-control: it is suggested that this would be more likely in environments such as art galleries where the value of the experiences to a visitor cannot so easily be estimated by a system through user context.

The GUIDE system takes a more cautious approach, allowing visitors to specify a series of interesting points-of-interest, then choosing the most suitable order for the visitor to experience them, providing navigation support between the points-of-interest (Cheverst et al., 2000). If a tour is not generated by the visitor in this manner, the system reverts to behaviour

[21] http://cordis.europa.eu/esprit/src/25574.htm (accessed 22/2/10)

similar to that of Hippie, advertising nearby points-of-interest prioritised according to both user context (including interaction history and interests) and the context of other relevant entities in the environment (e.g. the closing times of the points-of-interest). Interestingly the authors receive feedback regarding the added complexity of the system incurred by reducing the amount of control exerted by the system; while still offering the ability to create structured relevant tours, the functionality to allow visitors to structure these themselves before the tour starts and to restructure or deviate from the tours once begun added complexity to the exploration process.

CRUMPET supports exploration of tourist environments providing map overviews and, like other systems described here, advertise situated points-of-interest deemed relevant to the visitor (Poslad et al., 2001, Schmidt-Belz et al., 2003). Relevance is based upon user context, including location and preference (explicitly specified and learnt by the system over time). SmartRotuaari is a more extensive context-aware mobile system combining point-of-interest information, a map overview, personalised advertising and, in addition to these more common features, a 3D historical VR view of the immediate surroundings (Ojala et al., 2003). Unlike other systems reviewed here, SmartRotuaari is commercially-backed and thus the aim of personalised advertising is two-fold: seeking to advertise resources that are interesting to the visitors, and services and products that the visitors are most likely to pay for.

Two further map-based mobile exploration systems are reviewed here - the George Square guide (Brown et al., 2005) and Magitti (Bellotti et al., 2008) - as they introduce an interesting aspect of user context, i.e. the relationships between different users. As with previously mentioned systems, the George Square system suggests interesting content based on historical context, i.e. visitors past behaviour (using RECER (Chalmers et al., 1998)) but also on the behaviour of other users. The system attempts to determine which users are similar, then cross-recommends unvisited points-of-interest that similar users have already visited. To achieve this, centralised context management is necessary - user context of all users is aggregated so that relationships can be determined and utilised. Magitti attempts a similar approach, comparing the reviews given by visitors for restaurants and shops with specified and historical preferences to determine which points-of-interest to advertise in the future as the visitors travel through the environment.

Mobiles can also mediate the location of points-of-interest in a range of less traditional ways. Egenhofer describes four Spatial Information Appliances (SIAs) in an attempt to divert some design effort from more traditional ‘desktop-oriented’ GIS mechanisms in order to take advantage of increasingly powerful mobile computing components (Egenhofer, 1999):

1. Smart Compasses (directing a user in the direction of a POI);
2. Smart Horizons (allowing the user to see beyond barriers);
3. Geo-wands (allowing a user to choose POIs about which to gain extra information); and
4. Smart Glasses (creating overlays of useful information onto the real-world).

The four categories of SIA illustrate a consideration of both the traditional map overview’s benefits - allowing the visitor to see beyond the limits of their literal sight - and the view-based mechanisms such as photographic trails which utilise only that which the visitor can see and are thus more accessible and arguably precise. Egenhofer’s SIAs were not necessarily intended to be implemented using the mass-market mobile devices available today (except the Smart Compass, visualised as being implemented on a PDA), instead tailored portable devices were envisioned for each application. Fröhlich et al. attempt to refine Egenhofer’s SIA concept and concentrate upon applying the concepts to mediate the access of information or services attached to physical places using mobile devices (Fröhlich et al., 2006). The following four metaphors are proposed by the authors and are implemented and evaluated through user trials:

- Selection (specifying a POI to receive information about);
- Search (actively pulling information regarding nearby POIs);
- Sniffing (passively receiving information regarding nearby POIs); and
- Remote viewing (receiving information about remote POIs).

At a conceptual level, many of the map-based exploration systems reviewed previously implement these four metaphors: almost all systems allow selection of points on a map to trigger content relevant to those points, and due to this selection being afforded by an over-view many selections lead to remote viewing; there is a balance between sniffing and search depending upon whether the system advertises points-of-interest without being asked or the visitor actively asks for information – a number of systems utilise both mechanisms, advertis-ing while allowing adverts to also be pulled at will. Fröhlich et al investigate more intuitive implementations of these four metaphors in comparison to the map and pop-up advert model. The authors found a strong support for pointing gestures for selection and aug-mented-reality views as mechanisms for local search, especially from visitors who were less comfortable or able to read maps. Much of the positive feedback given by the trial subjects for the most visual of mechanisms - maps and augmented views - pertains to the ease with which physical landmarks can be identified; in particular, both allow the large landmarks visible in the outdoors environment in which the system was trialled to be easily identified. Such landmarks may not exist or be so visible in other types of environment, such as art galleries or museums.

ii. Situated devices supporting exploration

Having discussed examples of mobile exploration the review now turns to several examples of the use of situated technologies to aid in exploration. A key difference between the use of the mobile and situated devices is that the former can be addressed at all times, to provide synchronous guidance, whereas the situated technologies can by definition only offer discrete instructions. This observation may be logically extended to suggest that mediation by situated technologies, like static conventional signage, tends to occur in multiple steps that progress the visitor towards a goal rather than continuously providing direction. Coupling may indeed not necessarily be an end in itself, but may be used to mediate the journey of a user towards another coupling opportunity. Hornecker et al. discuss this mechanism using the term progressive lures (Hornecker et al., 2007). The term, originally introduced by Lidwell et al (Lidwell et al., 2003), is used by Hornecker et al. to refer to a step-by-step progression through a system via a series of entry points that each promise rewards and lead to the next. This notion might be applied to both the navigation towards a location via multiple steps, but also to a sequence of couples that are related and build upon one another somehow. This mechanism can be seen at work in the scenario outlined at the start of this section: the user first became aware of the opportunity to couple with the wifi access point in order to learn of suitable bus times (entry point); the user navigates to the wifi point and receives the data (access point); the user then becomes aware of the bus-stop (entry point); the user navigates to the bus-stop where they wait for notification of the bus (access point). The user is thus led from entry point (to access to point) to entry point (and again to access point), following a trail.

The MobiDiC and Rotating Compass systems are revisited here: both systems utilise the mobile in a couple as an alternative output, yet use a combination of user location and user preference to personalise the coupled interaction. In each case the user registers a preference before the coupling occurs, i.e. a location that the user wishes to visit; when the user then couples with one of the systems' situated devices, the device compares the location specified by the user with the current location of the user (deemed based upon the situated device's knowledge of its own location with regards to that of the other situated devices) in order to provide the user with personally relevant directions. In both systems the couples provide the user with a set of directions towards a situated resource: possibly another situated device, but more likely a non-computational point-of-interest. Unlike BluScreen or Celadon they do not aim to contextually reconfigure nearby situated devices to be as useful as possible in a particular context, but assume that the most useful resources are most likely to be not near the user and that the user will want to discover remote resources (couples or points-of-interest) and need to be directed to them, or that the user needs to be directed to resources that are most coherent as the next point of interaction whether or not they are explicitly chosen as such by the user. Both MobiDiC and Rotating Compass are clear examples of progressive lures, providing stepwise guidance over multiple situated devices to eventually reach the visitor's intended goal. There is no notion of narrative or conceptual progression during the process - here the goal is spatial navigation - but a visitor might also be progressively lured through a narrative environment, e.g. through a museum or exhibition, learning more of a story or concept at each situated resource and becoming informed enough to make sense of the next.

The GAUDI system (Kray et al., 2005), and Smart Signs (Lijding et al., 2007), both utilise situated displays to offer dynamic signage. In the case of GAUDI, no user context is used - the directions provided by the displays point toward a destination deemed relevant to all visitors in the area, the dynamicity of the displays offering a clear advantage over traditional static signage especially for particularly dynamic environments where different areas are active at different times. The directions provided by GAUDI are, however, personally-relevant only by chance - the output is not personalised to a particular visitor but rather to the context of the building (i.e. the event being held), thus the directions are relevant merely to the visitors attending the event currently being advertised. Smart Signs conceptually extend GAUDI to incorporate both user context and physical context. Each situated display offers directions as GAUDI did to one key location, yet the displays also offer a personalised version of these directions to any visitors that the displays detect (via sensing of tags worn by the visitors) in the immediate proximity. Personalisation in this case refers to adaptations to the directions based upon user context factors such as mobility capabilities (e.g. does the visitor require wheelchair access). All directions are further adapted to the displays' physical context, potentially adapting routes to weather conditions.

Müller et al observe a contrast in the situation of public displays regarding social context and visibility: situated displays used for navigation, e.g. as part of a progressive lure, must be situated where visitors will naturally encounter them as they walk, yet to encourage visitors to stop and use a public display for an extended period of time (i.e. as part of a couple) a display must be situated so as not to interrupt the flow of other visitors as - while this would naturally draw attention to the display - the situation becomes socially awkward for the coupled visitor (Müller et al., 2008).

Part II – Research method

4. Core model

Having discussed a broad body of prior art in chapters 2 and 3 this thesis proposes a basic core model of user behaviour in the coupling environment, grounding itself in and extending relevant work from the review. In this chapter the basic model is specified and then elaborated to explore the design issues that need to be addressed in order for couples and coupling environments to be most effectively designed. By isolating a range of key design issues at this stage, it is possible to propose and implement a range of couples and coupling environments, then test those implementations through user trials in order to refine a guiding framework for the design of coupling environments. Raising and solving the key design issues relevant to the coupling concept will benefit both the future designers of coupling environments, and their potential users.

In its simplest form, visitor behaviour might be modelled as consisting of two high-level stages of interaction, i.e. *exploration* and *situated interaction*, occurring in between couples (the coupling environment) and at the couple respectively. During situated interaction the user combines their mobile device with a situated device to operate the resulting combination as a *couple*. Exploration is the stage of interaction during which the visitor to the environment searches for the situated devices, i.e. the opportunities to create couples. Exploration and situated interaction form a cyclical process, where exploration leads to situated interaction, which leads back to exploration:

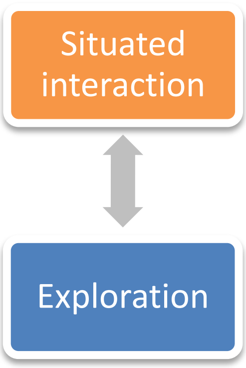


Figure 12 Simple model of behaviour of visitor in a coupling environment

Both stages raise particular design issues. In the case of situated interaction, if a couple is to be formed between a mobile device and situated device there must be consideration of how the process of coupling (to form the couple) and coupled interaction (once the couple is formed) is understood by the user, what different types of coupling and couple are possible, and what interactions these types afford. Considering exploration, it can be asked how the visitor's mobile might coordinate its owner and the environment to better orchestrate a visitor's experience in the coupling environment.

This chapter consists of two parts, approaching the stages of situated interaction and exploration separately to elaborate the two stages of the simple core model, raising key design issues and determining the extent to which these have been addressed by the work reviewed in the previous chapter, thus revealing the work that has still to be done.

4.1 Situated interaction

Behaviour at the couple can be referred to as *situated interaction* as it is located relative to and concerns a particular situated device. Although there are many aspects of the interaction at a couple specific to that couple, the situated interaction may be generalised to three distinct stages:

- **Coupling:** combining the mobile and situated devices
- **Coupled interaction:** operating the resulting couple
- **Decoupling:** disassembling the couple

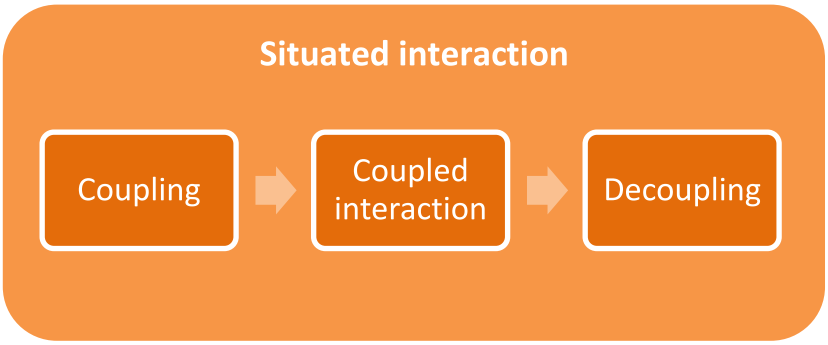


Figure 13 Model of behaviour during situated interaction

These stages are sequential: *coupling* and *decoupling* forming the start and end respectively of situated interaction (Figure 13). An example from chapter 2 - the Blinkenlights system (p.44) - illustrates this using the model:

> *The user couples their mobile phone to the Blinkenlights installation (the public 'display' being the lighting system situated in windows of the city hall) by dialling a specific phone number. An operational connection is formed, and the user can begin coupled interaction – moving their paddle as visualised through the system's lights by pressing buttons on their mobile's key-pad. Once the user has completed a game of Pong, or they tire of the experience, they break the connection and decouple their mobile phone by ending the phone call.*

The three stages of situated interaction from this example are shown in

Figure 14:

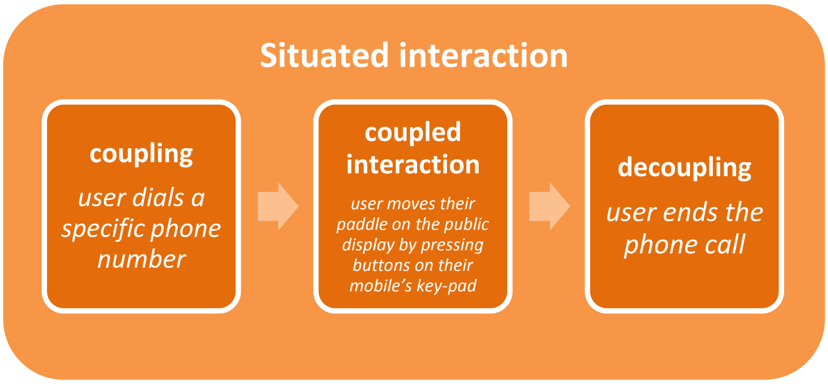


Figure 14 Situated interaction at Blinkenlights couple

Design questions

The design questions relating to situated interaction are as follows:

Q1. **Coupling mechanisms:** what are the different coupling methods and what affects their suitability?

Q2. **Types of couple:** what interactions do the resulting types of couple afford?

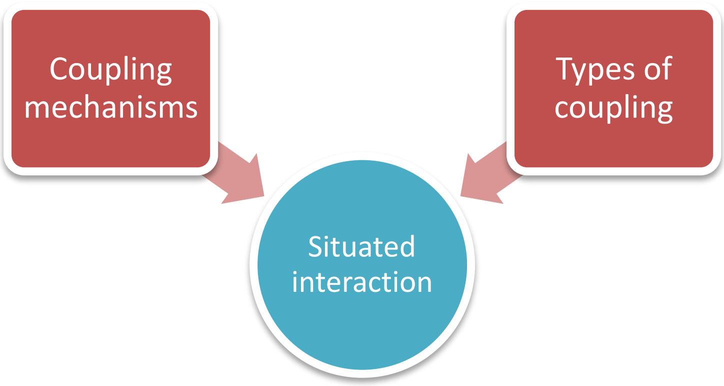


Figure 15 Design questions related to situated interaction

4.1.1 Coupling mechanisms

What are the different coupling mechanisms and how do they affect interaction?

In order to consider the different coupling mechanisms the physicality of couples may be referred to: some utilise a physical or *tangible* connection, while others utilise *intangible* or 'wireless' connections. The coupling, whether tangible or intangible, is also either an implicit or explicit step, referring to whether it is actively and consciously initiated by the user. Table 1 below links cases from chapter 2 to methods of coupling defined in these terms.

Table 1 Coupling mechanisms

	Implicit	Explicit
Tangible	History tablecloth; Key Table[22]	Dynamo (p.47); Touch and Interact (p.38)
Intangible	Personal Server (p.46)	Blinkenlights (p.44); QR code (p.37)

The review highlighted examples of 'automatic' coupling, e.g. Personal Server, whereby the connection is made without an explicit association step: the couple's connection is created *implicitly* (and in the case of the Personal Server *intangibly*) by coordination between mobile and situated device rather than through intentional action by the user. This assumes that both the visitor's mobile and the corresponding situated device are aware of the forthcoming coupling, and implies that the right combination will simply be created at the right moment for the resulting interaction to make sense to the visitor. This process assumes that the devices are capable of robust and intelligent context sensing in order to determine both the correct situated device and the correct moment.

Explicit coupling would require the use of a gesture such as the scanning of a code on the situated device (e.g. in the QR code example), or a button-press on the mobile device. In the case of Blinkenlights the user chooses to make a phone call to engage in coupling, an explicit gesture. When coupled interaction requires that the mobile and situated devices are physically assembled to some degree, the coupling process is the formation of that *tangible* interface. Dynamo is an example of explicit tangible coupling, where a mobile device is plugged into the situated device to couple the two. While the majority of examples of tangible device

[22] Both are technologies that augment furniture that responds in unexpected ways to the touch of other objects; these examples are not discussed in detail in the thesis, instead see http://www.equator.ac.uk/index.php/articles/632 (accessed 22/2/10)

combination are explicit, this coupling mechanism may also be implicit as demonstrated by the 'weight furniture' developed during the Equator project; in this comparison the intent with which the user creates a tangible connection between two objects defines the explicitness of the coupling – Dynamo will *only* react to specific intended coupling actions by the user (i.e. plugging in a mobile device) whereas the History Tablecloth will respond to tangible placement of any everyday object regardless of whether the placer intends it to elicit a response.

Key design issues

Issue 1 - There are two design issues regarding coupling mechanisms. Firstly, the suitability of implicit coupling for interaction within coupling environments may be questioned. Making the coupling step explicit ensures that the switch in device behaviour occurs when expected and desired, and that any necessary transfer in the visitor's attention, e.g. from the mobile to the situated device display, can be orchestrated. It can be suggested that the visitor will also retain a greater sense of control over their experience by making the coupling process explicit. Of course there is still a question of how the correct gesture is made clear to the visitor beforehand – this fact is overlooked in almost all of the reviewed cases of existing couples, leading to the belief that the users involved were explicitly instructed somehow before using the couples, yet the issue remains: ***how can coupling be made explicit and understandable?***

Issue 2 - It is also questionable whether there are benefits to making coupling tangible beyond these cases where this is absolutely necessary. In the case of coupling, a proponent of TUI theory might argue that, from the visitor's point-of-view, creating a physical connection between mobile and situated device makes the process (and the implications of the process) as explicit and transparent as is possible. The transition from exploration to situated interaction is clear and is controlled by the visitor. Yet using a tangible coupling mechanism places practical restrictions upon the physical design of the devices in the couple and potentially limits the number of mobile devices that may physically couple with a single situated device simultaneously. Given these arguments, ***in which situations does physical coupling give benefit over intangible coupling?***

4.1.2 Types of couple

What do the resulting types of couple afford?

The review of existing couples suggests two particularly influential factors affecting the coupled interactions afforded by a particular couple type: the *scale* and *control/feedback* of the couple:

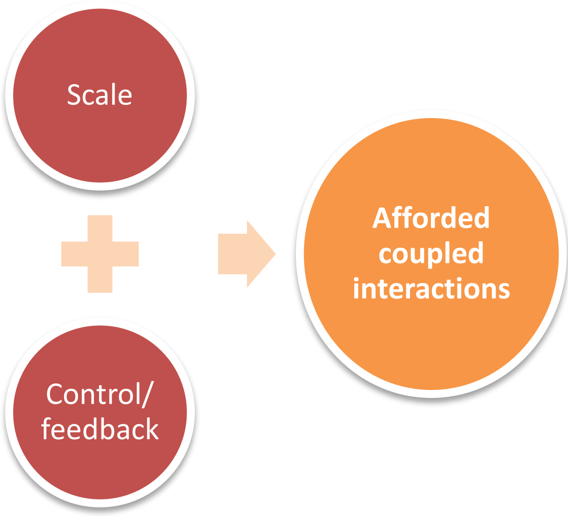


Figure 16 Two main elements of couple type, resulting in particular afforded coupled interactions

A result of defining these factors with reference to the literature review is the identification of permutations of the factors that are a) underexplored or b) particularly useful, thus requiring further investigation through implementation. The chapter looks first at scale (in section *i*) and then control/feedback (in section *ii*).

i. Types of couple: scale

Concern lies, in the scope of coupled interaction, with the scale of the couple and how that scale affects or implies particular forms of coupled interaction.

Two key ranges of device scale are defined in the reviewed literature: Weiser's tabs, pads and boards (Weiser, 1991) and Dix & Sas' extension of Weiser's scale to poppy seed and perch (Dix and Sas, 2008), followed by Gross & Do's object-, body-, room- and city-sizes (Gross and Do, 2004).

The two ranges can be merged by eliminating certain analogies (body replaces board; room replaces perch) to leave six scales to describe devices:

Table 2 Scales

Poppy	*Tab*	*Pad*	*Body*	*Room*	*City*
e.g. LED	Mobile phone	Laptop	Large TV	Cinema screen	Building-face projection

Using the examples of existing device combinations, three significant effects of scale on coupled interaction are revealed:

1) **Spatial interaction:** scale affects the type of spatial interaction that may occur between the user and the couple
2) **Staging:** scale determines the audience of any feedback produced by the couple, i.e. who may experience feedback from coupled interaction
3) **Collaboration:** scale also affects how multiple users or occupants of the space may collectively engage in coupled interaction

Spatial interaction

There is a key distinction between the tab/poppy-seed scales and pad scale, i.e. the degree to which the device lends itself to spatial input: a tab or poppy-seed size device is easily manipulated in hand, e.g. the desktop mouse is a good example of such a device, while a larger pad-size device such as a laptop is less easily manipulated. A mobile phone is tab-size and a number of examples have been reviewed where the mobile phone is used as a spatial input device in the couple (e.g. Chameleon, C-Blink, Virtual Graffiti, MobiSpray, etc.). For the mobile to be used as a spatial input device, there must naturally be a component of the couple that the mobile can be manipulated with respect to, i.e. a component that senses/receives spatial input, or which provides feedback to the input. Larger components of the couple, e.g. the situated device, are well-suited to these roles, for example the 'Active Map' might be a large situated display across which a mobile might be moved in order to drive interaction with and feedback on the map – in this case the situated device is the target of the spatial input while the smaller mobile device provides the input.

Table 3 Scale vs type of spatial input

Poppy	*Tab*	*Pad*	*Body*	*Room*	*City*
Spatial input component (e.g. mobile in MobiSpray, p.33)		**Recipient/feedback of spatial input** (e.g. public projected display in MobiSpray)			

Staging

Coupled interaction may either be private or staged. There are distinctions between object-size, body-size, and larger sizes of output component that determine whether coupled interaction at the couple is private or staged. Coupled interaction on a small-scale, e.g. using a mobile phone to enter and send text to a terminal screen, has a low visibility in public, i.e. it is likely to be difficult to observe and be perceived as private. In contrast a user's interaction through their mobile device with a room-size display is much more clearly visible, i.e. staged to the public. In section 2.1.2 the reviewed work by Dix & Sas and Brignull & Rogers proposed three types of actor and three activity spaces in the scope of interaction with situated devices (Table 4). The notion of actor and activity space provides terminology for an explanation of staging.

Table 4 Actor and activity space

Actor (Dix and Sas, 2008)	**Activity space** (Brignull and Rogers, 2003)
Participant (& system (Garzotto and Paolini, 2008))	Direct interaction space
Bystander	Focal awareness space
Passer-by	Peripheral awareness space

Coupled interaction occurs in the direct interaction space; if coupled interaction is not visible beyond the direct interaction space then it will not appear staged and it is unlikely that passers-by will be attracted to become bystanders. If the participants engaged in coupled interaction are clearly visible from beyond the direct interaction space, then the coupled interaction is staged to bystanders and will encourage passers-by to become bystanders (or bystanders to become participants), or indeed repel bystanders. In couples such as TexTales, the coupled interaction between a participant and situated display (occurring in the direct interaction space) is distinct from that of other bystanders/passers-by and the display (focal/peripheral awareness space), yet the scale of the couple encourages group *reflection* by making coupled interaction visible to all activity spaces.

It is this broadcast effect of larger-scale output components that has led to the previous suggestion that surrounding couples may exert an attractive or repulsive effect upon visitors engaged in exploration; Izadi et al have noted that larger situated devices are capable of augmenting the experiences of people who may otherwise be uninvolved in interaction with those devices(Izadi et al., 2002).

Table 5 Scale vs staging

Object (poppy to pad)	*Body*	*Room*	*City*
Personal feedback (e.g. mobile in Hermes, p.34)	**Personal feed-back/public staging** (e.g. public display in TxtBoard, p.41)	**Public staging** (e.g. public display in Tex-Tales, p.43)	

Collaboration

Somewhat related is the third observation, i.e. that object-size components are directly manipulable by only one visitor at a time, while body-size or larger components might be used simultaneously or in collaboration by multiple visitors. As such, the mobile device in a couple naturally plays the role of a personal interface, as its scale does not afford use by multiple visitors. The situated component, if body-size or larger, may afford interaction with multiple users. Consider, for example, a public display that is perch-size: this display, while coupled to a single mobile device might allow a single visitor to broadcast their interaction, but when coupled with multiple mobiles might allow multiple visitors to split the output into multiple personal workspaces (e.g. as in the QR-code system). Larger couples might allow visitors to *split* computational capabilities in this manner (where visitors' interactions are separate), or *share* the capabilities (where visitors' interactions may overlap). It has been stated previously that Gross and Do and other authors such as Izadi et al. (Izadi et al., 2002) note this link between larger scales and support for collaboration.

Table 6 Scale vs suitability for collaboration

Object (poppy to pad)	*Body* *Room*	*City*
Individual use (e.g. mobile in the Chameleon, p.30)	**Individual/group use** (e.g. public display in QR code, p.37)	**Group use** (e.g. public display in Blinkenlights, p.44)

Key design issues

Issue 3 - Firstly, while several examples of device combinations have been reviewed that utilise the mobile device none of those explicitly support or explore the notion of multiple users simultaneously interacting with the situated device in that manner. Spatial interaction, due to its similarity to staged performance, may encourage enjoyable social interactions between users and between the users and bystanders. Equally it may be predicted that the gestures of spatial interaction may fill the physical space easily and possibly cause conflict for that space between multiple simultaneous users. Subsequently it may be asked ***how does the scale of the couple and sharing of the interaction space affect the use of the mobile spatial input?***

Issue 4 - Scale may affect whether or not the feedback from the couple is personal or staged (i.e. who receives output), and that scale may either promote individual or group interaction (i.e. who may provide input). If these two effects are considered together a useful function might easily be suggested for each resulting couple type:

Table 7 Matrix of staging and suitability for collaboration with examples

	Personal	**Staged**
Individual	Private individual experience	Solo staged experience
Group	Collective personal experiences	Collaborative experience

While these couples are all useful applications, this matrix oversimplifies the issue somewhat. There is a significant grey area, illustrated in Table 5 and

Table 6, where body-size scale might provide feedback that is either personal *or* staged, and where body/room-size scale may support either an individual *or* group. Body- and room-size scales are also the most commonly implemented across those device combinations previously reviewed. The design issue raised relates to how possibly varying perceptions of a couple based upon its scale might be managed, i.e. ***how significant is scale to the user's perception of the couple as affording private vs. staged interaction? How do various scales restrict or ensure group interactions?***

ii. Types of couple: control/feedback

Once a couple is formed a particular combination of input and output components is created offering opportunities for particular coupled interactions. There may be a limitless combination of such components, but the distribution of *control and feedback* is a means by which the component mix can be more generally discussed, i.e. a comparison of whether responsibility for input and output are clearly delegated to mobile and situated device respectively and vice versa, or where there is *distributed* control and feedback, i.e. where the responsibility for either is shared (analogous, regarding control, to Pham et al's cooperative symbiotic relationship (Pham et al., 2000)), e.g. both mobile and situated device are used for output. Examples from the review are categorised using this comparison as a divisor in Table 8 below.

Table 8 Distribution of control and feedback with examples

			Distribution of control		
			Delegated		*Distributed*
			To mobile	To situated	
Distribution of feedback	*Delegated*	To mobile	-	-	Disc-O-Share (p.40)
		To situated	C-Blink (p.31)	Dynamo (p.47)	Personal Server (p.46)[23]
	Distributed		Virtual Graffiti (p.32)	ContentCascade (p.39)	Hermes (p.34)

A distributed responsibility affords new interesting forms of interaction where control and feedback may occur through multiple components, either simultaneously or in turn. The

[23] Utilising the Personal Server mobile device's jog dial as a means of control via the mobile

thesis has previously suggested (through discussion of Dix & Sas' work in section 2.1.2) that if feedback is presented through the situated component alone there are possibilities for tensions in both the content presented and the pace of the presentation: all visitors observe the same feedback (even if it is less/more relevant to certain individuals) and at the same pace. If feedback is distributed between the situated display and the visitors' mobiles, the situated display may feedback content suitable for all while the mobile might present aspects relevant to its owner. More interesting results may emerge from exploring couples that distribute the locus of interaction across the couple.

Exploring the distribution of control and feedback may also introduce practical issues. There may be an issue with managing the attention of the visitor, particularly when the locus of interaction shifts between different components, an issue raised in (Garzotto and Paolini, 2008). If the locus of interaction shifts from the mobile device, for example, to the situated device is this always clear to the visitor? When the two devices are close physically, e.g. in a fixed couple, changes in the feedback from the devices might be used to manage attention, but it may be more difficult to correctly shift attention between intangibly coupled devices when the visitor perceives the two parts of the couple as separate and may be focussed more heavily on one device in particular.

Table 8 illustrates a lack of implemented couples where the responsibility for feedback is delegated completely to the mobile device. Disc-O-Share is a standout example, where the situated device is used to extend the sensing capabilities of the mobile devices – controlling aspects of the coupled interaction – while relying upon the display capabilities of the mobile devices for output. Indeed, as previously discussed, the authors attempted to add visual output from the situated device, but found that this did not benefit the interaction significantly.

Key design issues

Issue 5 - A lack of further examples of combinations where the feedback is delegated to the mobile probably results from the obvious advantage of situated technologies over mobile devices for display, and the ease with which couples can be implemented that demonstrate this beneficial combination, however this leaves a distinct gap in the design space to be explored. Equally, there are few existing combinations in which both control and feedback are distributed – a type of couple that might demonstrate full exploitation of both devices. In general the design space, has not been explored using distribution of control and feedback to frame that exploration, thus a design issue is raised: ***how useful are the various distributions***

of control and feedback between devices within a couple, particularly where the mobile is delegated responsibility for feedback?

4.1.3 Summary

In section 4.1 situated interaction has been elaborated to the sequence of coupling, coupled interaction and decoupling. The focus so far has been upon coupling and coupled interaction, utilising (and where appropriate extending) selected concepts from the literature review to determine the most pertinent design issues relating to those two stages.

Table 9 Design issues related to situated interaction

Stages		**Design issues**	
Situated interaction	*Coupling*	**Q1) Coupling methods (4.1.1)**	**Issue 1** - How can coupling be made explicit and understandable? **Issue 2** - In which situations does physical coupling give benefit over intangible coupling?
	Coupled interaction	**Q2) Types of couple (4.1.2)**	*i. Scale* **Issue 3** - How does scale of the couple and sharing of the interaction space affect the use of the mobile for spatial input? **Issue 4** - How significant is scale to the user's perception of the couple as affording private vs. staged interaction? How do various scales restrict or ensure group interaction? *ii. Control/feedback* **Issue 5** - How useful are the various distributions of control and feedback between the devices within a couple, particularly where the mobile is delegated responsibility for feedback?
	Decoupling	*See note below*	

Decoupling

During the elaboration of situated interaction the process of *decoupling* has not been discussed in depth; this decision warrants justification. None of the reviewed pieces of literature regarding existing MP-PD arrangements considers the 'decoupling' stage of user-interaction. In TUI literature the disassociation step (where an assembly is broken) is acknowledged, e.g.

in (Holmquist et al., 1999), but not widely explored. Within mobile exploration system literature Cheverst et al. consider when a visitor should become aware of the next stage in orchestrated exploration of an environment (Cheverst et al., 2001), i.e. immediately following a located experience, or at a time of the visitor's discretion (leading to the discussion in section 4.2.1 regarding constraint of action during exploration) which raises the question of whether the definition of decoupling ("disassembling the couple"; "the end of situated interaction" – p.75) is ambiguous, i.e. whether the end of coupled interaction from the point-of-view of the visitor and of the system is different. From the system's point-of-view decoupling is often a symmetrical process to coupling – a mobile that is plugged into a situated device is unplugged, a user that presses a particular button on their mobile to create a couple presses another button to decouple, moving a mobile out of a particular proximity breaks a couple that was formed by moving it within a certain proximity, etc.

Once this device decoupling has occurred the system considers the mobile and situated devices as distinct. Is this true from the user's point-of-view? Cheverst et al. found that some visitors were confused when new instructions were pushed to them by their mobile – this may indicate that the design issues associated with coupling are also mirrored for decoupling, particularly how does a user know when an intangible couple is disassembled (mirroring Issue 1 -)?

There is also an argument that 'decoupling' does not occur for the user until they have finished reflecting upon the situated interactions that have just occurred, i.e. that while the devices may be decoupled the user's coupled *experience* continues. Section 4.2.1 considers the visitor's desire for time to reflect upon experiences and raise interruption by the system during this time as a potential issue (Issue 9 -) – one argument might be therefore that exploration begins not when the devices decouple, but when the visitor's *intent to find another situated device* is raised. In the process of investigating the visitor's need to reflect during exploration the aim is to revisit and reassess this issue.

4.2 Exploration

Public environments may contain multiple situated devices which have varying degrees of personal relevance to a particular visitor. It is unlikely that visitors will want to couple their mobile device with a situated device in such an environment randomly, but instead can be seen engaging in three stages of behaviour before beginning situated interaction:

- **Understanding the environment:** learning of and determining the suitability of situated devices in the environment
- **Choice:** choose the most relevant situated device to couple with
- **Movement:** move through the environment to the chosen situated device

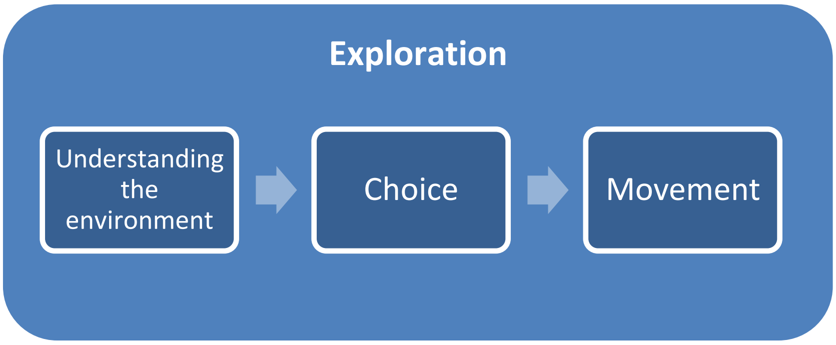


Figure 17 Model of behaviour to be supported by system during exploration

As with situated interaction, an example from the literature review – Magitti - demonstrates the stages of exploration. Although not a coupling system, exploration using Magitti is comparable to the process in coupling environments:

> *A visitor specifies (using their mobile device) the type of attraction they wish to visit. The Magitti application determines the most suitable attractions, assessing the type of the attractions closest to the visitor, according to their ratings by other visitors. The visitor chooses from a list of resulting recommendations and is shown on a map where the chosen attraction is located. The visitor follows the map in order to find the attraction.*

The three key stages of the exploration in this example are as shown in Figure 18:

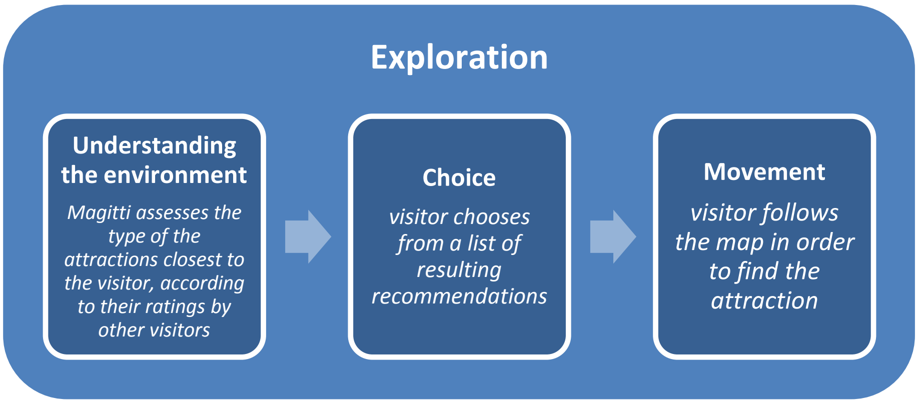


Figure 18 Exploration using Magitti

In this scenario, Magitti and the visitor share responsibility for the path of the visitor: it is Magitti's duty to mediate the visitor's understanding of the environment, i.e. to determine what possibilities there are and which are relevant to the visitor; even though the visitor makes the final choice, this earlier process influences that choice. Essentially the system (in this case the mobile device) *orchestrates* the visitor's experience within the environment: this notion of system orchestration is particularly apt in coupling environments, where the system (in this case the mobile and situated devices) may have both a greater knowledge of aspects of the environment than the visitor and have an agenda of sorts, i.e. particular trajectories that visitors should take through the environment.

Design questions

Following the two design questions regarding situated interaction (p.76), the design questions relating to exploration are as follows:

- Q3. **Orchestration:** What factors affect how suitable a situated device is for coupling with a user's mobile? How much constraint should the system exert over the visitor's choice of their own trajectory?
- Q4. **Location mechanisms:** How does a user locate and move to the chosen situated device in order to couple their mobile device to it?

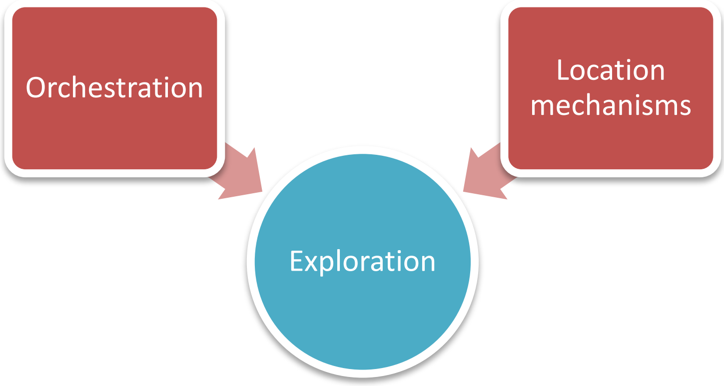


Figure 19 Design questions relating to exploration

4.2.1 Orchestration

i. Orchestration: relevance

What factors affect how suitable a situated device is for coupling with a user's mobile?

When a coupling environment consisting of multiple couples is considered, rather than the individual couple, the visitor's *trajectory* through the environment – consisting of several instances of situated interaction (at different situated devices) and the movement between the situated devices - is the key concern of the designer.

If there are multiple opportunities for situated interaction in an environment, choices must be made as to which situated device is most *relevant* (based on an understanding of the environment) at a particular moment. In section 3.2.2 entry points (contexts in which users are enticed into starting an interaction with a system) which might be either open or closed (Brignull, 2005) were discussed, referring not necessarily to whether couples are relevant, but whether a situated device represents a coupling opportunity or not. A coupling environment may provide multiple entry points whose relevance must be understood correctly by the visitor in order to avoid frustration: a visitor will become frustrated if their exploration of an environment leads to many closed entry points - situated devices that appear to but do not actually offer the opportunity to couple – or many open but *irrelevant* entry points.

Instead, the system, via the visitors' mobile phones, may ensure that visitors are only aware of *relevant* entry points (opportunities for coupling), or are able to correctly determine the relevance of entry points. In either case the system mediates or *orchestrates* the visitor's process of understanding the environment and choice of situated device. Both the visitor and the system understand the environment by understanding context; a system's understanding of context is limited by the aspects of the environment that can be computationally sensed or derived: while discussing how the system might orchestrate a visitor's exploration it is thus necessary to discuss those aspects of context that the system can understand. As use and presentation of context is not a new research area (as illustrated by the review of literature in section 3.1), the design issue for coupling environments is which of those aspects of context are specific to, or particularly pertinent to coupling environments?

Five particular aspects of context are useful for determining the relevance of situated devices. The *proximity* of situated devices to the visitor, and the degree to which the coupled interactions at the device match the visitor's personal preferences (i.e. the *visitor profile*) are important factors contributing to the measure of the relevance of a situated device (Figure 20). However, the thesis focuses here on three additional factors - *technology profile*, *narrative* and *capacity* – particularly relevant to coupling environments.

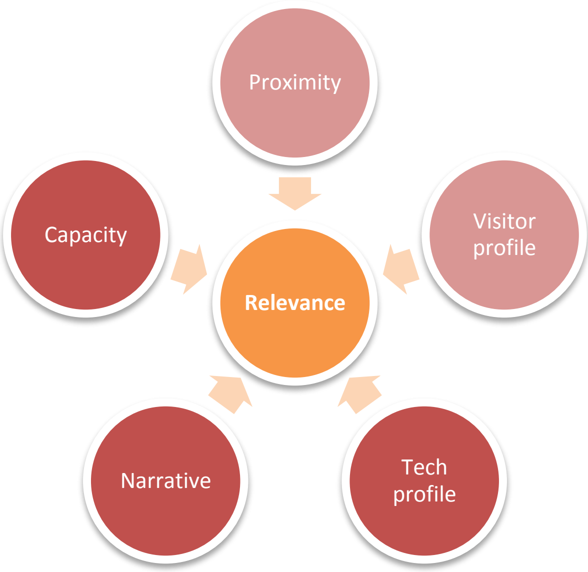


Figure 20 Factors considered by the system during orchestration of a visitor's exploration

Technology profile

Both Schilit et al and O'Grady et al include computing context in their categorisations. Particularly relevant to the coupling paradigm is the consideration of the capabilities of mobile devices in comparison to the capabilities required for the expected interaction at a situated device. Situated devices will not be designed to cater for all mobile devices, which are too heterogeneous for this to be feasible. In order for situated devices to be more effective than the mobiles carried by the visitors, they are naturally more specific and will thus have specific requirements for the mobile devices with which they are coupled. Consider MobiSpray (p.33) as an example: this installation requires the mobile device to have a motion sensor in order to control a public display and as such would have no relevance as a coupling opportunity to a visitor who does not have a mobile device with a motion sensor. *Technology profile* can be thought of as the capabilities of the visitor's mobile device, which may be compared to the technology requirements of situated devices.

Narrative

In the literature reviewed there are a few examples of what may be referred to as narrative dependencies. Hippie and GUIDE both aim to suggest sequences of related situated resources to the visitor – these resources form a narrative, where the resources are most relevant when visited in a particular order. Such structures are particularly relevant and common to many potential coupling environments: museums and galleries may feature themed strands of exhibits; shopping centres may provide routes that cater to particular shopping tastes, and so on. A narrative might be thought of as a network of experiences through which a visitor progresses; if the scope is broadened to consider coupling with situated devices narratives may include requirements for actions and the visitor must more actively progress through the narrative network, e.g. collecting particular content at one situated device and transferring to another specific situated device before they can progress further in the narrative.

Historical interaction is isolated as important by Baldauf et al and considered significant by Chalmers; ILEX is a positive example of interaction influenced by past actions, and – as is proposed in the discussion of narrative dependencies above - the relevance of some situated devices depends upon previous interactions. Previous interactions relevant to exploration of a coupling environment may take place while exploring or during situated interaction.

Coupling capacity

As interaction with publically-situated devices is made possible, contention for those devices may be introduced. This contention affects the relevancy of devices: a limited situated resource is less suitable to a remote visitor if it is currently engaged with another visitor; if the situated device is fully engaged it may be better for the visitor to utilise alternative devices until the original device is free. There is no discussion of this issue in the reviewed literature, partly due to a focus on situated resources that are not contentious, but also through practical implementations that are only tested in less-than-realistic situations (with low throughput). The work described in this thesis investigates forms of coupling that create fundamentally contentious resources, e.g. situated devices with limited physical interfaces, and explore mechanisms for dealing with the issue of contention. There are two opportunities here, firstly to convey potential for contention during the exploration stage so that contention might be *avoided*, and secondly to design the couple so that interaction at the couple involving non-coupled visitors might be possible, *alleviating* contention.

By being aware of these aspects of context, the system (through the visitor's mobile) may determine situated devices that it deems are relevant to the visitor and present those as choices. Equally, the system may present the information as a means of facilitating educated decisions by the visitor about which situated devices are relevant. In either case, the system is able to orchestrate the visitor's understanding of the environment and subsequent choice.

Key design issues

Issue 6 - Technology profile has been raised as a particularly relevant aspect of context in coupling environments; this is true due to the heterogeneity of both situated and mobile devices. It has been acknowledged that there will be some forms of coupled interaction that are clearly compelling, but yet require certain types of mobile device technology that are not homogenous. This highlights the design issue: ***can the environment react to varying mobile device capabilities to ensure that visitors do not encounter situated devices to which they are technologically incapable of coupling?***

Issue 7 - Narrative has also been discussed as an important influence during orchestration. Evidence of mobiles used to orchestrate exploration of environments with narratives has been seen in the literature review (e.g. GUIDE), yet no evidence has been seen of narrative used to enhance the experience of exploring coupling environments, where coupled interactions may be used to progress a visitor through linear narratives, or to determine their personal route through non-linear narratives. In particular, how can interactions such as the collection and transport of content via mobile device between couples, be used as part of narrative? More generally, the design issue raised is: ***how can the user experience in the coupling environment be enhanced by enforcing narrative dependencies between couples?***

Issue 8 - Finally, certain coupling mechanisms and types of couple place a restriction on the number of users that may couple with a situated device simultaneously, thus rendering that situated device a point of contention. ***How can contention for couples with limited coupling capacity be avoided or alleviated?***

ii. Orchestration: constraint of action

How much constraint should the system exert over the visitor's choice of their own trajectory?

Regardless of the factors used to determine relevance, the system is capable of orchestrating the visitor's exploration in various ways, depending on how the visitor's mobile is used to present information. The Magitti scenario at the start of this section illustrates one approach to orchestration in which the system exerts a relatively low degree of *constraint* over the visitor's exploration. The system combines proximity with ratings by previous visitors as a measure of relevance for the user, ranking the surrounding attractions. By presenting the visitor with a prioritised set of choices, responsibility for *understanding the environment* is taken by the system, while responsibility for the final *choice* lies with the visitor. The visitor also chooses when to pull the set of choices from the system, thus controlling the pace of exploration.

There are examples within chapters 2 and 3 that span the design space in terms of constraint of action during orchestrated exploration. Cyberguide is an example of a system that provides complete freedom during exploration, objectively facilitating (whenever needed) the visitor's own understanding of their environment and movement to chosen resources. An example of much stricter orchestration is the GUIDE system when following prescribed narratives. The mobile device tells the user what attraction to visit next and how to reach it, stepping through a sequence of attractions determined to be most suitable for the visitor.

Like Magitti, the majority of the exploratory systems reviewed previously fall somewhere between these two extremes. Hippie, CRUMPET and SmartRotuaari are three systems in which the system reduces the freedom of the visitor by prioritising or filtering the situated resources presented to the visitor, i.e. attempting to reduce the set of entry points to a *subset* deemed relevant by the system. Pham et al and Raghunath et al both suggest that coupling systems present users with 'pruned lists' of entry points deemed relevant (Pham et al., 2000, Raghunath et al., 2003), i.e. resources filtered and/or prioritised in order to influence the user's decision, while still offering a choice.

There are several analogies for this issue of freedom during orchestration. Brown and Jones describe a system that responds or reacts to requests from the user – as in examples such as Magitti - as *interactive.* In contrast to interactive systems, systems such as GUIDE (when behaving as previously described) and Personal Server may be termed *proactive* (Brown and

Jones, 2001). There is also a well-established notion of *push* and *pull* of information and services in a range of areas of research and design: push refers to a situation in which information is delivered to the user when the system deems appropriate, i.e. information is pushed from system to user, whereas pull refers to the user prompting the system for information, i.e. the user pulls information from the system. This thesis extends Fröhlich et al's development of the SIA concept (Fröhlich et al., 2006) previously discussed in section 3.2.2 to propose four subdivisions of the push/pull approaches - direction, update, search and selection - covering more finely the different areas of the design space:

Direction and *update* represent two approaches in which constraint of action by the system is increased. Direction refers to the system choosing the coupling opportunity that it deems most relevant to the visitor without input from the visitor – the system interprets the opportunities available in the environment, chooses the opportunity deemed most relevant, then mediates the visitor's movement to the location of that situated device. Update describes the impromptu suggestion of potential choices to the visitor, i.e. the visitor makes a final choice but is prompted to do so when deemed suitable by the *system*. There is a chance here for the system to offer all potential couples, or to present a subset that it deems suitable.

Search and *selection* represent approaches offering more freedom to the visitor. Search is the opposite face of update, whereby choice is presented to the visitor when the *visitor* prompts the *system*. Again, the system may present all couples when prompted by the visitor, or may present only the subset deemed relevant. Selection describes a mechanism by which a visitor chooses any coupling opportunity at any time, thus avoiding *any* mediation of the choice or orchestration of the visitor's experience.

Table 10 Mechanisms for orchestrated exploration

System role	Push/Pull	Mechanism	Constraint
Proactive system	*Information pushed to visitor*	***Direction*** System decides which couple is suitable for visitor, and makes the choice on behalf of the visitor	*More*
		Update System offers the visitor a set of choices of situated devices *deemed relevant by the system* *Or* System offers the visitor *all possible choices*	↑
Reactive system	*Information pulled by visitor*	***Search*** Visitor prompts the system for a set of situated devices *deemed relevant by the system* to choose from *Or* Visitor prompts the system for *all possible choices*	↓
		Selection Visitor finds and chooses one situated device from the environment	*Less*

One final yet significant observation to be made here is that even though situated resources deemed irrelevant are “hidden” by systems such as Magitti, the visitor can still happen upon them, i.e. even though a resource might have no preceding entry point, despite the best efforts of the system *all* are open access points. A best-case scenario is that this allows the visitor to encounter a situated resource opportunistically that the system may have incorrectly deemed irrelevant, yet on the other hand they may also encounter a resource that is unsuitable for them and engage in an *irrelevant* experience. A coupling system on the other hand (of which the Personal Server is a good analogy) might literally *deny* coupling with a situated device discovered by the visitor: since successful coupling requires coordination between mobile and situated device, either device might refuse to initiate a couple. This may be true even in the case of selection – even though a visitor locates and chooses a particular situated device, but the system may still refuse the visitor the chance to actually couple their mobile device to the discovered situated device.

Key design issues

Issue 9 - In different implementations of GUIDE Cheverst et al provide users with both push-based and pull-based approaches to accessing location-based information (Cheverst et al., 2001). It was found that when pull-only interaction was allowed users were often unsure about when to pull the information, and when push-only interaction was allowed users could be surprised or even interrupted by unexpected information pop-ups. The issue may be more generally presented as one of the impact of the orchestration approach on the *pace* of the overall experience. Should effective exploration be considered to be quantitatively efficient exploration, where the visitor is able to take advantage of as many different couples as possible in a limited time-frame, or are there additional needs for time between coupling experiences (e.g. for reflection) that would imply that *more* quantitatively efficient exploration is qualitatively *less* enjoyable for the visitor? To what degree should the control over the pace of a visitor's exploration be a factor when deciding upon an orchestration approach? More generally, how does the visitor perceive the influence of the system in these different approaches, i.e. ***what impact do the different orchestration approaches have on the user experience?***

Issue 10 - There is the possibility in a coupling environment for the system to deny coupling with situated devices, thus avoiding opportunistic but irrelevant experiences by visitors; yet the question remains as to whether closing access to a situated device that may be *perceived* as a coupling opportunity is wise. As will be discussed in this section's closing summary there are additional factors that can draw visitors to a situated device that are beyond the control of any system orchestration: consider, for example, a large public display that several visitors have their mobiles coupled to, and another visitor for whom the display has not been presented as a coupling opportunity – this visitor may question why this display is irrelevant and resent the fact that it is closed to them. Given the possible benefits of a policy of denial, ***how can the denial of opportunities deemed irrelevant be implemented as a safe and beneficial feature of orchestration in coupling environments?***

4.2.2 Location mechanisms

> *How does a user locate and move to the chosen situated device in order to couple their mobile device to it?*

It was stated in section 3.2.2 that "an entry point may well be dislocated from a corresponding access point to the same coupling opportunity" and that therefore exploration requires the “conception of a route bridging the gap between entry and access point and the mediation of the traversal of that route”. Coupling environments may be complex and unfamiliar to the visitor hence some form of guidance is required to aid *movement* between situated devices.

A map-based representation of the environment supports a visitor’s understanding of the environment, choice and movement: the visitor can use a map to determine the suitability of resources, i.e. where each resource is as well as additional context depending on how the map is augmented, indicate on the map a chosen resource, and move through the environment using the map as a guide. Examples of systems that provide these services have been reviewed in section 3.2.2. On the other hand, map-based representations of the environment naturally place an emphasis upon the proximity of resources such that this aspect of context is potentially over-represented to the visitor in comparison to other aspects of context that may in fact have a greater bearing on whether or not the resources are relevant. Magitti represents a particular visual compromise that attempts to provide both guidance based upon a map and additional contextual information (Figure 21, right).

Figure 21 Map-based guidance: Google Maps (left) and Magitti (right)

A list-based representation of the available resources supports only the understanding and choice processes, not movement, but has a greater propensity for treating all aspects of context equally when providing a view of the environment to the visitor. As a list does not provide guidance for a visitor’s movement through an environment an additional mechanism is required to aid the visitor in navigating the space between the entry point (where the choice of coupling opportunity is made) and the access point (the situated device).

Beeharee & Steed present to the mobile computing field the use of photographic trails for general guidance between points-of-interest in an environment in comparison to and in conjunction with maps (Beeharee and Steed, 2006). Goodman et al present photo trails as a superior alternative for those users less able to read maps (Goodman et al., 2005). More than a decade earlier, much work had occurred in other fields concerning more widely accessible alternative guidance mechanisms to maps: photographic trails are an efficient spatial memory model consisting of nodes (that are pictorial snapshots of a location as it is traversed, i.e. views) and edges connecting those views (when the views immediately follow one another for a visitor walking in reality) proposed by Scholkopf and Mallot (Scholkopf and Mallot, 1995); many years before this landmarks (the qualities of which have been previously defined (Appleyard, 1969, Kaplan, 1976, Lynch, 1960)) were known to form a reference framework on top of which other layers of knowledge might be efficiently built to aid navigation and the understanding of spaces (Sadalla et al., 1980). Beneficial potential cross-over between cognitive science work on photographic trails and that of architectural design is suggested by Franz et al. in a comparison of graph-based models of space as a move towards hybrid models of space that combine metric, qualitative and topological information (Franz et al., 2005). This work suggests that such human-centric graph-based representations as photographic trails may communicate well to and practically represent the mental conception of visitors of an environment. In a well-respected paper, Gillner and Mallot determined that visitors to an environment learnt and navigated the space based on local information (in the form of views of their surroundings) in steps, and that the most effective representation of this model for the navigation of environments was a set of distinct photographic steps without reference to an overview of the entire route being navigated (Gillner and Mallot, 1998). Chittaro & Burigat use quantitative and qualitative user trials to compare the use of map overviews with photographic trails, directional arrows and audio instructions, concluding that a combination of photographic trails and traditional map overview is as effective for guidance as a map alone but that users highly appreciate the combination (Chittaro and Burigat, 2005). There is also a large body of literature regarding in-vehicle navigation systems, e.g. (Burnett, 2000), that also attests to the benefits of using visual landmarks to aid navigation and conception of spaces.

It is not within the scope of this thesis to assess the qualities of different location mechanisms: this brief review suggests that photographic trails are simple yet effective mechanisms for aiding movement and as such they will be utilised. From a visitor's point-of-view a trail presents itself as a sequence of photographs, leading the visitor in steps from a recognisable landmark near the point of choice to the coupling opportunity. The key benefit of photographic trails is that progress through them may be self-reported, and hence no sensor infrastructure to update the location of the user (particularly difficult inside buildings) is required.

Key design issues

Issue 11 - Although the choice of photographic trails as a means of supporting movement is grounded in established literature and a decision not to over-represent proximity, photographic trails are much less frequently implemented in comparison to map-based mechanisms, thus there is less existing study into their effectiveness as a means of locating destinations using mobile devices. As such the issue remains: ***are photographic trails suitable as a less cognitively-demanding means of locating chosen situated devices?***

4.2.3 Summary

Section 4.2 has elaborated the exploration stage of the simple model of visitor behaviour to highlight three processes – understanding the environment, choice and movement – all of which may be mediated by the system such that the trajectory of the visitor through the coupling environment is orchestrated by the system to both be relevant to the visitor and to reflect the agenda of the environment designer. Orchestration of an individual's experience by the system can occur due to the use of the personal mobile device (controlled by the system) by the visitor to understand the environment, make choices and navigate. Approaches to orchestration have been discussed through which the system may use five aspects of context in order to influence a visitor's decisions and resulting path through the environment. Design issues have been raised regarding these five aspects of context and the different orchestration approaches (Table 11).

Table 11 Design issues related to exploration

Stages		Design issues	
Exploration	*Understanding the environment & choice*	**Q3) Orchestration (4.2.1)**	*i. Orchestration*: relevance **Issue 6** - Can the environment react to varying mobile device capabilities to ensure that visitors do not encounter situated devices to which they are technologically incapable of coupling? **Issue 7** - How can the user experience in the coupling environment be enhanced by enforcing narrative dependencies between couples?

			Issue 8 - How can contention for couples with limited coupling capacity be avoided or alleviated? *ii. Orchestration: constraint* of action **Issue 9** - What impact do the different orchestration approaches have on the user experience? **Issue 10** - How can the denial of opportunities deemed irrelevant be implemented as a safe and beneficial feature of orchestration in coupling environments?
	Movement	**Q4) Location mechanisms (4.2.2)**	**Issue 11** - Are photographic trails suitable as a less cognitively-demanding means of locating chosen situated devices?

Unfortunately visitor behaviour during exploration is susceptible to a much wider range of influences than can be mediated by the mobile device alone. It is easy to suggest several such external influences by example: the Smart Signs system adapts guidance according to the weather local to the visitor, recognising that a visitor may not wish to visit a resource situated outside when it is raining. Schilit et al's physical context groups a range of possible external influences, including weather, but also others such as lighting, noise level and temperature (Schilit et al., 1994), many of which can be controlled through architectural decisions. Consideration of these additional influences leads to two further design issues.

Issue 12 - Interestingly, the entities within the environment – visitors, mobile devices and situated devices – also affect the decoupled behaviour of a visitor in ways beyond those considered thus far. With increasing amounts of situated technology comes the impact that these technologies may have on our attention even from beyond the visible range, and the amplified effect they may have on us when nearby. Previously discussed is the impact of a couple's scale on whether coupled interaction is staged (section 4.1.2i): Brignull et al. discuss this "honeypot effect" stating that viewing others interacting with a couple, particularly larger couples, may encourage additional users to join the interaction (Brignull, 2005, Brignull and Rogers, 2003), yet in coupling environments this may mean attraction to a situated device *even if the coupling opportunity has already been deemed irrelevant and potentially has been closed*. It may perhaps be important to reconcile the attractive effects of situated technologies with the orchestration of exploration, and in particular the proactive denial strategy, i.e. exploring means of controlling the expectations of a visitor who has been attracted to an irrelevant or closed coupling opportunity. This further design issue may be simply phrased:

how do larger couples or those that stage coupled interaction affect the system's orchestration?

Issue 13 - It is not only the visibility of situated devices that might affect a visitor's choices, but also other visitors; Schilit et al suggest that other visitors are significant factors, while Chalmers also notes the significance of the interrelation of one's actions with the actions of others. The majority of visitors to a number of potential future types of coupling environments visit as part of a group rather than alone, e.g. less than one in four visitors to a museum might typically be expected to visit alone(MORI, 2005, Brehaut and Simonsson, 2006). The relevance of couples to the different visitors within a group will, if considered individually, be highly varied, yet the group members may often alter their own decisions by deferring to another group member, resulting in a trajectory through the environment that reflects aspects of all (or indeed none) of the individual group members. As such a final design issue is raised: ***how do the relationships within a visiting group affect orchestration?***

4.3 Summary

In this chapter a model of visitor behaviour within the coupling environment (exploration) and at the individual couple (situated interaction) has been proposed and elaborated. There have been discussions of both exploration and situated interaction as sequences of three stages of behaviour which combine to form a cycle of interaction (Figure 22).

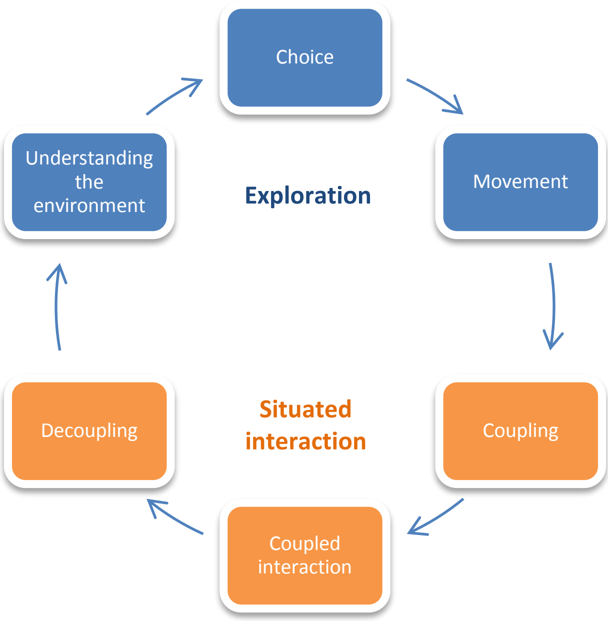


Figure 22 Visitor behaviour in a coupling environment

Concepts drawn from the reviewed literature have been used in chapters 2 and 3 to understand the extents to which the system and environment may mediate each stage of the cycle and thus suggest key design issues that still need to be addressed in order to afford the intended interaction within a coupling environment (Table 12).

Table 12 Key design issues regarding situation interaction and exploration

Stages			Design issues
Situated interaction	*Coupling*	**Q1) Coupling methods (4.1.1)**	**Issue 1** - How can intangible coupling be made explicit and understandable? **Issue 2** - In which situations does physical coupling give benefit over intangible coupling?
	Coupled interaction	**Q2) Types of couple (4.1.2)**	*i. Scale* **Issue 3** - How does scale of the couple and sharing of the interaction space affect the use of the mobile for spatial input? **Issue 4** - How significant is scale to the user's perception of the couple as affording private vs. staged interaction? How do various scales restrict or ensure group interaction? *ii. Control/feedback* **Issue 5** - How useful are the various distributions of control and feedback between the devices within a couple, particularly where the mobile is delegated responsibility for feedback?
Exploration	*Understanding the environment & choice*	**Q1) Orchestration (4.2.1)**	*i. Orchestration*: relevance **Issue 6** - Can the environment react to varying mobile device capabilities to ensure that visitors do not encounter situated devices to which they are technologically incapable of coupling? **Issue 7** - How can the user experience in the coupling environment be enhanced by enforcing narrative dependencies between couples? **Issue 8** - How can contention for couples with limited coupling capacity be avoided or alleviated? *ii. Orchestration: constraint* of action **Issue 9** - What impact do the different orchestration approaches have on the user experience? **Issue 10** - How can the denial of opportunities deemed irrelevant be implemented as a safe and beneficial feature of orchestration in coupling

		environments? *Additional issues* **Issue 12** - How do larger couples or those that stage coupled interaction affect the system's orchestration? **Issue 13** - How do the relationships within a visiting group affect orchestration?
Movement	**Q2) Location mechanisms (4.2.2)**	**Issue 11** - Are photographic trails suitable as a less cognitively-demanding means of locating chosen situated devices?

The description of the stages of behaviour in a coupling environment as a cycle raises two questions:

1. Where does the cycle begin and end?
2. Can the user retrace their steps through the cycle, i.e. does the cycle in Figure 22 only allow the user to transition clock-wise or can they also move anti-clockwise?

In answer to the first question, a visitor to a coupling environment can be expected to begin by understanding the environment, i.e. this is the user's entry point to the environment and the infrastructure underlying the environment. This is also likely to be the exit point, i.e. where the user assesses the possible interactions within the environment and chooses to leave rather than to find another couple. Obviously a user may potentially stop engaging with a couple or any aspect of the coupling environment at any moment, hence there is the possibility that the exit point (both from the point of view of the infrastructure and the user experience) might be more arbitrary; on the other hand the entry point is less flexible due to the restrictions enforced by the infrastructure (at least the infrastructure described in the next two chapters, as implemented in our trials), which prevents the user from coupling with a situated device, or receiving adverts from situated devices without use of the mobile client, which starts a user experience at the stage of understanding the environment.

In answer to the second question, the mobile client encourages movement in a clock-wise direction through the cycle (as illustrated in Figure 22), but does allow the user to retract their steps. At any point in situated interaction the user is able to cut short the interactions at the couple and return to exploration (beginning again at understanding the environment); this allows a user who does not enjoy an experience at a couple to end the experience early, or for a user who initiates coupling with the wrong couple to interrupt the process of coupling. In a similar manner the user may restart the process of exploration at any point and return to understanding the environment; this might be useful if a user is attracted by a different situated device (or dissuaded from the chosen destination) during their movement towards the destination, or if the user feels that the suitability of different destinations might have changed by the time they are faced with a choice (i.e. that the choices of suitable destinations needs to be updated). It might be argued that in these situations the user is not retracing their steps but simply going straight to the start of another cycle, leaving the current cycle unfinished. In either case the trial infrastructure does not allow the user to use this possibility as a chance to 'skip' experiences within the environment that form a necessary part of a narrative – this safeguard was discussed in response to requirement 7.

5. Instantiating the model

Chapter 4 elaborated a model of visitor behaviour in a coupling environment to allow a discussion of the six stages in the cycle of exploration and situated interaction; from this elaboration a set of design issues were proposed and summarised in Table 12 (p.105). In this chapter the model proposed in chapter 4 is realised in the form of a test-bed consisting of:

- a set of six *couples*
- a software *infrastructure* and
- three different (spatial and narrative) *configurations* of the couples

The chapter describes how each of these components of the test-bed are arrived at as a result of the design issues from the previous chapter – the couples span aspects of coupling mechanism, scale and control/feedback and are discussed in section 5.1; the software infrastructure allows an exploration of orchestration and location approaches which are discussed in section 5.2; the configurations offer the chance to determine how the layout of couples in the environment affects the individual and social experience (section 5.3). Finally section 5.4 also describes the plan for trialling the test-bed with users: in order to explore the design issues the test-bed is employed in a range of trials that draw on representatives of both potential visitors and environment designers.

5.1 Couples

In the discussion of situated interaction, distinct *coupling methods* and *types of couple* have been proposed, identifying the underexplored design issues relating to them. In this section a set of novel couples that have been constructed that span the couple design space are proposed in order to explore those design issues. Table 13 highlights the requirements for the constructed couples resulting from the previously identified design issues:

Table 13 Requirements for novel couples

Design issues	Requirements
Issue 1 - How can intangible coupling be made explicit and understandable?	**Req. 1 - implement various mechanisms for coupling intangibly**
Issue 2 - In which situations does physical coupling give benefit over intangible coupling?	**Req. 2 - implement both physical and intangible couples**
Issue 3 - How does scale of the couple and sharing of the interaction space affect the use of the mobile for spatial input?	**Req. 3 - implement couples of varying scale and capacity utilising the mobile for spatial input**
Issue 4 - How significant is scale to the user's perception of the couple as affording private vs. staged interaction? How do various scales restrict or ensure group interaction?	**Req. 4 - implement couples of varying scale explicitly supporting either group or private activities**
Issue 5 - How useful are the various distributions of control and feedback between the devices within a couple, particularly where the mobile is delegated responsibility for feedback?	**Req. 5 - implement couples that fully span the various delegations of control/feedback**

Each couple is briefly described below, alongside an image showing the couple as it has been implemented.

Visitor profile registration (Registration)

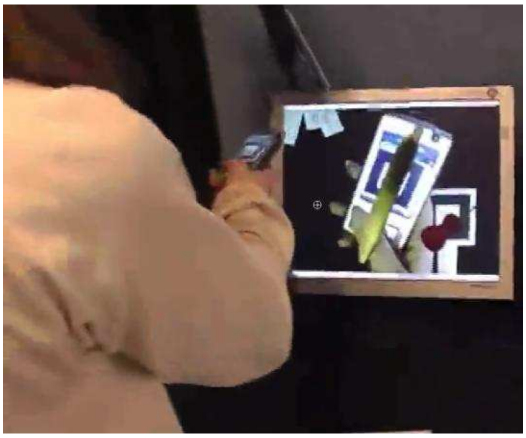
At the *Registration* a user tangibly couples their mobile device with a computer terminal, attaching the mobile so that its screen and any face-directed cameras are pointing toward the user when they sit at the terminal. The resulting couple allows the user to enter textual data using the situated display and keyboard/mouse while the mobile's display and camera will allow the user to pose and capture a portrait photograph.

Interactive map (World Map)

The *World Map* is a large printed surface annotated with labels that encode unique IDs. These IDs are linked to dynamic information held in a computer situated at the map. The user's mobile's camera may be held to the surface to scan and decode a label, linking the mobile and surface intangibly and revealing the linked information on the mobile's display.

Interactive slideshow (Slideshow)

At the *Slideshow*, an intangible connection is formed between the user's mobile and a large projected display, allowing the user to control slide-shows in real-time while seated using their mobile (via the mobile key-pad) while experiencing rich information[24] on the large display and through situated speakers.



Augmented Reality (ART)

At the *ART* couple the user displays a data matrix on their mobile phone, placing it in the view of a situated camera attached to a public display. The public display shows the view of the camera, essentially providing a mirrored view of the interaction space. The camera identifies and tracks the matrix, and thus is able to augment the public display such that, in their mirror image, the user sees a virtual 3D object sitting on the matrix on their mobile. Thus an intangible connection and spatial interaction space are formed, allowing the user to rotate and move their mobile to rotate and move the virtual object.

[24] Drawn from http://www.wikipedia.org and http://www.flickr.com

Interactive photo wall (Photowall)

The *Photowall* couple allows visitors to connect their mobile device briefly and intangibly to a public display to transfer and display images captured on their mobile device with the click of a button on the mobile key-pad. All visualisation takes place on the public display.

Interactive virtual environment (Google Earth)

At the *Google Earth* couple, the mobile device is intangibly connected to a large public display to allow the user to use their mobile device as a remote control to navigate a 3D virtual environment[25] displayed on the large situated display. Users may use the mobile's keypad to navigate the environment, or if the mobile has the capability its motion sensor may be used to allow the user to tilt the mobile to control the visualisation spatially. The user may select the country currently centred on the public display to cause music[26] to be played from that country via situated speakers.

[25] http://www.google.com/earth (accessed 10/6/09)
[26] http://www.last.fm/api (accessed 10/6/09)

Requirement 1

Implement both physical and intangible couples

The act of placing the mobile device in a physical holster as a coupling mechanism at the *Registration* is the means of exploring physical coupling in comparison to intangible coupling that takes place at all other couples. Intangible couples are more easily implemented with available interface technologies, and a range of intangible interfaces are required to address requirement 2, hence skewing the proposed couples in favour of more intangible interfaces.

Requirement 2

Implement various mechanisms for coupling intangibly

At the *Slideshow*, while the mobile is not physically coupled with the situated device, coupled interaction would be simply and clearly initiated and ended by a particular button press on the mobile device. At the *World Map*, intangible coupling occurs by scanning the data matrices. At the *ART* couple, the intangible coupling may be less explicit as the user is required to move their mobile into a specific interaction space, defined by the viewpoint of the situated camera. The user may interpret this interaction space by referring to the mirror image of the space on the public display; these cases provide a means of exploring the legibility of intangible coupling mechanisms.

'Coupled interaction' at the *Photowall* is an interesting example as it is literally momentary: the mobile is connected to the situated display for only as long as it takes to transfer any stored images – no interaction with the situated display takes part on behalf of the user. From the user's point-of-view a single button press couples the devices, transfers the photographs, then decouples the devices: this allows exploration of the user's understanding of such brief coupling and coupled interaction in comparison to those more sustained experiences at other couples.

Requirement 3

Implement couples of varying scale and capacity utilising the mobile for spatial input

While the coupled interaction at the *ART* couple is not explicitly collaborative or social, the interaction space is large enough to accommodate multiple users simultaneously. Spatial interaction using the mobile within a shared confined space may provoke social interaction between users, including conflict for that space, allowing identification of interactions within a spatial interaction space that might be mediated further. While the interaction space at the *Google Earth* couple is also large (indeed larger) in contrast to the *ART* couple, only one user is explicitly supported for coupled interaction. As such a single user is using the space for spatial interaction, sharing the space with others who are not interacting (bystanders and passers-by), providing a comparison of the use of the space with the *ART* couple.

Requirement 4

> *Implement couples of varying scale explicitly supporting either group or private activities*

Both the *Slideshow* and *Google Earth* couples are large (equal in terms of physical space to the *World Map*) but intended for use by only one user, thus the effect of scale on the users' perceptions of the purpose of the couple and whether users attempt to engineer group interactions in the space when they are explicitly denied by the couple may be explored. Conversely the *Registration* couple has the smallest scale of all couples – on the border of pad and body-size – thus allowing exploration of the other extent of user perceptions of privacy/staging.

The *World Map* couple provides an interaction space capable of being occupied by multiple users simultaneously, but in this case (unlike the *Slideshow* and *Google Earth* couples) multiple simultaneous couples *are* supported and thus the space is shared. However, the coupled interaction is intended to be personal, i.e. it is not explicitly a group or collaborative coupled interaction, thus the couple allows exploration of whether the large scale causes this distinction to become blurred, adding group aspects to the intended personal coupled interaction. The scale of the *Photowall* couple is also large yet no group interactions are explicitly supported, and no sustained coupled interaction is supported to encourage observation by bystanders or other potential social interactions. This allows determination of whether scale itself will foster social interaction at the couple.

Requirement 5

> *Implement couples that fully span the various delegations of control/feedback*

The *World Map* couple delegates responsibility for control and feedback in the coupled interaction to the mobile device; the situated device provides only extended capabilities for storage (of the information to which the matrices are linked). The mobile is deemed capable enough of control and feedback here, while coupling is used to transform a static public display into an interactive installation, exploring the underdeveloped aspects of the feed-back/control space. At the *Slideshow* and *Google Earth* couples, control and feedback are clearly divided amongst the two devices with control delegated to the mobile and feedback to the situated display. At the *Registration* and *ART* a more typical combination of control delegated to the mobile and feedback distributed across the two devices. By utilising both the mobile device and situated device for input and output at various points during coupled interaction the user must transfer their attention between the two devices at the *Registration* couple. While the *Registration* aims to encourage transfer of attention, in the case of the *Slideshow* control is delegated to the mobile and feedback to the situated display, and as such the user's attention should remain with the situated display. This provides an opportunity to witness unexpected distractions.

Table 14 Proposed couples vs. requirements to be met

	Requirements				
Couple	**How can coupling be made explicit and understandable?[27]**	**In which situations does physical coupling give benefit over intangible coupling?**	**How does scale of the couple/sharing of the interaction space affect use of the mobile for spatial input?**	**How significant is scale to the user's perception of private vs. staged interaction? How does it affect group interaction?**	**How useful are the distributions of control/feedback between devices in a couple?[28]**
Registration	P	n/a	n/a	Pad-size, private	C delegated to situated; F distributed T
World Map	I	By successful matrix scanning	n/a	> Body-size, shared	C+F delegated to mobile
Slideshow	I	By single button press	n/a	> Body-size, individual	C delegated to mobile; F delegated to situated
ART	I	By placing mobile within interaction space	Body-size, shared	Body-size, shared	C delegated to mobile; F distributed T
Photowall	I	By single button press	n/a	> Body-size, individual	n/a
Google Earth	I	By single button press	> Body-size, individual	> Body-size, individual	C delegated to mobile; F delegated to situated

[27] P = physical coupling; I = intangible coupling
[28] C = control; F = feedback; T = substantial transfer of attention required

Table 14 above summarises the contributions of the proposed couples towards exploring the first five design issues. As the table illustrates, the design issues are explored by spanning the interesting and variable aspects of couple design highlighted in section 4.1. Although the design variables are not exhaustively explored through the six implemented couples, interesting design combinations have been represented.

The following section briefly describes the implemented software infrastructure's role in facilitating user exploration of the coupling environment.

5.2 Exploration

In order to compose the constructed couples as a *coupling environment* a software infrastructure has been developed. This infrastructure - including a mobile client application, server applications for situated devices, a context database and communication protocols to link each of these components - facilitates the process of *exploration* as defined in the model of behaviour. To mediate the process of exploration, the client application installed on the mobile forms an interface between the visitor and the coupling environment. This section describes the mobile client's role in *orchestrating* the visitor's exploration and in providing *guidance* between situated devices.

5.2.1 Orchestration

Table 15 below states the design issues related to orchestration and the resulting requirements for the developed software infrastructure:

Table 15 Requirements for infrastructure

Design issues	Requirements
Issue 6 - Can the environment react to varying mobile device capabilities to ensure that visitors do not encounter situated devices to which they are technologically incapable of coupling?	**Req. 6 - Fully utilise all mobile technologies for coupled interactions, resulting in couples unsuitable for less full-featured mobiles, and deny coupling to such couples**
Issue 7 - How can the user experience in the coupling environment be enhanced by enforcing narrative dependencies between couples?	**Req. 7 - Require that visitors have completed previous actions before particular couples are deemed suitable by the system**
Issue 8 - How can contention for couples with limited coupling capacity be avoided or alleviated?	**Req. 8 - Limit the coupling capacity of some couples and consider capacity as a suitability factor when mediating exploration**
Issue 9 - What impact do the different orchestration approaches have on the user experience?	**Req. 9 - Implement system mediation of the understanding of the environment and choice of the user ranging from direction to selection**
Issue 10 - How can the denial of opportunities deemed irrelevant be implemented as a safe and beneficial feature of orchestration in coupling environments?	**Req. 10 - Deny the opportunity to for visitors to couple with situated devices deemed irrelevant, ensuring that visitors may be able to observe other visitors for whom the devices are not denied**

The developed infrastructure utilises a central database of limited contextual information (the *context database*) that can be populated and accessed by both situated devices and mobile devices, containing the following information:

- *Location of the users/mobiles* and *location of the situated devices* to determine proximity – location in the test-bed is considered in a relatively coarse manner, locating the visitor/mobile according to the situated device they most recently coupled with.
- *Visitor profile* – a visitor's profile might consist of a wide range of information, such as gender, occupation, likes, and so on. For the trials visitor name and age are considered as examples to allow demonstration of how the environment might adapt to visitors with different profiles.
- *Mobile technology profile* and *situated device technology requirements*, allowing coupled interaction to be either denied or adapted if the mobile does not possess specific technologies (**requirement 6**). Couples that require non-standard mobile technologies have already been described: *World Map* and *Registration* require use of a mobile's camera[29], and *Google Earth* requires a mobile's motion sensor.
- A record of past significant interactions by the users (which situated devices have been visited, whether coupled interaction has been completed at those couples, and whether photographs have been captured while exploring) and situated devices' requirements for the completion of particular significant interactions, i.e. the situated devices' *narrative dependencies* (**requirement 7**).
- A *total capacity* and a *current free capacity* for each situated device (**requirement 8**); the total capacities of the couples vary broadly: the *World Map* couple supports up to 8 coupled visitors simultaneously, *ART* supports 3, while the remaining four couples support only one visitor at a time.

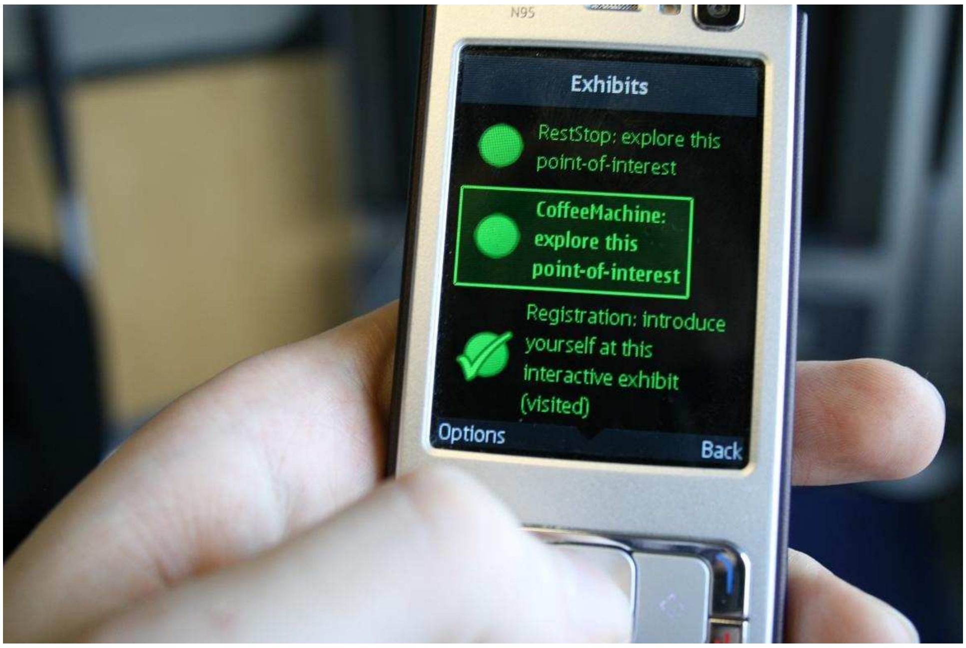
The system uses this information to determine the relevance of situated devices to a particular visitor. Depending upon the particular orchestration approach being explored, the infrastructure allows either the mobile client to *pull* details of 'relevant' situated devices from the database when the visitor desires (enabling *selection* or *search*), or for the context database to *push* details of those situated devices to the mobile client when the system deems suitable (enabling *update* or *direction*), as detailed in Table 16 below:

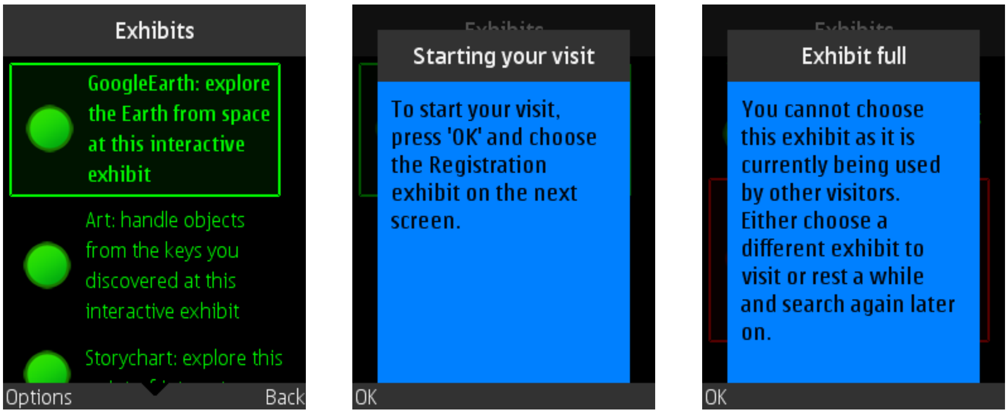
[29] The *World Map* requires a typical snapshot-style mobile phone camera, whereas the *Registration* requires the rarer video-calling style person-facing mobile phone camera.

Table 16 Types of information delivered to mobile by system for varying exploration mechanisms

Exploration mechanisms	Information delivered to mobile device from context database
selection	None until a choice is made, following which the relevance of the chosen couple is delivered to the mobile
update or search	A prioritised and/or filtered list of potential couples is delivered to the mobile
direction	A statement of the most relevant couple chosen by the system is delivered to the mobile

In all cases, the mobile device visualises the received information, either requiring the user to make a choice from a list in the case of update or search (Figure 23a), accept the choice made by the system in the case of direction (Figure 23b), or respond to a potential denial of the chosen couple in the case of selection of a couple deemed irrelevant by the system (Figure 23c).





(a) (b) (c)

Figure 23 Information from the context database visualised by the visitor's mobile

5.2.2 Movement

Section 4.2.2 proposed that photographic trails are a suitable means of providing aid for movement from point to point within the coupling environment. This translates to a simple requirement for the software infrastructure, as stated below:

Table 17 Requirements for software infrastructure

Design issues	Requirements

Issue 11 - Are photographic trails suitable as a less cognitively-demanding means of locating chosen situated devices?	**Req. 11 - Implement a photographic trail-based location system**

Via the developed infrastructure, when a choice of situated device has been made the visitor's mobile client presents a sequence of photographs of highly-visible landmarks in the environment, representing steps on the path to the chosen couple (Figure 24). These photographic trails are dynamically generated, leading the visitor by plotting the shortest route through a graph of photographs of landmarks thinly covering the entire coupling environment, thus satisfying **requirement 11**.

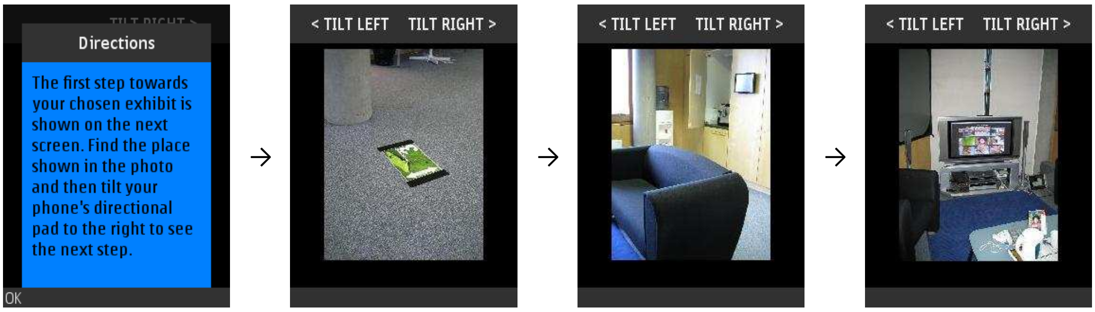


Figure 24 Mobile supporting movement via photo-trails

5.3 Configurations

The layouts of the couples in conjunction with particular narrative structures may be described as *configurations*. The ability to vary the configuration of the coupling environment is important to allow the process of visitor exploration, mediated by the developed software infrastructure, to be observed: three different configurations have been implemented to explore design issues. For the sake of the trials the configurations will form a small museum-like educational experience ("Global Explorer") as a representative of a potential candidate for uptake of the coupling design paradigm; the limitations of choosing to represent this particular type of coupling environment are discussed in a critical reflection at the start of part 3 of the thesis.

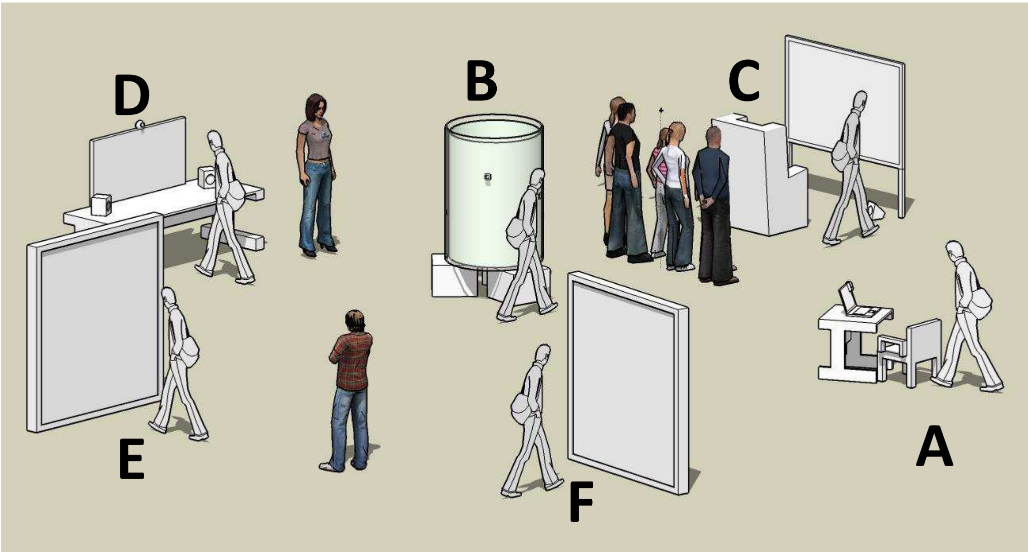


Figure 25 The final six couples (A: Registration; B: World Map; C: Slideshow; D: ART; E: Photowall; F: Google Earth)

The initial configuration (summarised in section 5.3.1) allowed for testing of the *robustness* of the core couples and environment infrastructure. The second configuration (section 5.3.2) introduced mechanisms for affording *variety* in visitor trajectories, e.g. branching narrative and adaptive couples. The final configuration (section 5.3.3) – the most complex coupling environment – allowed exploration of the effects of configuration on *social interaction* in the coupling environment.

5.3.1 Configuration 1: basic robustness

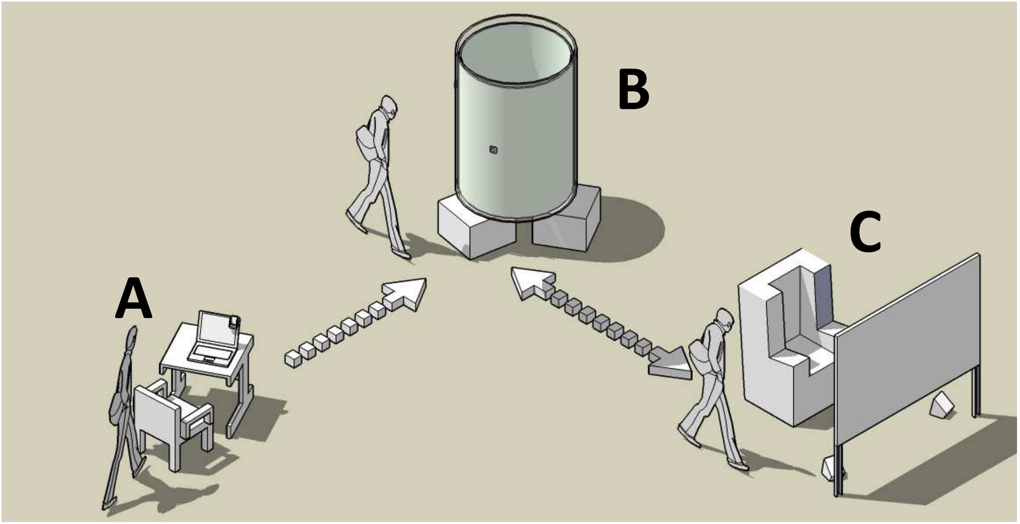


Figure 26 Layout of the couples in the first configuration and the intended movement between them

The three situated devices in the initial configuration form a simple linear sequence (Figure 27): the *Registration* couple provides the gateway to the coupling environment and completion of the coupled interaction at this couple is the prerequisite of any further coupled interaction in the environment.

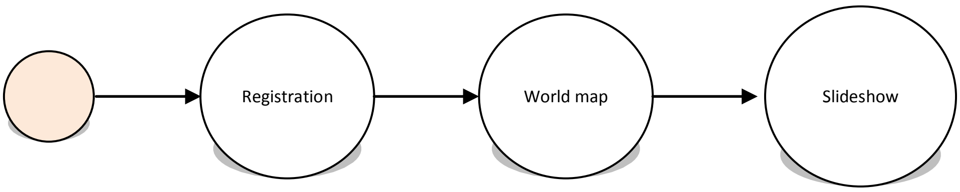


Figure 27 Narrative structure in first configuration

In all configurations the *World Map* couple is intended to act as a staging post for further couples, providing accommodation for multiple visitors and a conceptual overview of the coupling environment (allowing the visitors to view a map of the world before learning about particular places at subsequent couples); this couple is the next step in the narrative dependencies of the coupling environment.

The *Slideshow* relies upon coupled interaction at the *World Map* having taken place: a slideshow will only be available for viewing at the couple if the visitor has scanned the related matrix at the *World Map*. The software infrastructure provides the means for content to be recomposed in a form suitable for viewing on the visitor's mobile and for storage and transfer. The *Slideshow* couple gives the visitor access to this feature, allowing visual content to be 'grabbed' from the situated display to the mobile phone.

This configuration allows both the basic implementation of the test-bed and the assumptions regarding the structure of the individual experience within the coupling environment to be explored. In particular the configuration facilitates the investigation of the use of *direction* to orchestrate the visitor's experience, *photographic trails* for supporting movement and a basic coupling environment with *linear narrative dependencies*.

5.3.2 Configuration 2: introducing variety

The initial configuration was extended to include two further couples – *ART* and *Photowall* – in order to allow exploration of further design issues, particularly:

- Deployment over a larger, more varied space, allowing a richer exploration of the range of factors affecting exploration of the coupling environment, in addition to the effectiveness of the photographic trail guidance method.

- Exploration of the perception of and support for branching narratives in contrast to the linear progression afforded by configuration 1. Additionally the environment includes a new coupling opportunity that is not part of *any* narrative (*Photowall*).

The layout of the five couples in configuration 2 is visualised in Figure 28:

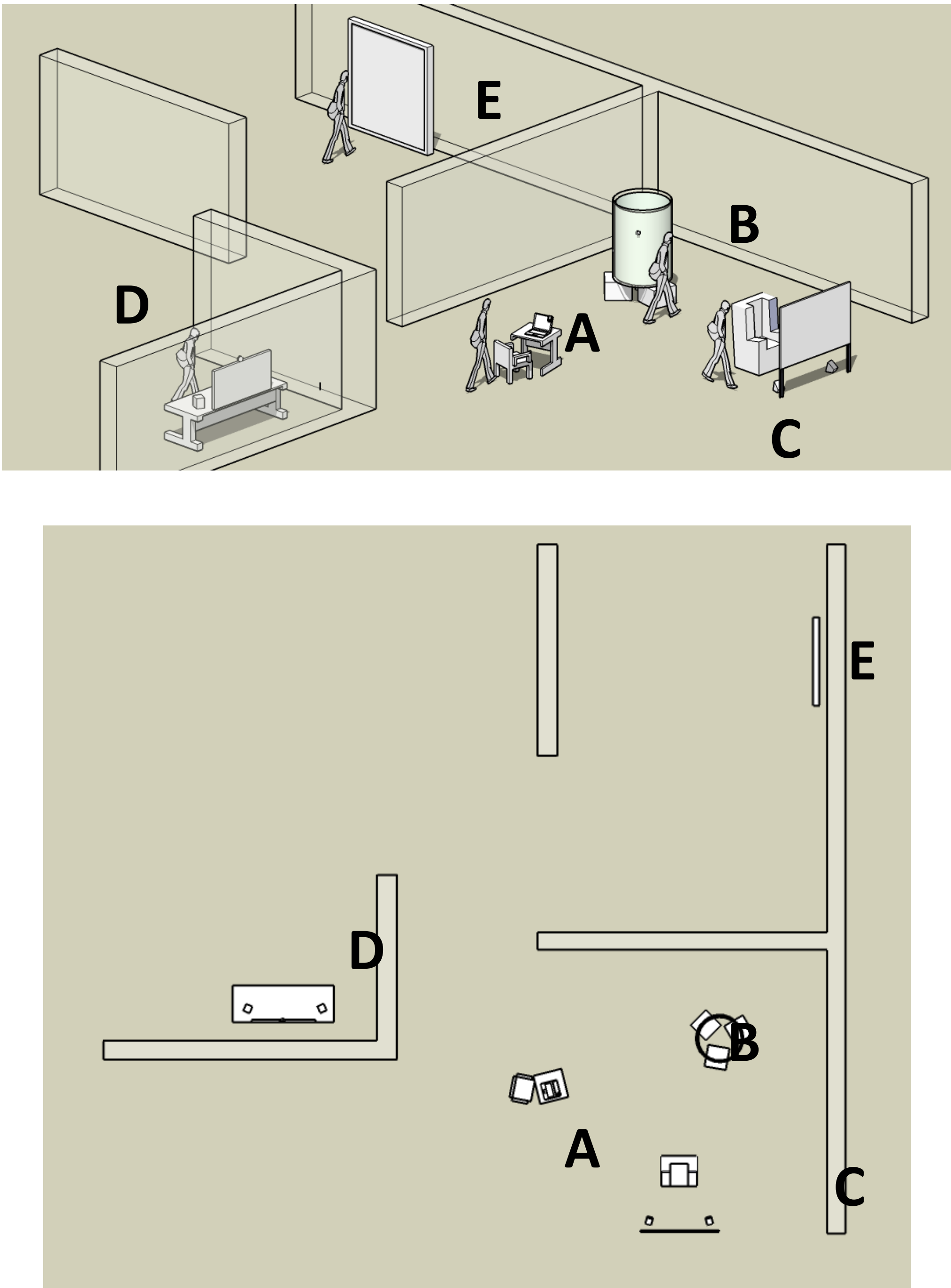


Figure 28 Layout of couples in configuration 2

ART naturally follows, as the *Slideshow* couple did, the *World Map* in narratives as the visitor is required to have discovered locations at the *World Map* before receiving any data matrices to display at *ART*. Figure 29 illustrates the branch that *ART* causes in the narrative in comparison to the linear sequence in the initial configuration.

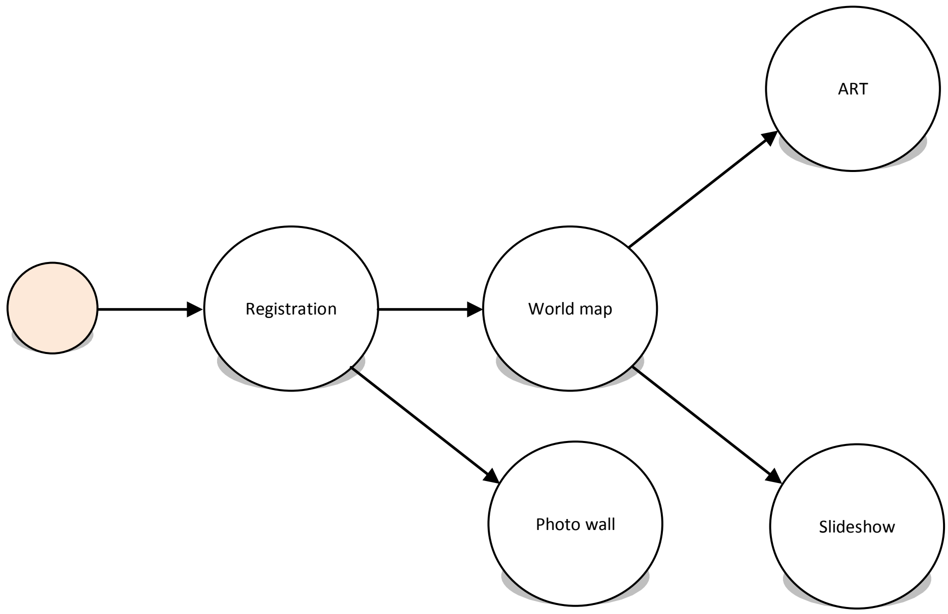


Figure 29 Narrative structure in configuration 2

By introducing non-linear narrative other approaches to orchestration beyond direction becomes an interesting prospect as the visitor now has the potential for choice.

The mobile client allows visitors to capture photographs while exploring the environment (see Figure 30 top). The mobile also plays the role of container for these photographs (in addition to content collected during coupled interaction), allowing the visitor to transfer them to other points in the environment in the same way that content could be carried away from the *Slideshow* couple. All such content is collected in the visitor's 'wallet' accessible through the mobile client.

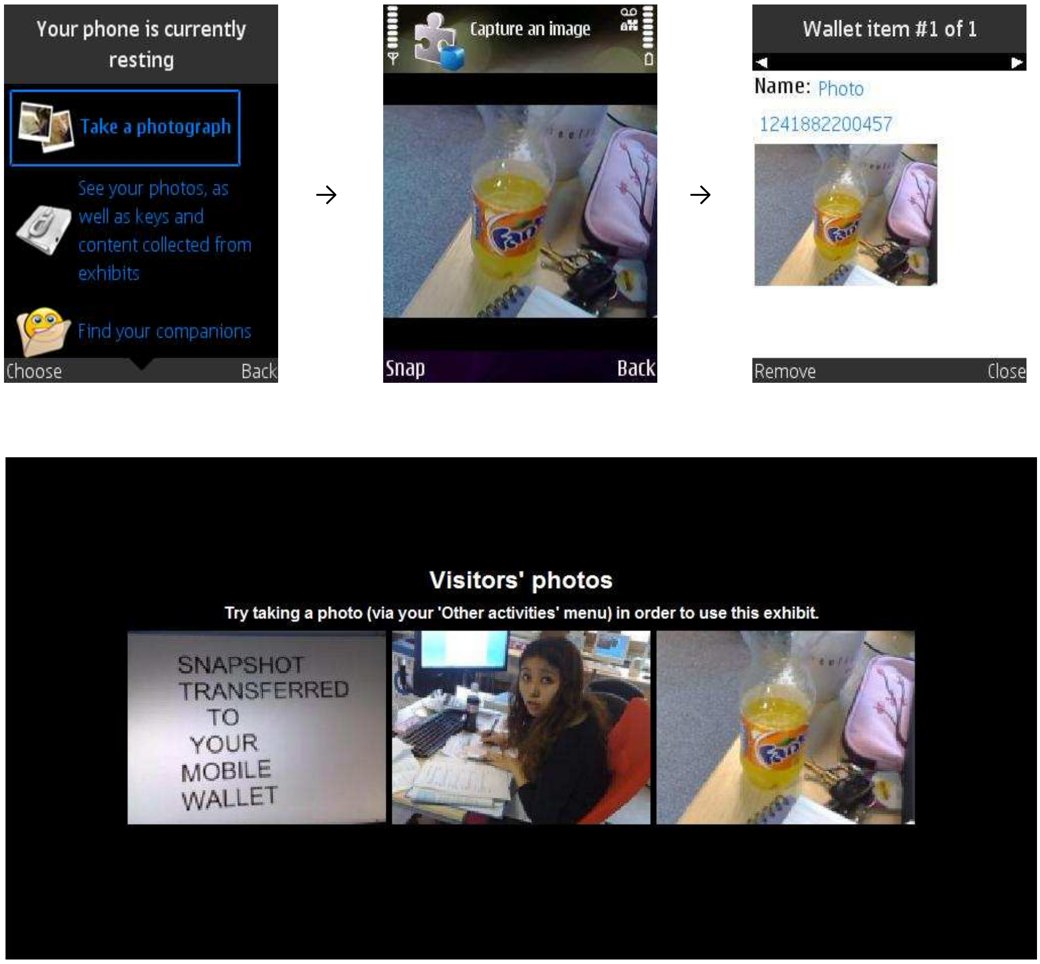


Figure 30 Capturing and viewing a photograph via the mobile client (top); photographs publicly staged via the *Photowall* situated display (bottom)

The *Photowall* serves as a means to publicly stage such personally-created content (see Figure 30 bottom). The *Photowall* coupling opportunity relies upon the visitor having completed an experience at the *Registration* couple but also relies upon the visitor having captured a photograph in order for the coupling opportunity to be relevant for coupling.

5.3.3 Configuration 3: social interaction

The final environment configuration consisted of the previous five couples in addition to one final coupling opportunity – *Google Earth*. This final configuration focuses upon exploiting layout to:

- encourage beneficial social interactions at couples: layout is used to limit the observation of those couples where the coupled interaction is intended to be private (*Reg-*

istration), and to provide enough space for use by groups or multiple individuals (*World Map, ART* and *Google Earth*).

- better reflect the narrative structure, such that the three couples that follow the *World Map*, i.e. *ART*, *Google Earth* and *Slideshow*, are all located together, yet separate from the World Map so as not to encourage movement from the World Map to any one of the three in particular.
- match the nature of the couples with the areas in which they are placed. The *Photowall* couple is separated from other displays so as to be more prominent, yet within an area where visitors to the environment typically rest and drink coffee, better matching its role as a less interactive and thus less attention-grabbing couple.

This strategic use of layout contrasts with configuration 2 where layout was used simply to test the effectiveness of photographic trails as a means of guidance. In order to use layout for these aims, and to continue verifying the guidance mechanism, the couples are spread over a larger space (Figure 31).

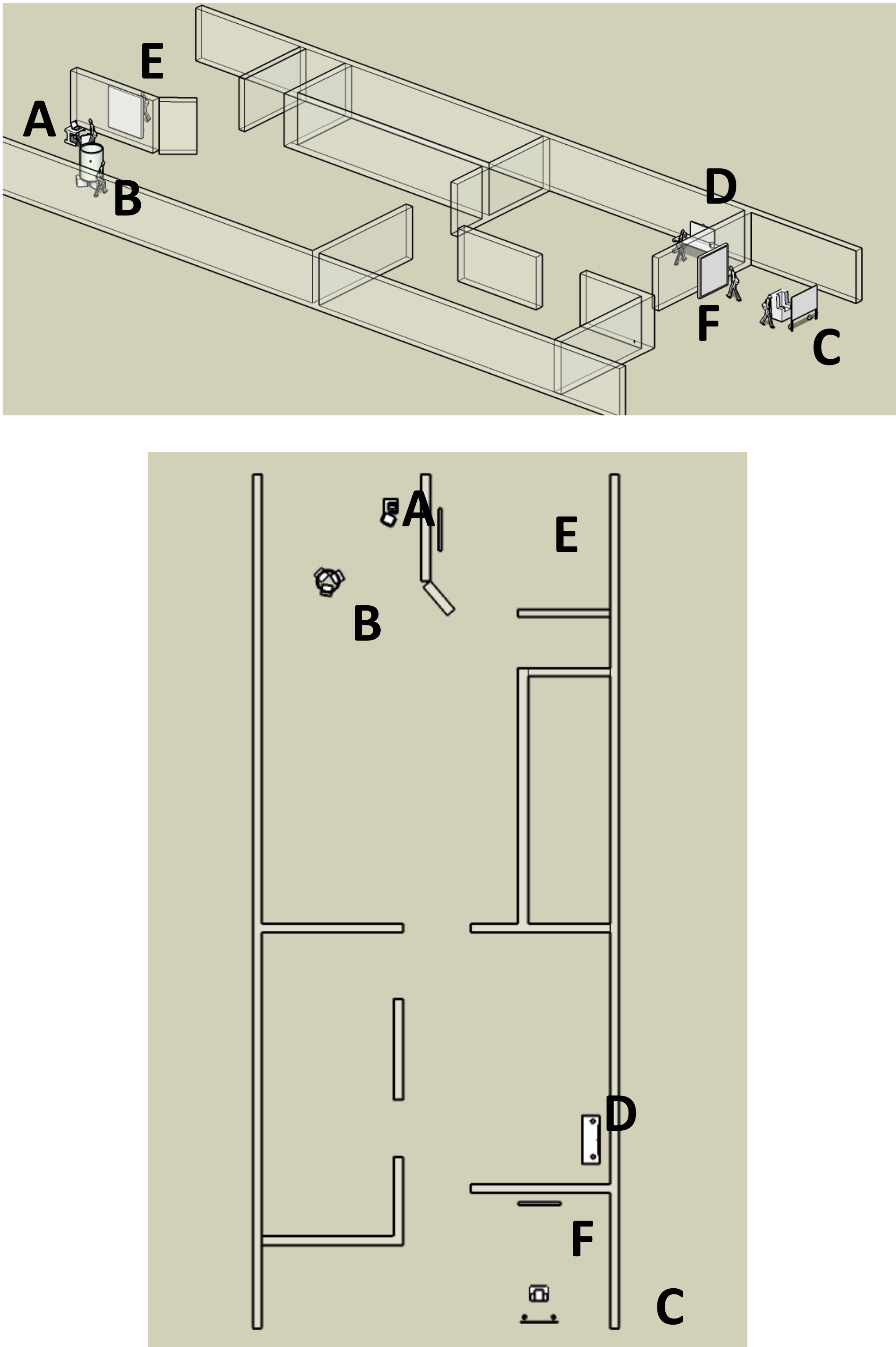


Figure 31 Layout of the coupling environment in configuration 3

Again, as with *Slideshow* and *ART*, the *Google Earth* visualisation is adapted according to previous interactions at the *World Map*, in this case using overlays to indicate which locations have been found and which have yet to be found. The couple follows the *World Map* in the environment's narratives alongside *ART* and *Slideshow* providing a greater variety of choice after the first visit to the *World Map*. At this stage the *World Map* appears more and more to resemble a form of ‘hub’ experience, providing the basis for a number of later experiences. Figure 32 shows the state of the narrative structure in the final trial.

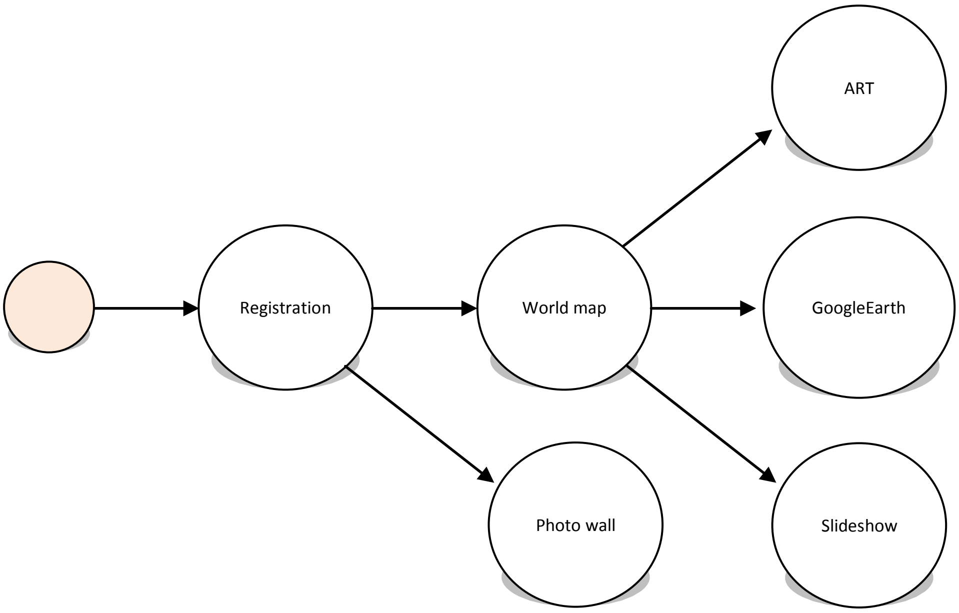


Figure 32 Narrative structure in configuration 3

Configuration 3 represents the most complex narrative structure of the three configurations and thus serves as the best means to test the different orchestration approaches and the understandability of the environment from the point-of-view of the visitor.

5.4 Trials

It was stated in the introduction to this chapter that, in order to explore the varying couples, configurations and orchestration techniques, it is necessary to test them with users, i.e. to conduct trials. During the trials the configuration of the environment changes (as described in the previous section), yet the design of the software infrastructure and the couples themselves was also treated as a work-in-progress in order to explore emergent issues exposed by testing with users. The sequence of trials thus comprise a formative approach to exploration of the design issues, whereby different design issues are explored in different trials and addressed, while at the same time improving the robustness of the test-bed. Later in chapters 7 and 8 the significant lessons learnt during this formative process are reported, while summative reflection determines how these lessons might be applied to maximise the benefits that can be gained from guided design of coupling environments.

In order to address the final remaining design issue (13), the trials must consist of varying *types* of visitor in terms of individuals vs. visiting groups, the relationships between visitors, their design expertise and the number of visitors in-trial simultaneously.

Table 18 Requirements for trials

Design issues	Requirements
Issue 13 - How do the relationships within a visiting group affect orchestration?	**Req. 12 - Trial coupling environments with both individual visitors and with visiting groups with a variety of internal relationship structures**

In total five trial sessions have been conducted. *Trial 1* utilises configuration 1. In this basic iteration of the coupling environment it was expected that implementation issues with the test-bed would emerge, hence 10 test subjects were drawn from tech experts with a background in the design of mobile and novel technologies – test subjects that were both more accommodating than the average member of the public of the flaws in the system yet also more critical of its potential. The participants' ages are distributed relatively evenly between 18 and 45 years old with one user over the age of 45; only 3 of the users were female, in contrast to 7 male users. The majority (6) of these test subjects experience the trial environment *individually* while two pairs visit the environment concurrently (although each with their own mobile device), thus there were 8 sessions in total.

In *trials 2-4* configuration 2 was used, allowing orchestration approaches and a broader variety of visitors to be explored. As previously stated, it can be expected that the majority of visitors to many types of coupling environment will visit in groups. Also, within some of these groups (e.g. groups of friends) individuals will bring and use their own mobile devices, while other groups (e.g. families) may tend towards the sharing of a central device. Investigation of a variety of group types in these trials serve as a means of exploring the potential for the mechanisms implemented in the trial environment to cater for group visits, in particular how potentially varying roles within the groups might need to be supported.

Trial 2 draws from volunteers less familiar with the technologies employed in the trial environment. Employed are two family groups (both of two parents: one with one child and one with two children) and three groups of friends (one group aged 18-19 consisting of three testers and two aged 21-22 consisting of two and three people). These groups all experience the coupling environment separately, i.e. only one group at any one time, resulting in five sessions, thus the inter-group effects are not studied in favour of exploring intra-group issues. Within the two family groups the children are all aged from 10 to 17 years old while the parents are aged 36-45.

Following trial 2 two further trials are conducted with potential environment developers and designers, beginning with Architecture students. 14 students from the penultimate year of their University studies experienced the coupling environment through 5 mobile phones concurrently in one session with their own aim of exploring how mobile phones might be used to create dynamic public spaces. The majority of the students (11) were aged from 18-25 years old with 3 further students falling in the range of 26-35; in fact this data from the questionnaire (see appendix 10.5) possibly fails to fully reflect the similarity of the students ages, as students at this stage in their course are typically either 24, 25 or 26 years old. There was an almost even split between male and female users in this trial, skewed very slightly towards the former (8:6). The students operated essentially as a single large group of visiting friends with a number of mobile phones that often changed hands. As such this trial forms the largest group trial of the series and is the first opportunity to explore the dynamics both within and between social groups as affected by the mechanisms employed within the coupling environment.

Following the Architecture student trials a workshop was held for 12 professionals from the region including art gallery and museum curators, exhibition designers and researchers. This trial aimed to tap not just into raw ideas as the student trial did, but into grounded experience of professionals involved in the design of traditional exhibitions. As with the previous trial, the test subjects shared 5 mobile phones but split naturally into small groups of 2 or 3 subjects based upon their familiarity with one another which varied across the group (as opposed to the students who were all familiar with one another). All professionals were aged over 26 years old, with the majority (9) aged from 26 to 45 years old; there was one user aged 56 or above. The majority (10) of the professionals were male.

A final non-expert test (*trial 5* in configuration 3) concluded the trial programme and consisted of 14 non-experts drawn from a local student community, thus ranging from 18 to 45 years (with the majority clustered within the typical university undergraduate age range of 18-22 years of age). The majority (9) were male. The volunteers tended to consider themselves to engage in an "above average" adoption of new technologies but did not show a common tendency to use their mobile devices more than those visitors in the family/friend trials or for any uses beyond those of the family/friend visitors. These visitors were encouraged to form groups if they were familiar with one another, resulting in 7 individuals, two pairs and one group of three. The visitors experienced the coupling environment split into two separate sessions, the first consisting of four individuals and one pair, the second consisting of the remaining three individuals, pair of visitors and group of three.

Table 19 Summary of trials

Trial #	Visitors	Configuration #
1	10 tech experts in 8 sessions: • 6 individual sessions • 2 sessions with 2 visitors with personal mobiles	1
2	15 family visitors in 5 sessions: • one session with a group of 4 sharing a mobile • 3 sessions with groups of 3 sharing a mobile • one session with a pair sharing a mobile	2
3	14 design students in one session: • students share 5 mobiles, shuffling groups regularly	
4	12 exhibition design professionals in one session: • one session where 3 pairs of visitors each share a mobile and two	

	groups of 3 visitors each share a mobile	
5	14 visitors in 2 sessions: • one session where 4 visitors use their own mobiles and one pair share a mobile • one session where 3 visitors use their own mobile, one pair share a mobile and one group of 3 share a mobile	**3**

5.5 Summary

This chapter has stated requirements and matching implementations of couples and a software infrastructure to address the design issues isolated in chapter 4. Having constructed six couples and an infrastructure to allow the orchestration of visitors' experiences while exploring the environment, three distinct configurations of the coupling environment have been proposed that will form the basis for user trials. The physical aspects of the three configurations, i.e. the couples involved and the layout of those couples, are summarised in Table 20 below.

Table 20 Physical aspects of configurations

Configuration #	Couples	Layout
1	*Registration, World Map, Slideshow*	All couples side-by-side
2	As above + *ART, Photowall*	Couples spread within a large room (with some visible disconnections) containing other unrelated situated devices
3	As above + *Google Earth*	Couples spread over three rooms (with some visible disconnections) containing other unrelated situated devices

Implementing various configurations of the situated devices allows the attracting/repelling effects of coupled interaction to be explored. The possibility that the visibility of users engaged in coupled interaction may affect passers-by, and that sounds and light projecting from a couple into the surrounding space could also do so have been identified (issue 12), thus reorganisation of the space to minimise and maximise such phenomena allow these theses to be tested. In all three configurations situated devices are placed near one another, other unrelated situated devices and/or on thoroughfares that lead to other couples, but the combinations of the devices are altered such that different situated devices are adjacent to one another in different configurations. This provides ample means to explore design issue 12.

Table 21 Requirements for configurations

Design issues	Requirements

Issue 12 - How do larger couples or those that stage coupled interaction affect the system's orchestration?	**Req. 13 - Locate the couples in the environment such that large couples or staged interaction is on or near thorough-fares**

The choice of users for five trial sessions spanning the three configurations has been made such that varying behaviours of the different types of visitors and visiting groups that might visit a coupling environment can be explored.

Chapter 6 now gives a more detailed technical account of the developed software infrastructure. This chapter provides particulars regarding not just the functions of the mobile client (as was the brief focus in section 5.2) but of the composition of the complete system – from context server to mobile clients – the generic functionality of each of the components, and a specific example of how the generic infrastructure has been extended to implement real trial coupling environments.

6. Software infrastructure

The previous chapter introduced the designs of the six couples, provided a brief overview of the features of the software infrastructure for supporting exploration and presented three configurations of coupling environments required for user trials. This chapter discusses in more detail the implementation of the software infrastructure. Section 6.1 covers the architecture of the software infrastructure as a three-tier structure underpinned by a profile-database. Section 6.2 explains how that architecture facilitates orchestration of visitor exploration. Section 6.3 gives details of the process by which the system generates photographic trails to provide visitors with guidance between couples. Section 6.4 describes how a generic representation of a couple in the software infrastructure is extended to create specific couples. Finally section 6.5 summarises the chapter by illustrating (through real example) how the software infrastructure is used by a visitor to find, couple with and engage in coupled interaction with an implemented couple.

A secondary goal of implementation of a software infrastructure is to contribute in a more tangible sense by providing a generic yet extensible software infrastructure for the design of further coupling environments, both for future research and for other designers to practically explore the coupling concept. While the system is implemented using Java (ME and SE) and MySQL this was simply a logical choice given the author's development experience – the software infrastructure has not been designed from a specifically-Java perspective and is intended to inform developers at a conceptual level. When references are made to the test-bed's Java/MySQL implementation these references are examples, not directions for implementation, particularly given the rapid pace with which new development platforms such as Android[30] are emerging that may better suit future implementations.

[30] http://www.android.com (accessed 24/2/10)

6.1 Architecture

The system infrastructure consists of three tiers (presentation, logic and data). Columns 1 and 2 of Table 22 below indicate the software infrastructure components:

Table 22 System architecture tiers

Conceptual tiers	Infrastructure components	Deployment
Presentation	Mobile clients (Java ME midlets)	*Mobile devices*
	Instances (Java SE processes of middleware servers)	*Situated devices*
Logic	Situated installations (Java SE server applications)	
	Context server (Java SE application)	*Database device*
Data	Context database (MySQL data-base)	

At the lowest level a persistent database deployed on a single central device stores context[31]. This data tier serves a logic tier consisting of:

- a single context-server which manages (updating and serving context from) the context database and
- multiple server applications distributed across the situated devices ("installations") in the environment that represent couples for visitors.

The installations pass updates in the state of their situated device back to the context server and request context from the context server as required for orchestration. They also generate and manage one instance of the functionality of the couple per visitor that couples with their situated devices. During *coupled interaction* the instances and mobile clients coordinate in order to provide presentation of content and a functional interface to the visitors. Depending upon the distribution of interaction across the couple, visitors may interact directly with the situated device at a couple (and thus with their personal instance), with their mobile client as

[31] The term 'context' here refers to a fairly limited selection of attributes, listed in section 5.2.1.

a proxy to their personal instance, or with both. In the latter cases the mobile client represents an additional presentation layer on top of the visitor's personal instance. While decoupled the mobile client may communicate with the context server in order to present functionality to its user relevant to *exploration*.

Columns 2 and 3 of Table 22 indicate the devices on which the various components are deployed. Mobile clients are deployed to the mobile devices carried by visitors in the environment. Installations are deployed to the situated devices to which visitors will couple their mobiles to afford coupled interaction, i.e. one installation is deployed to each situated device. Each installation may spawn one or more instances, each of which accommodates one visitor; these instances also reside at the situated device on which their parent middleware server is deployed. There is only one context database and one corresponding context server to negotiate database transactions.

The message-passing mechanisms, management of the context database and the way in which devices are addressed in order to allow communications are all detailed in appendix 10.1.

6.2 Orchestration

One of the major processes involving the use of information held in the context database is to determine relevant couples for visitors. In section 5.2 it was stated that, in order to support direction, update, search and selection visitors must be able to pull a list of couples prioritised by relevance as determined by the system, and the system must be able to push the same information to the visitor. The visitor's mobile is the proxy here, visualising the couples for the visitor, thus orchestration focuses upon the relationship between mobile client and context server.

The context server is capable of forming a list of couples currently existing in the coupling environment by querying the context database for registered installations and their relevant attributes (name, description, current capacity, narrative dependencies and technological requirements). This list can be delivered to a mobile client to allow the visitor (via the mobile client) to sort the list according to any of the attributes, or simply view the value of the attributes for each opportunity – in this way the visitor may utilise raw context to make their own unmediated understanding of the environment. Alternatively the context server may process the attributes somewhat before sending, e.g. by hiding or magnifying a particular attribute, thus providing processed context to shape the visitor's view of the opportunities. In order to provide a prioritised list of opportunities to the visitor rather than simply context, the context server may *sort* the opportunities before sending them, the results of which the mobile client can simply display, an example of which is shown in Figure 33, without allowing the visitor to explore the context underlying the sort order.

Figure 33 Mobile client UI displaying a prioritised list of adverts for the visitor to choose from

In order to determine the priority of a particular coupling opportunity, the context server creates *adverts*[32] whereby the contextual rules are applied to context from the context database in order to categorise the coupling opportunity. These categories each have a priority level and are delivered with the prioritised list to the mobile client so that notions of category or priority level may be represented to the visitor in addition to the sort order alone.

Finally, as previously proposed, the context server may *filter* the adverts, sending only those it deems relevant to the visitor's mobile. The filtration process essentially thresholds the sorted list of couples, delivering only those of particular advert categories.

In order to provide support for direction, update and search, transfer of this information from the context server to the mobile client is triggered by a particular message from the mobile client. This message may be sent either by the mobile client when it deems the information necessary (update) or upon a particular UI gesture by the visitor (search). To support direction, the mobile client may request a filtered list of couples to learn which coupling opportunity is most relevant, and then simply begin the movement process, bypassing interaction with the visitor.

As previously proposed, selection requires no mediation on behalf of the visitor regarding the choice of a particular coupling opportunity. However, since the intention is to deny access to couples deemed unsuitable for the visitor, the mobile client still requires the information from the context server to inform the visitor whether or not the coupling opportunity they have selected is available for coupling. The test-bed provides a mechanism to allow the visitor to enter a codeword (the name of the coupling opportunity) or scan a data matrix (in which is encoded the coupling opportunity name) in order to select a coupling opportunity; the mobile client then requests a prioritised list of couples and cross-references in order to determine whether the selected opportunity is open for the visitor. The mobile client then reflects its decision back to the visitor; Figure 34 shows a negative response by the mobile client to a selection of a coupling opportunity with no free capacity for another visitor to couple, denying the visitor access to the couple.

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[32] See bzb.se.adverts.Advert for contextual rules used in the final trial and bzb.se.adverts.Adverts.Priorities for resulting advert categories

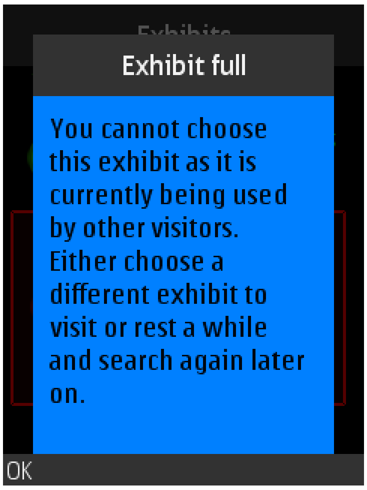


Figure 34 Proactive denial enforced by the mobile client upon *selection* of a particular coupling opportunity by the visitor

6.3 Visitor guidance

Given that the context database contains the location of situated devices (and the potential for additional, non-coupling opportunity points-of-interest), and the last known location of the visitors, as well as paths that connect the points-of-interest, it is a fairly trivial task to provide photographic trails to guide a visitor from their last known location to a destination of choice.

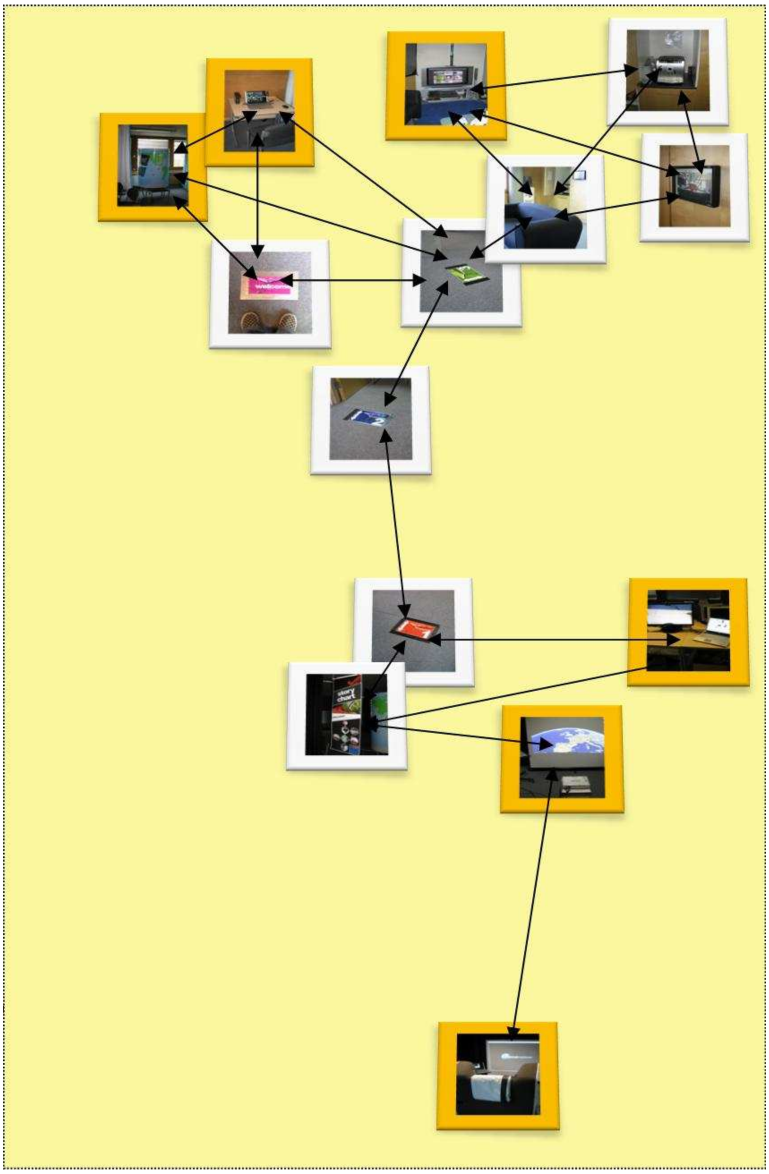


Figure 35 Topographic representation of photographs of nodes in final trial coupling environment

Figure 35 represents visually the photographs attached to points-of-interest in a coupling environment's topography[33], in conjunction with the connectivity of those points. Nodes representing couples are highlighted in orange. Gaps in connectivity are due to architectural features in the environment, e.g. walls, that block visibility as it cannot be guaranteed that a visitor can conceptualise a path to a point they cannot see, thus a route must be plotted between visually connected points[34].

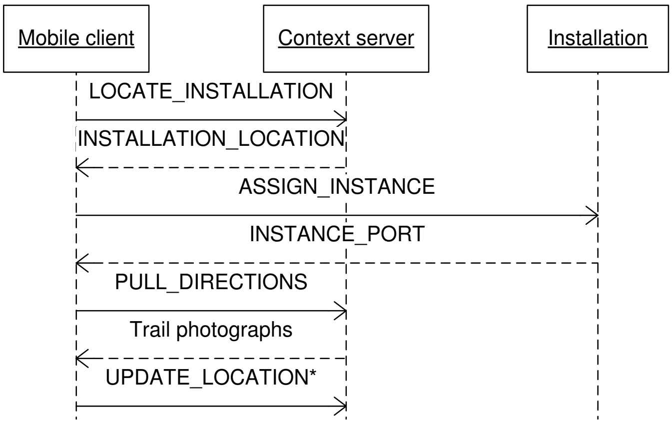


Figure 36 Message passing between components supporting movement

Figure 36 illustrates the message passing between system components during the movement phase of exploration. Once a choice of next coupling opportunity has been made (following understanding the environment as discussed in the previous section) the visitor's mobile device requests the IP of the relevant installation from the context server (LOCATE_INSTALLATION); having received this, the mobile client requests that a free instance is assigned to it by that installation (ASSIGN_INSTANCE). The client then requests a set of directions to the coupling opportunity from the context server (PULL_DIRECTIONS): a set of photographs representing a suitable photographic trail to take the visitor from their last known location to the location of the situated device affording the coupling opportunity. The context server assesses the topography of the environment using Dijkstra's shortest path algorithm[35] to find the most efficient path according to the lengths of the edges between

[33] See appendix 10.3 for the XML representation of the coupling environment used during the final trials

[34] There is no mediation available as yet via the test-bed infrastructure for the creation of such topography, yet experience points towards this visibility theory as being a careful and effective assumption of visitors' wayfinding abilities. DepthMap (http://www.vr.ucl.ac.uk/depthmap/) is one example of a tool suitable for the analysis of environments using theories of visibility for the placement of path turning points

[35] See bzb.se.macroenvironment.EnvironmentMap and bzb.se.macroenvironment.dijk.*

nodes as specified in the context database. A repository of photographs relating to the nodes in the topography is deployed alongside the context server such that, having determined the shortest path through the environment the context server can determine the analogous sequence of photographs of those points-of-interest (e.g. see Figure 37) and return them to the mobile client. As the context server has knowledge of the screen resolution of the mobile device it can re-size the photographs to the optimal resolution before delivering them, thus negating any costly processing overheads on the mobile device.

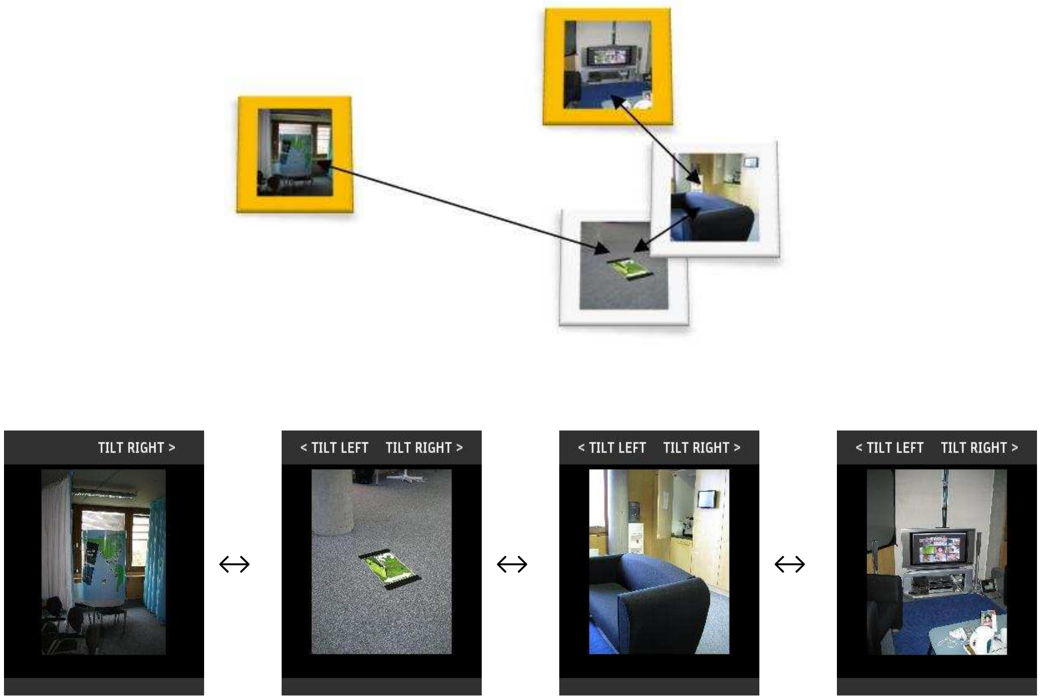


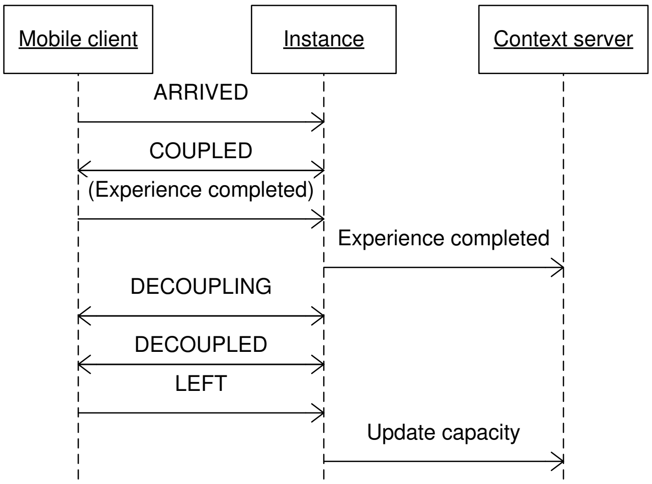
Figure 37 A single path between two couples isolated from the coupling environment (top); representative photographic trail displayed through four mobile client UI screens (bottom)

Once received by the mobile client, the client offers the visitor the photographs one at a time, asking the visitor to confirm when they have reached the location shown in the photograph. Every time the visitor confirms that they have reached a location the mobile client passes a message back to the context server updating the visitor's current location to the previous point on the photographic trail (UPDATE_LOCATION). This continuous updating of location allows the system to support changes of destination mid-navigation if required. The mobile client offers the visitor the ability to walk backwards along the trail as well as forwards if necessary.

6.4 Coupling and coupled interaction

Once a coupling opportunity is reached (i.e. the visitor reaches the end of a photographic trail), coupling and decoupling follows a common structure, regardless of the specific coupled interaction at a particular couple. The test-bed provides a common definition of an instance[36] which is extended to provide specific coupled functionality for each coupling opportunity; similarly the mobile client provides a common definition of coupled functionality[37] which is extended to support coupled interaction at the different couples. The common components provide the common coordinating structure for each experience from coupling to decoupling, consisting of messages[38] passed from the mobile client to the instance to indicate when the visitor has arrived at the situated device (ARRIVED), and left the situated device (LEFT) – actions preceding and following coupling and decoupling respectively – and from either the mobile client to instance or vice versa (depending upon the situation) to indicate that the devices have been coupled (COUPLED), that the devices are decoupling (DECOUPLING) or that the devices have decoupled (DECOUPLED). Either component may also indicate whether the experience at the couple has been "completed" (COMPLETED_EXPERIENCE), i.e. whether the visitor can now progress on to any further couples in the environment's narrative dependencies. The instance passes information about complete experiences back to the context server via its installation. Figure 38 illustrates these common steps in the process.

[36] See bzb.se.installations.instances.Instance
[37] See bzb.me.microenvironments.MicroExperience
[38] See bzb.se.meta.MessageCodes.*.Instance



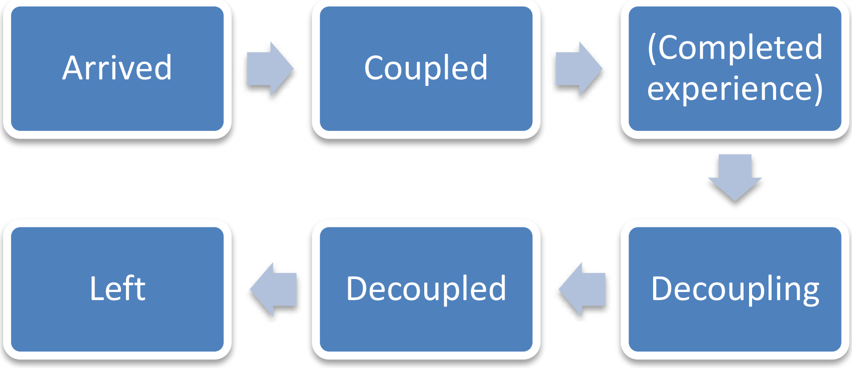


Figure 38 Messages passed (top) and common stages (bottom) from arriving at a coupling opportunity to leaving

While both mobile client and instance communicate in order to coordinate the coupled interaction process, both components present an interface to inform the visitor of the current stage of interaction and to allow the visitor when necessary to drive the interaction. The mobile client provides generic GUI components for the process in the form of a typical set of instruction screens that may be retained if desired, or overridden for a specific coupling situation (see Figure 39).

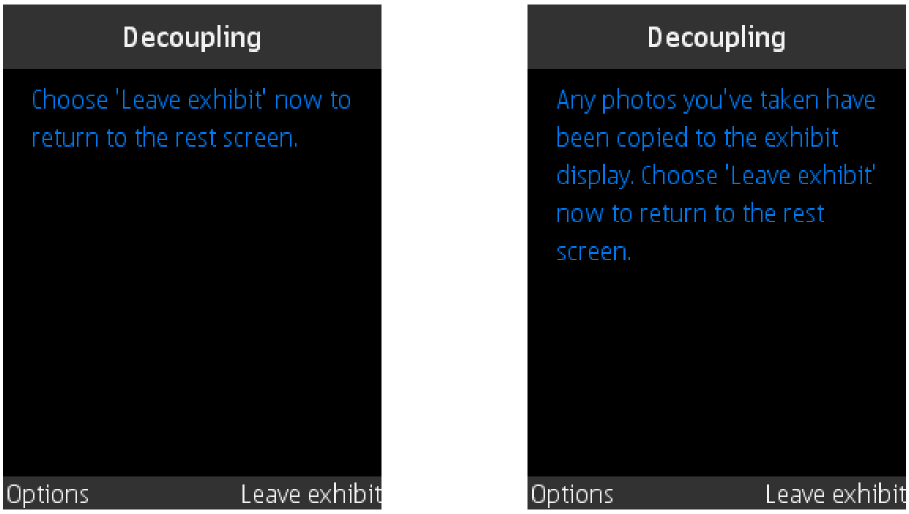


Figure 39 Generic decoupling mobile client screen as used at Registration (left); extended decoupling screen as used at Photowall (right)

The majority of extension of the mobile client and instance is to provide the specific coupled interaction between coupling and decoupling, during which – at some point – the visitor may or may not “complete” the experience. Beyond adding functionality to the mobile client or instance, extension of the two components may involve utilising information from the context database to adapt the coupled interaction to the particular visitor/mobile. Depending upon the mobile technological capabilities, for example, the instance may send differing messages to the mobile client to trigger different interaction, or may present a differing interface to the visitor.

Section 6.5 presents in more detail the *Registration* couple as a clear example of how the common coupling to decoupling process can be extended.

6.5 Bringing it together: an example

This chapter ends with an example of a small episode of exploration and coupled interaction via the implemented infrastructure, illustrating specifically how a particular couple's installation and instances are extensions of generic installation and instance components.

> *A visitor has been pushed adverts by the system upon entering the coupling environment. As the visitor has not yet completed coupled interactions at any couples, only the* Registration *is deemed relevant by the system as all other couples have narrative dependencies to be satisfied. As such the mobile client directs the visitor to choose this couple (Figure 40).*

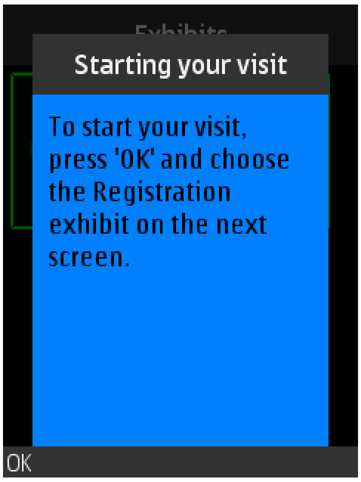


Figure 40 Direction to choose first couple

> *Once the visitor accepts this direction, the mobile client requests the IP address of the* Registration *installation from the context server, requests a private instance of the* Registration *couple's functionality to be assigned to the visitor and then requests a photo-trail to guide the visitor from the current location (the entrance to the environment) to the* Registration *couple. The context server responds with the photographs which the mobile client displays for the visitor.*

Having reached the end of the photographic trail leading to the situated device providing the situated part of the *Registration* couple (Figure 41), the visitor's mobile client sends an ARRIVED message to the instance assigned to it on the situated device.

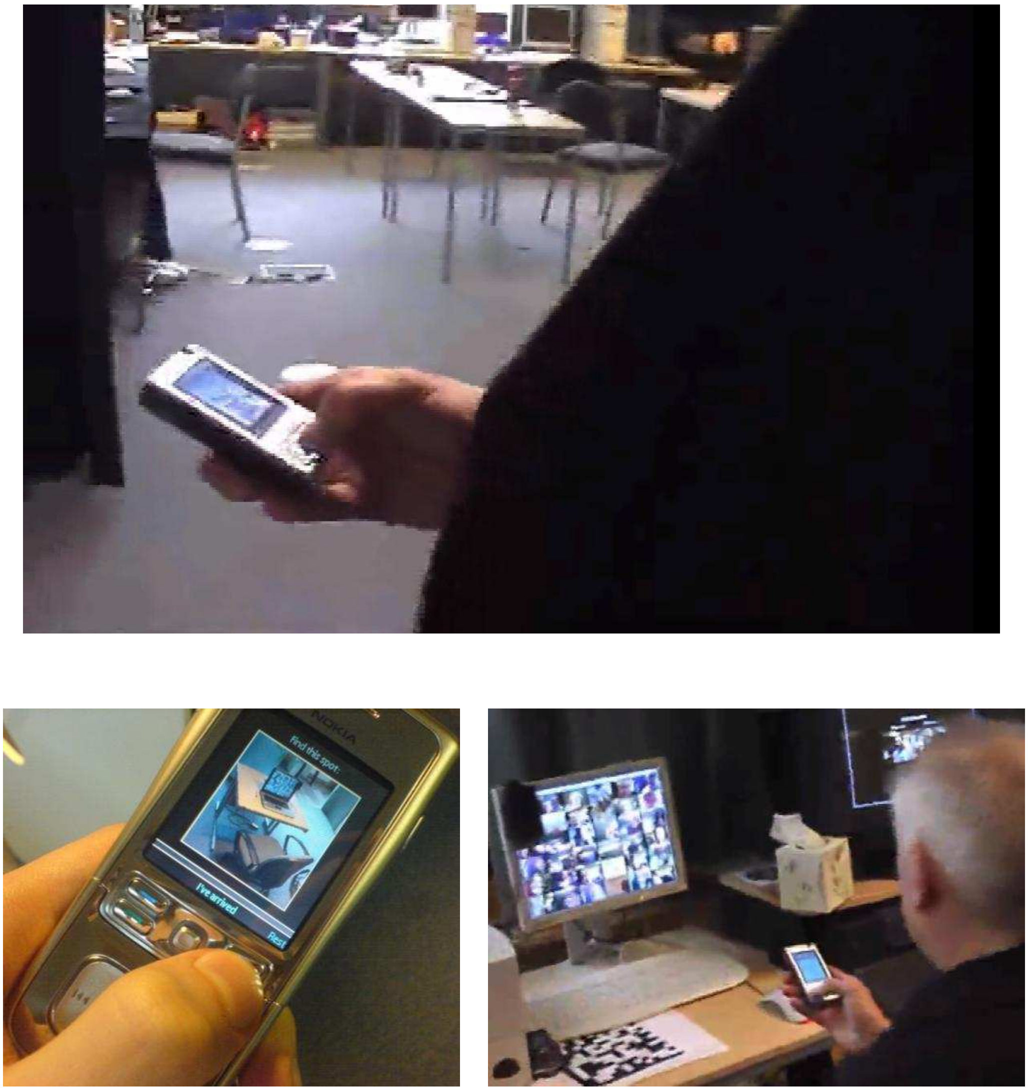


Figure 41 User following photo trail; mobile client displaying final step in photographic trail leading to *Registration* couple (bottom left); user arriving at *Registration* couple (bottom right)

The common functionality of all instances providing a GUI[39] (from which the *Registration* instance[40] inherits) specifies that the instance should display the text "Welcome" on its situated display upon receipt of this message; the *Registration* instance does not override this. After 2 seconds the display attempts to show a new screen, this time indicating to the visitor how to couple their mobile device to the situated device; all instances deriving from the common GUI instance definition are required to define their own specific instruction screen to be displayed at this point. The *Registration* instance defines a screen ordering the

[39] See bzb.se.installations.instances.GUIInstance
[40] See bzb.se.installations.instances.Registration

visitor to place their mobile device in a holster attached to the situated display, via a photograph and text (see Figure 42).

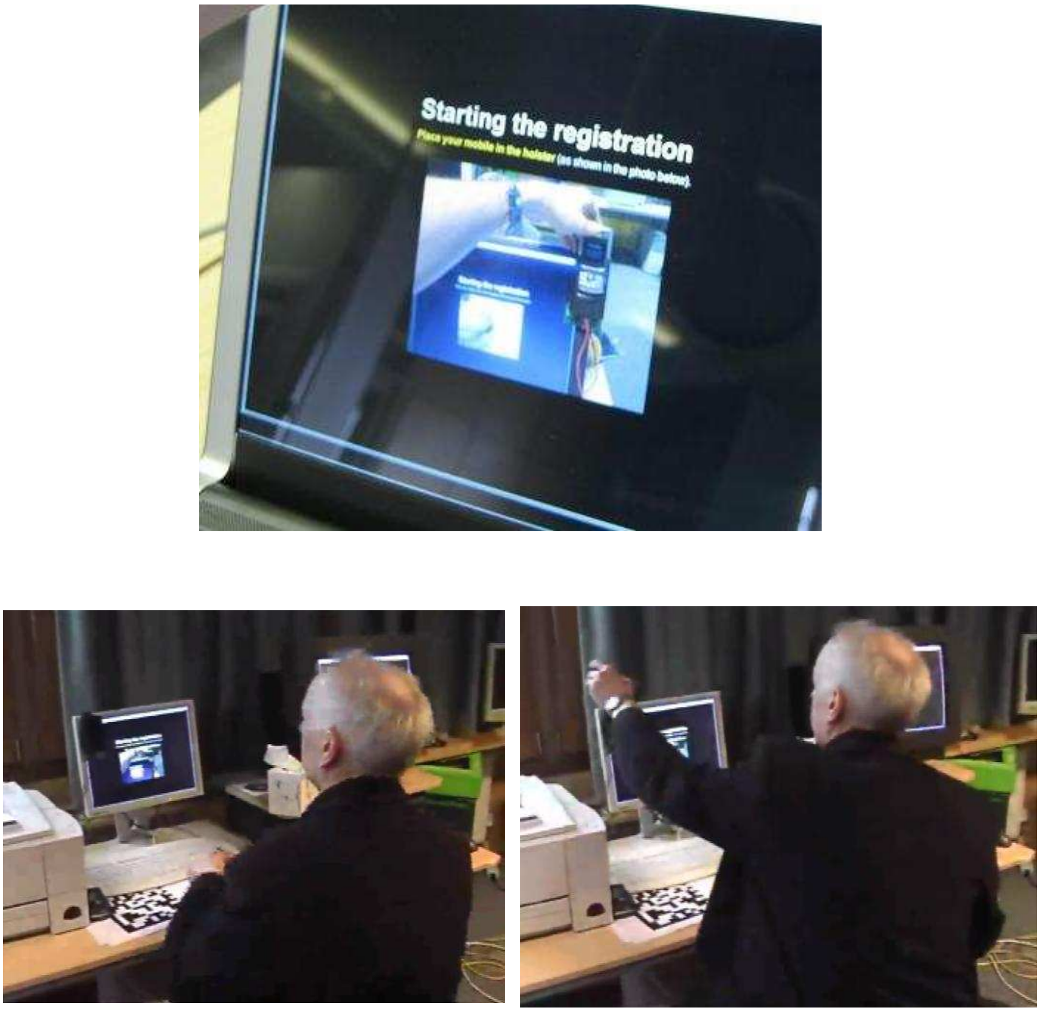


Figure 42 Situated display showing coupling instructions (top); subject viewing instructions (bottom left) then placing mobile in holster as per instructions (bottom right)

Once the visitor places their mobile device in the holster a micro-switch is pressed; this action is captured by the *Registration* instance (as part of its extended functionality[41]) and causes the instance to send a COUPLED message to the mobile client. Once the mobile client is aware that coupling has occurred, as part of its extended coupled functionality for the *Registration* couple, it switches its display off (as during this particular coupled interaction it is not needed). The visitor is then asked via the situated display to enter their name and age (which are then passed back by the instance to the context server) and to press a particular key (see Figure 43).

[41] See bzb.se.installations.instances.Registration.SwitchListener

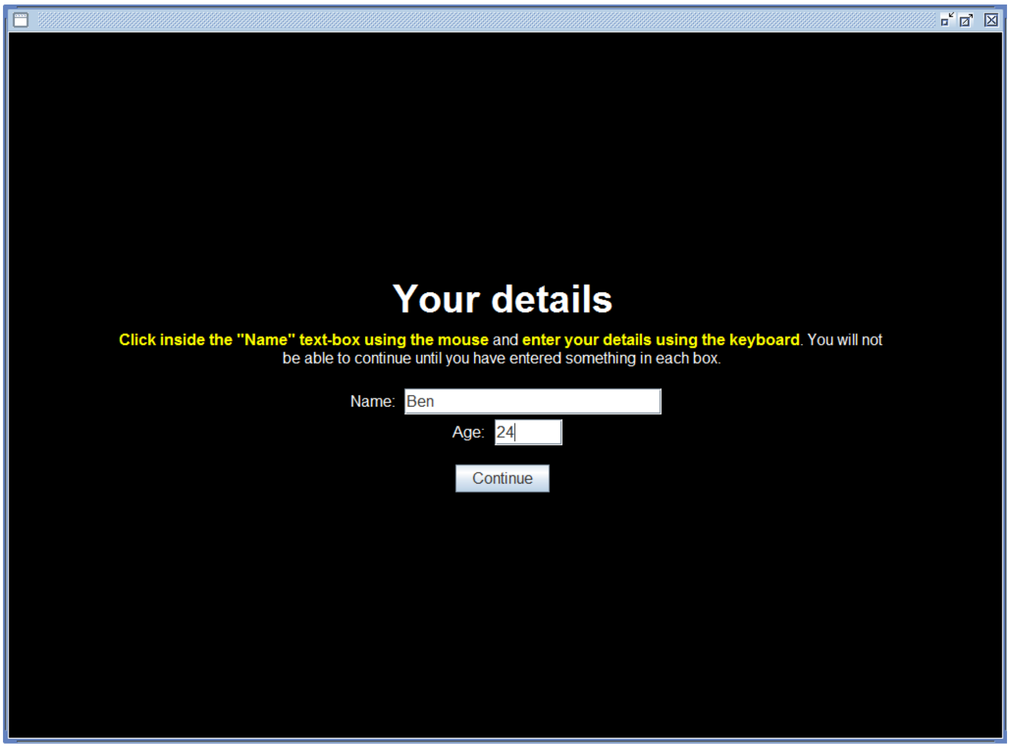


Figure 43 Screen grab of the situated display GUI requesting name and age from the visitor (top); subject entering requested details via situated keyboard (bottom)

Upon this key-press, the instance requests details of the mobile device's technological capabilities from the context server to determine whether the device has a secondary camera (i.e. a camera now facing the visitor); if this is found to be the case, the instance sends a START_FACE_CAMERA message to the mobile client. This message is received by the message handler instantiated by the mobile client to receive message specific to the *Registration* coupled interaction, and triggers the mobile device to turn its display back on and initialise its secondary camera. The situated display then prompts the visitor to press the same key again; this second key-press causes the instance to send a CAPTURE_FACE_CAMERA message to the mobile device which captures a snapshot from the camera facing the visitor (Figure 44).

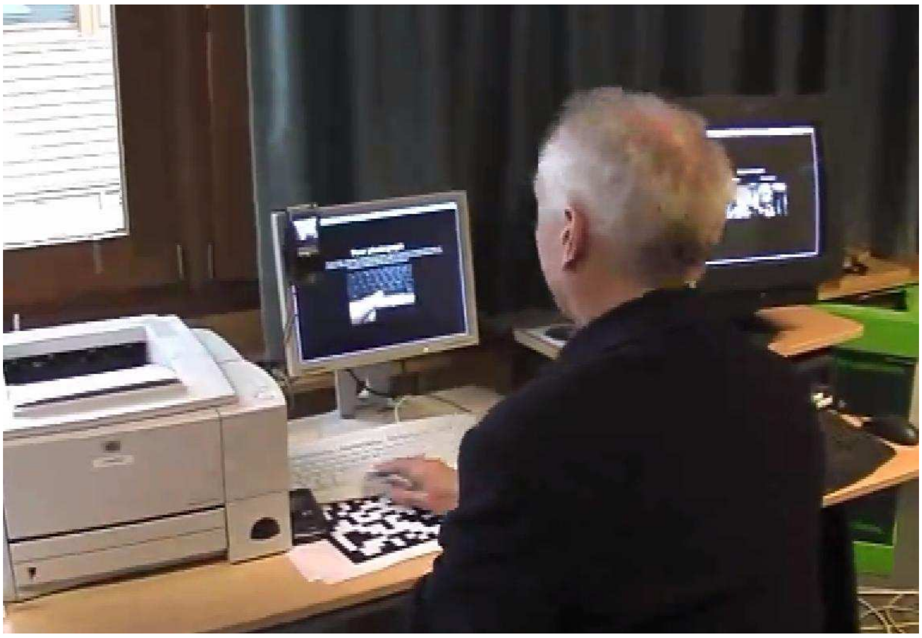


Figure 44 Subject capturing self-portrait through mobile by pressing key on situated keyboard (top); resulting self-portrait stored in context database (bottom)

Once captured, the mobile client sends the snapshot to the instance which passes it back to the context server to be stored in the context database as part of the visitor's profile. At this stage coupled interaction is complete, thus the instance informs the context server that the visitor has "completed" the experience at the *Registration* couple; the context server adds this record to the visitor's historical interaction. The situated device also informs the visitor that they have completed the coupled interaction (see Figure 45).

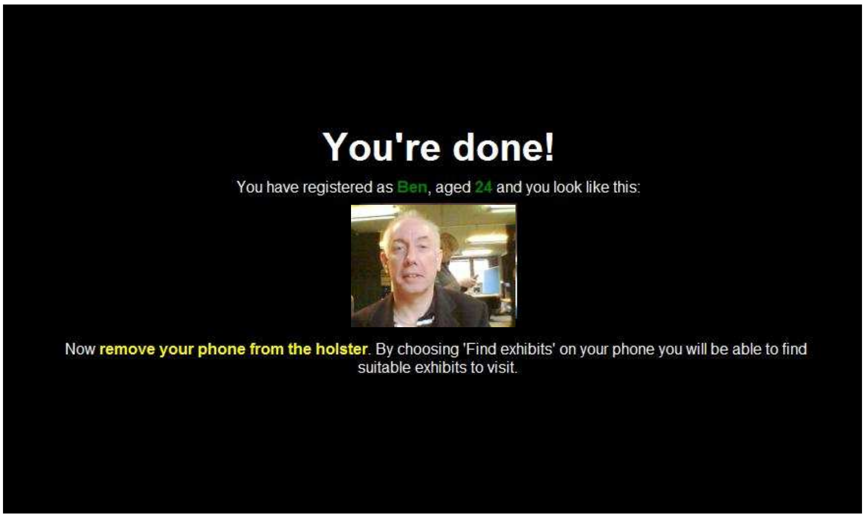


Figure 45 Feedback prior to decoupling at the *Registration* couple

The visitor is also prompted to remove their mobile device from the holster; doing so triggers an event at the micro-switch to which the instance responds by sending a DECOUPLED message to the mobile client. Note that there is no protracted decoupling or leaving step here (hence the lack of DECOUPLING and LEFT messages); in some cases further interaction between the mobile client and instance may occur during the decoupling process, or even after decoupling. The mobile client reacts by ending the coupled interaction on the mobile. The instance breaks its assignment to the visitor's mobile, the free capacity of the coupling opportunity is updated and the installation returns the situated display to its default decoupled behaviour (in this case overridden to provide functionality specific to the coupling opportunity: displaying the most recent snapshots taken during coupled interactions (see Figure 46)).

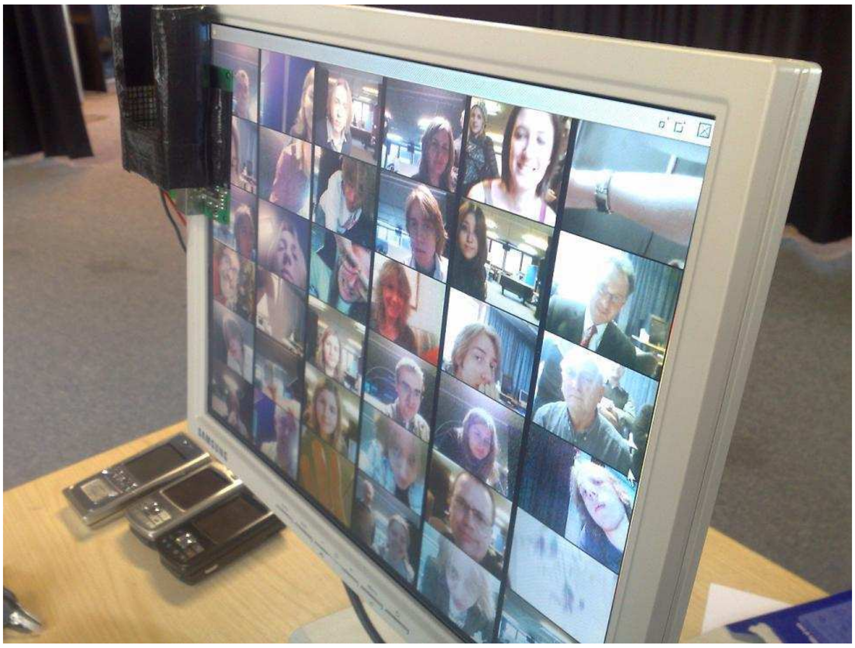


Figure 46 *Registration* situated display after decoupling (top); subject removing mobile from *Registration* holster (bottom)

Figure 47 provides a comparison between the messages passed at a specific couple (*Registration*) with the generic messages available to coordinate interaction at all couples (Figure 38 top).

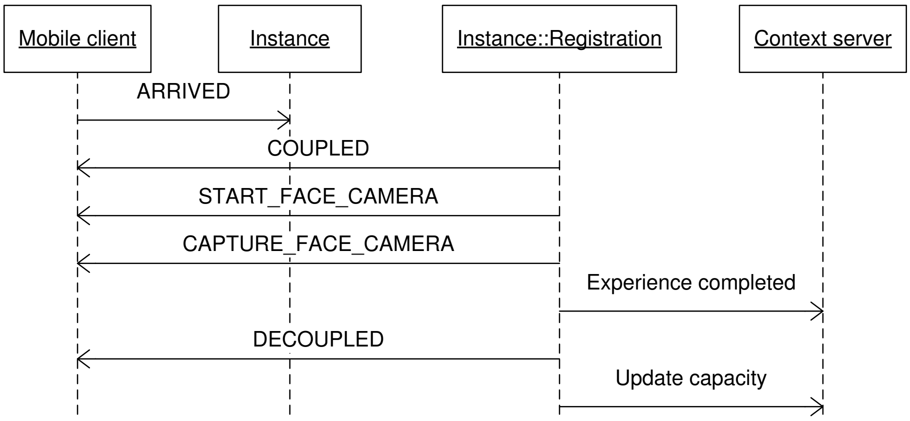


Figure 47 Messages passed between components during coupled interaction at Registration couple

The mobile client returns to its main or 'resting' menu where the visitor may choose to wait or initiate a search for new adverts for couples. Doing so now pulls adverts for the Registration *and* World Map *couples, rather than only the* Registration *as was the case previously: this is because the visitor has now satisfied the* World Map*'s narrative dependency for completing coupled interaction at the* Registration *couple. The advert for the* World Map *is prioritised higher than the advert for the* Registration*, as the* Registration *is deemed less relevant given that the visitor has already experienced it. The* Registration*'s advert is also annotated with the word "visited" to make transparent the reason for this prioritisation to the visitor (Figure 48).*

Figure 48 Mobile client displaying choice of adverts following search by user

Having now described the developed infrastructure in some detail the thesis moves on to presentation of the user trials and findings in chapters 7 and 8.

Part III – Research trials and key findings

Chapter 5 described how a set of couples and environment configurations had been implemented using the core model to ground their design. Also described was a plan for five user trials in section 5.4, discussing how many users were involved in each trial, their relationship to one another and their exposure to technology. The trials are summarised below:

Table 23 Summary of trials

Trial #	Visitors	Configuration
1	10 tech experts in 8 sessions: • 6 individual sessions • 2 sessions with 2 visitors with personal mobiles	**1** *Registration, World Map, Slideshow* All couples side-by-side
2	15 family visitors in 5 sessions: • one session with a group of 4 sharing a mobile • 3 sessions with groups of 3 sharing a mobile • one session with a pair sharing a mobile	**2** As above + *ART*, *Photowall* Couples spread within a large room (with some visible disconnections) containing other unrelated situated devices
3	14 design students in one session: • students share 5 mobiles, shuffling groups regularly	
4	12 exhibition design professionals in one session: • one session where 3 pairs of visitors each share a mobile and two groups of 3 visitors each share a mobile	
5	14 visitors in 2 sessions: • one session where 4 visitors use their own mobiles and one pair share a mobile	**3**

	• one session where 3 visitors use their own mobile, one pair share a mobile and one group of 3 share a mobile	As above + *Google Earth* Couples spread over three rooms (with some visible disconnections) containing other unrelated situated devices

Methodology

Before moving on to presenting the findings arising from the trials, it is pertinent to discuss the nature of the observation and analysis of the trials.

Users suitable for the different trials were recruited from the local student/academic population, and through social networks to help "test an interactive exhibition": the details of the content of the trial provided to the participants were kept as limited as possible in order to avoid shaping their expectations prior to use of the system. How the participants were to react to the novelty of the interactions with the environment was one of the key factors being investigated (as coupling environments and interactive technologies in public are novel concepts), thus it was deemed important that participants encountered the trial environment as if for the first time. Upon arrival at the lab participants were given an explanation of the theme of the exhibition and were allowed to familiarise themselves with the mobile devices (if not already familiar with the Nokia hardware and software conventions) in order to reduce the novelty of the mobile device. In later trials where a range of mobiles were available the participants were helped to choose a device that was most similar to their own mobile.

During the trials the users and their behaviour were continuously observed, both passively via video camera (recorded for replay and analysis after the trials), typically using one video camera per coupling opportunity to capture both the coupled interaction and the effects of the couples on the bystanders and passers-by, but also actively where possible by an observer who took notes and was able to intervene where terminal issues with the system arose. During the later trials the video cameras were equipped with directional microphones in order to better capture these thoughts; this strategy was deemed more effective for capturing the perceptions and opinions of the visitors during the experience in comparison to the use of personal microphones, the suggestion of which made several of the first trial users highly self-conscious. Frames taken from the surveillance videos are used in the following sections to visually illustrate descriptions where particularly effective.

All users completed a post-experience questionnaire (a sample of which can be found in appendix 10.5) posing general questions regarding their experience and capturing demographic data to allow the reasoning behind certain observations to be qualified. Following the experience in the coupling environment the architecture students and museum professionals (trials 3-4) engaged in group critical discussion ('focus groups') led by the observer, and in the case of the museum professionals, also carried out group brainstorming to determine applications for the coupling environment concept. All users were (where possible, i.e. approximately $^2/_3$ users) engaged in a short interview with the observer to reflect and elaborate on particularly interesting aspects of their experience (raised by both visitor and the observer).

The transcripts from the interviews, group sessions and the trials are relied upon heavily in the following chapters, providing illustrative examples for the discussions of findings. As the configuration and type of user are highly-relevant in most cases to the discussion, each quote taken from the transcripts is labelled with the trial number and type of user.

The observation of the trials (and post-experience processing of the users) was not intended to be systematic or exhaustive; instead the aim was to use the test-bed to dig more deeply into previously identified issues and their implications for coupling, as well as to provoke any emergent issues through detailed observation of the visitors' behaviour. The findings in the next two chapters reflect this leaning toward description and discovery in that they are almost entirely qualitative, in contrast to the types of quantitative analyses that might be produced by approaches based upon metrics and measures (e.g. UEAs (Scholtz and Consolvo, 2004)). Observation was carried out for both formative and summative aims, i.e. on the one hand configurations and couples have been implemented to challenge the users in order to explore the design issues, calling forth behaviour and thus allowing the refinement of knowledge and better understanding of the observations of later trials (and indeed to improve the robustness of the test-bed): the knowledge gained from the process of implementing and staging one trial session informs the next. On the other hand, with the accumulation of knowledge gained over all five trials it is possible to reflect on and frame these formative explorations leading to guidance on the design decisions that must be made to reap those benefits.

Observation of both individual users vs. groups and trials that segregate (as is the case in trials 1 and 2) users vs. those in which users visit simultaneously (trials 3-5) led to two types of observation: on the one hand of the individual user experience while on the other of how the user experiences overlap, resulting in social interactions. Chapter 7 discusses observations of the individual visitor experience (which is introduced in terms of the 'personal trajectory'), while chapter 8 reflects upon observations of social interactions between visitors and their effect upon the user experience.

Critical reflection

Before moving on to chapter 7 it is important to critically reflect upon the chosen methodology and discuss the implications of the choice upon the generalisability (external validity) and ecological validity of the resulting trials. As stated previously, the trials are not intended to be exhaustive in their coverage of the coupling environment design space (including couples, configurations, orchestration approaches and users) due to the constraints on time, yet it is imperative that aspects of the trial are 'real' enough that guidance based on observations of the trial might be justified. Equally, by identifying the limitations of the trials the guidance may be qualified.

Three aspects of the trials that need to be reflected upon are:

1. the environment
2. the participants
3. the experience content

It is hoped that the findings from the trials can be applied to the design of coupling environments in general (as suggested in the thesis' introduction: shopping centres, museums, city centres, and so on), yet the trials are based in a mock-museum environment. There are key differences between the environment in which the trials are held and these other types of environment to which it is hoped that the framework might be applied (and indeed differences amongst public environments in general). In particular the scale of environments may be flagged as a significant factor that may affect generalisability: public environments may well cover a much larger physical space and contain many more than 6 different potential couples. This will have implications for the complexity of the environment and the applicability of the orchestration approaches as they are implemented in the test-bed. True public environments may also involve a greater amount and throughput of visitors (consider a busy city centre in comparison to a small museum): it might be expected that the sense of social awkwardness and the distracting affect of other visitors may be greater in busier environments than might be observed in the trials. On the other hand, discussion with the museum and exhibition professionals who took part in trial 2 provided reassurance to the generalisability of the findings, as they formed the consensus that the trial environment was similar in terms of visitor flow, scale and connectivity of space to that of either small exhibition spaces, or of parts of larger exhibition environments. Further investigation of the generalisability of the findings in the trial environments to real environments of larger scales is noted as a source of further work in section 9.4.2. The observations of the trials should be considered as observations of a *part* of a user's experience in a coupling environment, not necessarily an entire experience.

The five trials place a wide range of participants (detailed previously in section 5.4) in the trial environment in order to provide insights into the potential user experiences of the wide range of visitors to different coupling environments (and indeed the thoughts of potential designers). The key factor held in mind while recruiting the participants was coverage of the various social structures that might exist amongst real visitors to coupling environments: since visitors to the types of public spaces suitable for coupling environments typically visit as groups, participants connected by existing social structures were sought (hence colleagues in trial 1, families in trial 2, friends in trial 3 and a range of these relationships in trial 5). However as social relationships do not typically extend beyond visiting groups in public, it was important that some trials involved a mixture of familiar and unfamiliar visitors. This was achieved to an extent but certain types of group were not represented to the extent that might be necessary to achieve wider generalisability. In particular there were few family groups and more groups of friends – since there are social mechanisms that are unique to family groups (Hope et al., 2009) the low representation of this type of group may skew the resulting observations towards a representation of a typical 'friend' group experience instead. While the need to represent the different types of group and individual visitor was a priority when recruiting participants, there were practical restrictions on the pool from which these participants could be drawn, particularly on the locality. As such, the majority of participants come from Nottingham (whether this is where the participants live during academic terms or permanently), and the remainder come from elsewhere within the UK. Except for a minority of the participants (2 in trial 3 and 2 in trial 5) all may be considered White[42] (the majority of which are White British). Additionally, if considered in socio-economic terms the participants are relatively homogeneous, falling almost exclusively into upper middle (A)/middle class (B)[43] and managerial & professional (1)/intermediate (2) occupations (Office for National Statistics, 2005)[44] (or in education for such occupations). Although it can be argued that these catego-

[42] http://www.ons.gov.uk/about-statistics/classifications/archived/ethnic-interim/presenting-data/index.html (accessed 15/6/09)
[43] Referring to NRS Social Grade, as presented at http://www.nrs.co.uk/lifestyle.html (accessed 14/3/10)
[44] Referring to the eight-class version of the NS-SEC occupational classes, p. 15

ries of visitor are better represented in some potential coupling environments (particularly campuses, museums and galleries) than they are in society generally, there is an open question then as to how the observations of the participants might generalise to other socio-economic classes and cultures, and how the behaviour of the type of participant represented in the study might differ if interacting in an environment alongside other classes.

In terms of the content of the experiences within the trial environment, the intention was to provide an engaging yet generic overall experience based on a theme that provided the possibility for linear, non-linear and branching narratives within the user-experience. Geography (or place) was chosen as the unifying concept linking the content of the experiences at the individual couples as it is well understood, the notion of geographical relation between places, the people that occupy places and the culture belonging to places being familiar to all participants. There is also a wealth of publicly-available content that may be drawn upon to rapidly develop experiences, as demonstrated by the use of media from Wikipedia, Flickr, Google and Last.fm within the trial environment. In the case of the trial, the type of experience provided was clearly most analogous to that of a museum, and intentionally so. Resource constraints prescribed that experiences (and hence more trials) could not be implemented to attempt to replicate the types of experiences in a broader range of potential coupling environments. With regards to the success of the analogy, the professionals that took part in trial 2 commented that the narrative structure of their experiences during the trial (particularly the use of a "hub" exhibit, i.e. the *World Map*, from which visitors to 'drill down' into a topic to explore in more detail) was similar in structure to those that they attempt to create in existing museums. Similar visiting behaviour can be seen in other public environments such as city centres where a visitor might explore to learn more about/focus on a particular category of experience and specialise their visit; it is thus likely that the type/content of experiences in the trial generalises well to other potential coupling environments. A particular issue relating to the decision to tailor the content of experiences to the declared age of users is discussed in more detail in section 7.2.1i and is not related to the generalisability of the type of experiences provided by the test environment.

Finally there is a more general criticism that may be made of the trial methodology, given recent trends towards the trialling of novel technologies in the 'wild' rather than in the controlled lab settings. The benefits and disadvantages of the high-level approaches to trialling are a topic of much research (Kjeldskov and Graham, 2003, Edwards et al., 2003, Nielsen et al., 2006, Duh et al., 2006, Lindgaard, 2006). To attempt to reach a balance between control (for ease of deploying the tools to observe the participants and to provide a semicontrolled environment into which to place a rapidly-developed, complex technology infrastructure that might be adjusted on-the-fly) and ecological validity, the trials conducted for the sake of this thesis take place in a lab that aims to imitate the key features of a museum setting. As the trials are part of the formative development of the framework rather than an exhaustive usability test of a product the lab provides the correct environment for striking the balance of realism and ease of observation/control over the environment.

7. Trajectories through the environment

This chapter reflects on observations of the individual visitor experience, particularly from the point of view of the visitor's *path through the environment*, i.e. the sequence of couples that they visit, what drives them to visit these particular couples (or prevents them from visiting others), and their understanding of the environments as spaces to explore and engage with. Over the course of the trials, and in particular following the introduction of more complex narrative constructs and mechanisms, the visitor experiences can be seen as **trajectories** taken through the coupling environments. Trajectory is a well-worn notion and may be used to describe various aspects of the user-experience, from trajectories of components of the user-interface (from a mouse pointer to an avatar in a virtual environment (Accot and Zhai, 1997), to the cycles in and interactions between different workers in a team that combine to complete a task (Fruhling and Wilson, 2007, Fitzpatrick et al., 1996). The notion of trajectory bridges different technology user scenarios: recent work by Benford et al. explicitly utilises trajectory as a bridging concept, combining knowledge from dramaturgy and HCI to describe trajectory as a user's movement not just through interfaces, but also through physical and virtual space, time and roles (Benford et al., 2009). Benford et al.'s framework addresses the ambiguity of the boundaries in performative experiences such as "Uncle Roy all around You" (Benford et al., 2006) and the episodic engagement with experiences such as "Day of the Figurines" (Benford and Giannachi, 2008); these characteristics (particularly the former) are less evident in coupling environments of the type implemented for the trials. In the scope of coupling environments trajectory is a useful concept to encompass:

1. the subset and sequence of the possible couples visited (*where*),
2. the coupled interactions that took place at those couples (*what*), and
3. the times at which actions occurred (*when*).

Section 7.1 introduces the personal trajectory, but also discusses **ownership** as a key concept emerging through the trials which is defined as *understanding how and being able to shape* one's own trajectory, linking this closely to the visitor enjoyment of the coupling environment. Section 7.2 explores the design features of the test-bed that encouraged ownership. Conclusions in section 7.3 propose that a key aim of the environment designer might be to promote a sense of ownership and encourage visitors to instil a sense of ownership amongst one another.

7.1 The personal trajectory

The uniqueness of a visitor's trajectory was important to visitors when questioned regarding exactly what made an experience enjoyable or not. Through the progression of the trial coupling environments a significant shift in the perception of the visitor experience from that of a **common shared process** to a **personal journey** was seen. The perception of ownership was the differentiating factor here, i.e. that in later trials the users felt a keen sense of owning – both understanding and being in control of - their trajectory while in earlier trials the users perceived that their own experience was equal to and indistinguishable from those of other users and that shaping their trajectories was out of their control.

This section discusses the two perceptions of ownership (highlighted in red in Figure 49), first describing participants' experiences where they were perceived not to be owned, then experiences in later trials where the opposite was the case. Characteristic behaviours that resulted from those perceptions (highlighted in green below) are described.

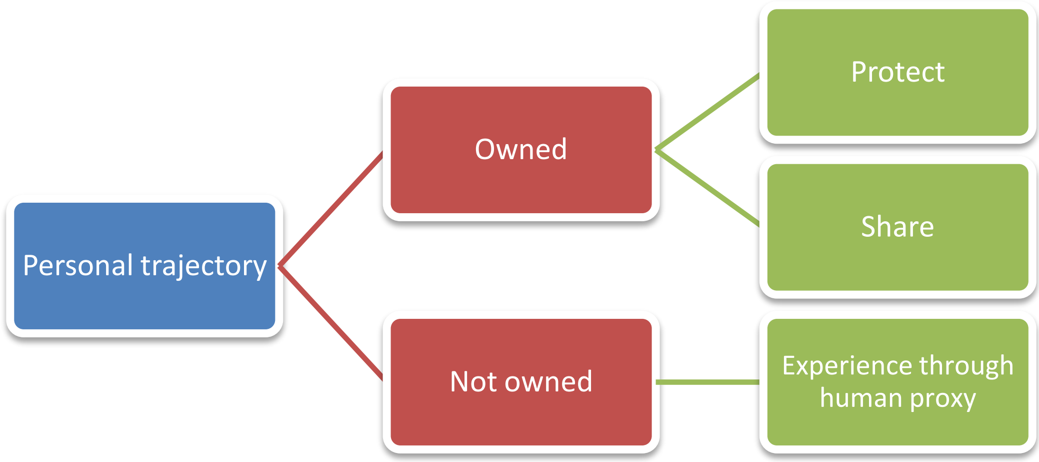
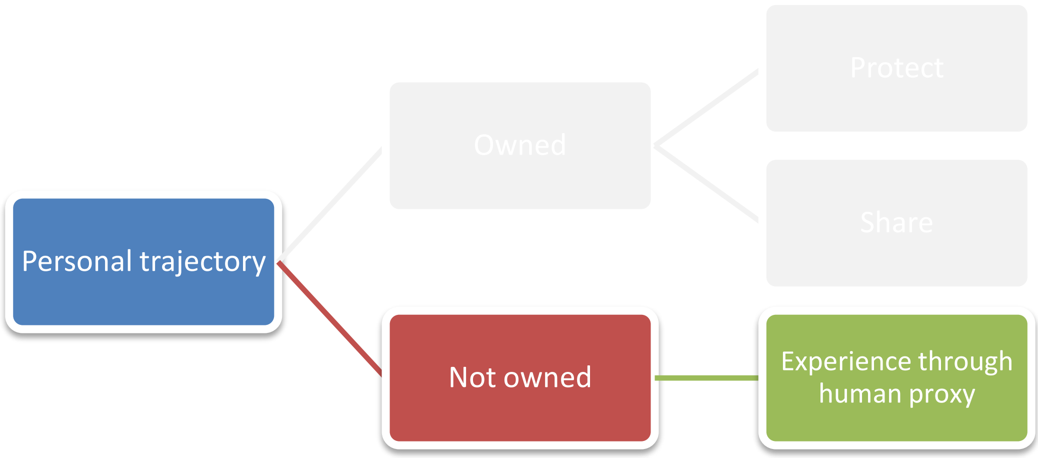


Figure 49 Relationships between perceived ownership of personal trajectory and characteristic behaviours

7.1.1 Non-ownership



i. Experience through a human proxy

In earlier trials, a significant proportion of visitors expressed a tendency to experience parts of the coupling environment **through a human proxy**, either observing others' coupled interaction or in a smaller selection of cases simply by observing other visitors relate their experiences.

Experiencing others' interaction was a very common phenomenon across all trials consisting of multiple concurrent visitors (indeed this is explored in greater detail in the next chapter), yet in earlier trials there was a higher proportion of users that would, after observing another user at a couple, not proceed to experience the couple for themselves.

Q1: "Sometimes I didn't have to go to another station because I could just watch someone else using it." – trial 1 (pair session); interview

Q2: "It was easier to be part of the audience because I didn't waste time starting it all over again for myself [and] maybe hold others up …" – trial 2; interview

The view expressed in Q2 also alludes to a compounding factor – that of an enforced pace – which is discussed in more detail in section 7.2.2.

The behaviour represented by Q3 and Q4 is another illustration of this lack of a need to own the experience – in these cases a verbal description of the coupled interactions were evidently sufficient to remove the need for the visitors to experience the couples themselves.

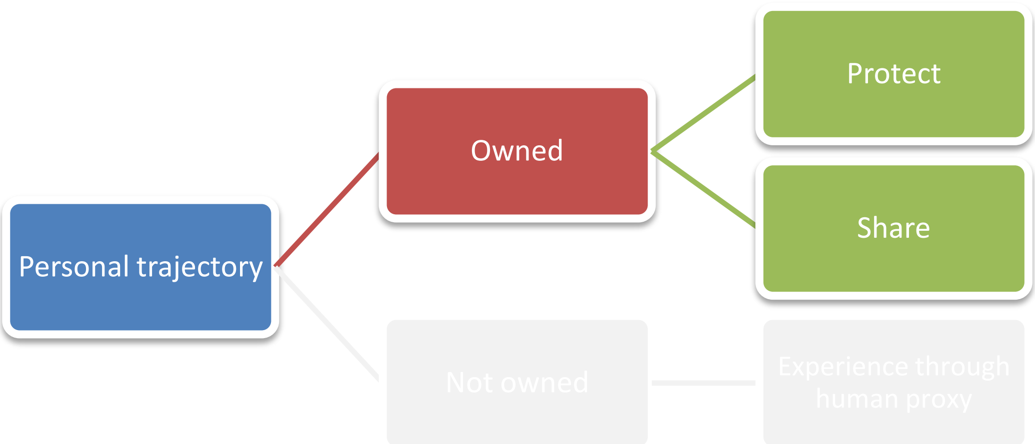
Q3: "[An earlier user] told me what happened at the Slideshow *so I didn't worry about missing some of the slides" – trial 1; interview*

Q4: "I could tell what was going to happen by what other people were saying so I skipped [a set of slides] at the Slideshow*" – trial 3; interview*

The visitors responsible for Q3 and Q4 both refer to the *Slideshow* couple which both visitors personally experienced only part of (viewing only one of the two possible sets of content) revealing that they felt that others had sufficiently described the "highlights" of the remaining content sufficiently that there was no need to experience it for themselves. In many cases there appeared to be no additional value attached by users to personal experiences in comparison to those experienced by proxy, corroborated by such responses as Q5 below, given by a user who had twice witnessed the same slide-show being experienced by other visitors:

Q5: "there was no need to do [the Slideshow *couple] myself; I'd already seen the other groups watch it twice so we just went somewhere else instead" – trial 3 interview*

7.1.2 Ownership



In later trials (particularly trials 4 and 5) users clearly spoke of individual coupling experiences and personal trajectories as commodities. Considering experiences as such, two distinctive characteristics of visitor behaviour in the later trials - **protection** and **sharing** – may be identified which are absent from earlier trials.

i. Protect

Later users spoke differently of their experience, describing a drive to experience "more" couples or "as many as possible".

Q6: "I wanted to see everything" - trial 4; group discussion

Q7: "I wanted to have the best record, [to experience] more than the others" - trial 3; group discussion

Q8: "I felt that it is important to do as much as the other people" - trial 5; interview

Q9: "[I] did not want to finish and then talk to someone else and find out I missed something and be disappointed" - trial 4; group discussion

While Q6 reveals a desire simply to be sure that the visitor's experience is as complete as possible Q7-9 imply a comparison between the visitor's experience and those of other visitors – each states that the visitor is satisfied only if their own experience is as extensive as that of other visitors.

Users in later trials continued to observe other users, but utilised these observed experiences as a means of determining parts of their own experience that were as yet incomplete. In comparison to earlier trials where the experiences by proxy were deemed adequate replacements for one's own experience, the experiences by proxy in later trials served often to spur the observer on to re-experience them for themselves.

Episode 1: collaborative catch-up

In trial 3 interesting group behaviour was observed at the *Slideshow* couple when groups of bystanders would gather while waiting to couple with the installation which had a capacity for only one participant. Coupled interaction tended to last approximately 5 minutes and involve the viewing of 2 slide-shows (each of which has between 6 and 10 slides). During one participant's coupled interaction new bystanders would arrive and take an immediate interest in the ongoing interaction. On a number of occasions the newly-arrived bystanders would enquire as to how the participant had navigated to a particular slide in order to be able to do so themselves when they took control of the couple.

Q10:

Bystander A: "[to participant] I didn't finish seeing that …
[to bystander B] How did he get to that one?"
Bystander B: "[to bystander A] It's Japan"
Bystander A: "[to bystander B] I know that … did he do anything else? I only chose Japan [at the World Map*]"*
Participant: "[to bystander A] I think it was the fourth slide. Maybe the fifth one"
Bystander B: "[to bystander A] You'll see when you do it"
Bystander C: "[to bystander A] No don't worry, it was the fifth one I think."
- trial 3; observation

Episode 2: prowling

Trial 5 consisted of two sessions; in the second session a group of three users shared one of the five mobiles that were active in the coupling environment concurrently. Interesting behaviour was observed from the group of three whereby whilst the group's mobile was coupled and two of the group were engaged in the coupled interaction (with one as participant and one as bystander), the remaining member of the group would move off and observe other visitors in the environment to determine which experiences their group had left to complete.

When questioned after the session about this "tactic" the group suggested that the behaviour was not necessarily planned, nor intended to be surreptitious but that they felt they had stumbled upon an advantage and that they did not want the other visitors to be aware of this.

Q11:

Group member A: "Yeah it just sort of happened"
Group member B: "We didn't really plan it but [group member C] got interested in what one of the others was doing and started watching ..."
Group member C: "I noticed that the one I was watching had got all these extra slides – that you could get other [slideshows] too. We didn't think about that so I came back and told you two [group members A and B]"
Group member B: "... then we went straight back and found another country because you [group member C] knew it was Japan because he saw a sumo wrestler on the other guy's slide"
Group member C: "I kept watching the same guy then out of the corner of my eye – I started to feel a bit guilty because I kept catching his eye!"

*Group member B: "Yeah I think we all started feeling guilty then because you [group member C] saw him go off to the [*ART *couple] and saw that it was really good so we went straight over there ..."*
Group member A: "Only after he left though!"
Group member C: "Yeah I think he stayed away from us after that, right?"
Group member A: "Wouldn't you?"
- trial 5; interview

Defence of experience

On several occasions where a bystander was perceived to be observing a participant's experience the participant, or indeed other bystanders, would become noticeably protective over the ongoing interaction. Re-consider Q10: for example: on this occasion a degree of defensiveness was observed on the part of bystander B who had arrived earlier and thus was aware of how the participant had reached the content that interested bystander A. Bystander B was singled out for an individual interview after the session ended, questioned about this particular situation and in response stated that:

Q12: "I was a bit annoyed that [bystander A] just turned up and started asking questions straight away; I'd already been standing there for ages" - trial 3; interview

Bystander B felt that he had a more "legitimate" claim over the information gleaned by observing the interaction than the later-arriving bystander.

In this case the participant did not appear to feel negatively regarding observation by any of the bystanders, yet this was not always the case. In the same session one visitor was interacting with the *Slideshow* couple in front of 7 bystanders and was reluctant to view the second of her available slide-shows until almost all the bystanders left (evidently due to their frustration with her deliberately slow pace). When she was questioned after the experience the user explained:

Q13: "[comments from the bystanders] didn't really bother me - I felt really strongly about it because I knew I'd found the slide-show that they hadn't – lots of people didn't find it and I didn't want them to see it. They should go and try harder! It made me laugh really" - trial 3; interview

ii. Share

A number of visitors to the coupling environments in later trials (particularly 4-5) routinely expressed a desire to affect their own trajectory, and those of others, wherever possible. For such visitors the greatest enjoyment would be derived from identifying ways in which coupled interaction could be shaped; these visitors enjoyed the knowledge that their own experiences were distinct from that of the other visitors in the environment.

Q14: "When I realised that we were all getting different slides it was more exciting – I wanted to see what I would get" - trial 3; group discussion

Q15: "I thought it was great that we received different content – it made it seem more yours" - trial 4; group discussion

Q16: "I felt like I was doing my own thing rather than just following the other lot" - trial 5; interview

Visitors oriented towards sharing would utilise observation as a means of determining factors that could affect their trajectory. In some cases where the users perceived that the coupled interaction could not be significantly differentiated, observation of another's coupled interaction might be sufficient to replace their own experience as, like the earlier trial users, re-experiencing these would not add value to their experience of the environment. In other cases where observation, particularly of the same coupling opportunity experienced by multiple other visitors, revealed the potential for differentiation, the observer would be spurred on to experience the coupling opportunity for themselves. Q17-19 illustrate this use of observation.

Q17: "When we all saw that [the current participant] got different slides from [the previous participant] I tried to work out why" - trial 5; interview

Q18: "We were all trying to guess how it was working – I think [the participant] knew why he had different objects [at the ART *couple] but I didn't really want to ask so we had to try and figure it out ourselves" - trial 3; interview*

Q19: "I figured out that I [the participant] had some new slides because he said he was a kid [at the Registration *couple] – you could tell from the cartoons on the slides; I* *wanted to go and try the other stops to see if the same thing happened there" - trial 5; interview*

Unlike a large number of protection-oriented users, later users were more willing to share their knowledge of the techniques that could lead other visitors to the different possible experiences. Sharing-oriented users enjoyed the knowledge that their experience varied from those of others, yet these visitors did not compete to protect that differentiation, but instead showed an overriding satisfaction from being an (albeit temporary) "expert" regarding the differentiation mechanism(s), playing a role similar to that of a guide in some cases and eventually indirectly shaping the trajectories of others. Episode 3 demonstrates this type of behaviour well.

Episode 3: expertise transfer

During trial 5 one particular visitor took an early "lead" in the environment, being the first to complete experiences at the *Registration*, *World Map*, *Slideshow* and *Google Earth* couples. A number of other visitors had observed her progress through the environment and had congregated at *Google Earth* as she was coupled with it in order to ask her advice. The participant had previously identified (also by observation) that another visitor had received different content at the *ART* couple and correctly determined that this was due to the varying ages they had entered at the *Registration* exhibit. She had also noticed that the visualisation at the *Google Earth* couple appeared to have been adapted according to the particular content that she had previously uncovered at the *World Map* couple. She was keen to share this information.

Q20:

Participant: "Look when I go down here you can see the place I found … Kenya"
Bystander A: "So I wouldn't get that?"
Participant: "You didn't scan that one?"
Bystander A: "No I didn't scan very many ..."
Bystander B: "I did – I think I got it"
Participant: "You'll get different slides over on [the Slideshow *couple] too then"*
Bystander A: "Really? Maybe I'll just watch [bystander B]'s then when he gets there"
Participant: "How old are you? I mean how old did you put yourself back at the start? Because that makes a difference too ..."
Bystander A: "It does? What did you put?"

Participant: "I said I was really young – like 1 - so I think I got kid stuff"
Bystander A: "Oh OK I didn't lie about mine … so will I get something different here?"
Participant: "I don't think so – what could change? Well maybe, I don't know – have a go"
- trial 5; observation

When briefly questioned afterwards, the participant discussed her motivation for actively offering the information:

*Q21: "I wanted to show that I had done it, you know, that I had made it do something special. It's sort of like bragging isn't it, but then it made them happy too and we got to try and work it out together too. Nothing really did happen when [bystander A] used the [*Google Earth *couple] but it was fun to see." - trial 5; interview*

During both the brainstorming session with the museum professionals (trial 4) and the group discussion with the architecture students (trial 3) this urge to share, or at least demonstrate, expertise regarding the tactics for "opening paths" was frequently raised as a potential means for encouraging discourse amongst visitors, or even collaboration, such as that demonstrated in episode 3. In all trials (as there were sessions in all where this behaviour *might* have been possible) such a sharing of expertise was only ever witnessed amongst visitors with at least a basic familiarity of one another – in no cases did social contact between unfamiliar visitors appear to be encouraged. Following trial 5 the users were questioned as to whether they felt that they would engage with other unfamiliar visitors in coupling environments – answers, such as those in Q22-4 commonly suggested that the users felt that they would be more interested in learning by observation, or conversely demonstrating to any bystanders, but that in neither case would they feel comfortable verbally transferring expertise.

Q22: "It was fun to show [my friends] that I knew how to get those extra slides but I wouldn't just start telling some stranger – I'd feel like I was showing off" - trial 5; interview

Q23: "I think I would just watch someone if they were doing something new – you know to see how they got that, because that's what this is all about right? But I'd feel a bit embarrassed to ask, like I was getting something for free"- trial 5; interview

Q24: "Yeah I would tell everyone – the Google Earth *thing with the flags? No-one else noticed that! But I think I'm louder than normal anyway. [Another user] wouldn't find anything unless there was someone like me around!" - trial 5; interview*

7.1.3 Ownership as a result of diversity within the coupling environment

This chapter has discussed two characteristic types of behaviour – protection and sharing - exhibited by users during the trials which are related to the varying senses of ownership of personal experiences. A clear shift has been observed in the dominant characteristic over the course of the trials: users in earlier trials exhibited only a tendency towards protection, while the incidence of tendency towards sharing increased becoming dominant in trial 5. There is a relationship between the tendency towards regarding expertise in differentiation as a commodity and the *increase in the possibilities* for differentiation within the coupling environment.

From trial 2 onwards various mechanisms were introduced to either enforce diversity amongst visitors' trajectories or allow visitors to shape their own trajectories – these are referred to as **differentiation mechanisms**. In trial 1 where the environment is in configuration 1 (section 5.3.1) there is no possibility for differentiation: all users' trajectories through the environment, in terms of the sequence of couples experienced, and the features of the coupled interaction at those couples (e.g. the content viewed at the *Slideshow*) were identical. Key in this trial is the particular implementation of the *World Map* coupling opportunity which in this case consisted of only three data matrices attached to the surface of the large map. The changes made to this couple in particular and the implications of these changes towards the potential for diversity are discussed in more detail later in the chapter.

The similarity of personal trajectory can be seen illustrated clearly even in the duration of the users' time in the environment: all 10 users' complete experiences lasted between approximately 12 minutes with a standard deviation of only one minute and 24 seconds over all 10:

User ID	Total experience duration (seconds)
1	740
2	802
3	800
4	770

5	690
6	709
7	887
8	626
9	800
10	599
Mean	742.3
SD	83.6

Table 24 Durations of experiences in trial 1

It is understandable that in this first trial several users felt that to repeat coupled interactions that they had experienced by proxy would be simply redundant. In fact the two users with significantly atypically short durations (user ID 8 and 10) were those visiting concurrently with other users and had observed their fellow visitors interacting at the *Slideshow* couple.

In such a coupling environment where there is no possibility of diversity of trajectory there is no expertise to share and as yet little reason to protect – from their own experience, users were aware that they had no ability to affect the form of their own trajectory and as a result felt no compulsion (or ability) to affect the trajectories of others, positively or negatively.

In contrast, the possibility for diversification of trajectory introduced from trial 2 onwards via differentiation mechanisms provided the possibility to miss experiences, i.e. it became a non-trivial task to have a "complete" experience – users were responsible, to an increasing degree over the remaining trials, for driving their own trajectories in their own chosen directions. As such knowledge of the mechanisms became commodities that could be owned and either **protected**, stifling the progression of other visitors, or **shared** through the transfer of knowledge of the mechanisms that opened access to those couples or interactions, thus encouraging the progression of others:

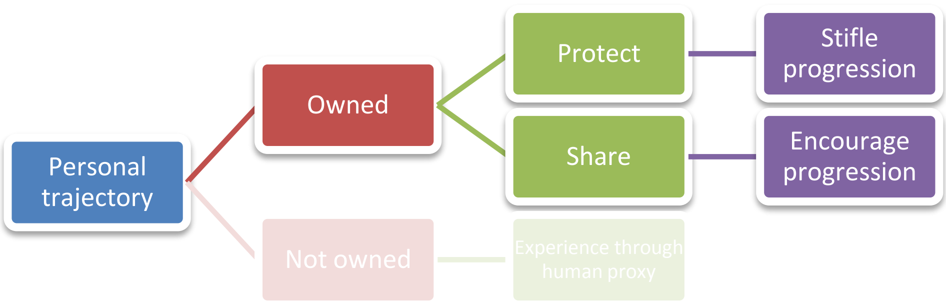


Figure 50 Observed characteristic behaviours and results on progression of *other* visitors

A sense of ownership has been discussed as being a direct result of the ability to differentiate trajectories. Both the senses of competition and collaboration evident in later trials were subsequent results of this ownership of experience and featured significantly in the reflections of users who found their experiences highly enjoyable. Mechanisms to afford personal differentiation of trajectories within coupling environments might be considered important design features and section 7.2 continues to relate the mechanisms that have been employed thus far.

7.2 Creating and managing diversity

Section 7.2.1 discusses the mechanisms introduced into the coupling environments that provided the possibility for the differentiation of personal trajectories. This expands upon the merits of the various mechanisms with respect to their effects upon the visitor experience, continuing to relate in section 7.2.3 the necessity of a keen consideration of the visibility and accountability of the mechanisms on behalf of the environment designer as an important caveat to differentiation. Equally important, and also discussed, is the effect of enforced pace on the coupling environment experience – this is highlighted in section 7.2.2 as a potential pitfall of design lacking sufficient mechanisms for differentiation of personal trajectory.

Before continuing it is important to clarify that the mechanisms described here (and thus their combined effect upon visitor behaviour observed during the trials) are strongly related to the novel coupling paradigm. Several of the mechanisms are possible only through the nature of the paradigm and may be considered unique to this style of interaction; the significance of the discussion of these mechanisms is defended further in the final section of the chapter.

7.2.1 Differentiation

The mechanisms employed in the coupling environments may be described in terms of whether they *restrict* or *conceal* possible trajectories for a visitor (Figure 51), the fundamental difference between the two being that the former reduces the range of possible experiences for a visitor, whereas the latter limits particular possibilities *until certain conditions are met*, thus not reducing the experiences possible for the visitor.

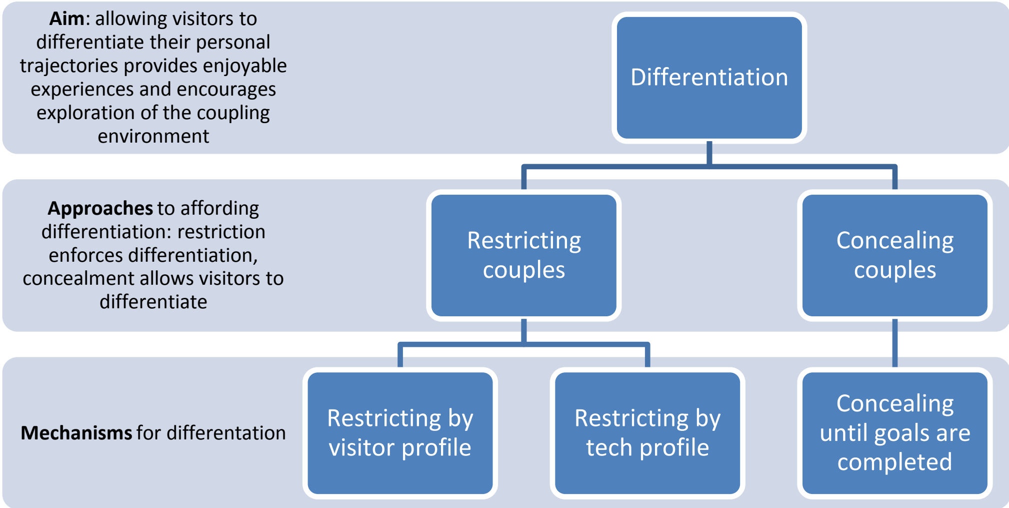


Figure 51 Mechanisms to allow differentiation

i. Restricting mechanisms

Mechanisms that discriminate between visitors based upon *static contextual information* - the technological capabilities of the visitor's mobile device, or the demographic profile of the visitor, for example – restrict the progression of an *individual* visitor's trajectory. On the other hand, this enforces *variety* amongst the trajectories of multiple visitors – such mechanisms guarantee that visitors will have experiences that are different from one another, *provided that* the visitors are distinct at the level of the contextual information on which the mechanisms discriminate, e.g. if a couple can only be formed if a user's mobile has Bluetooth capabilities then two visitors – one with a Bluetooth enabled phone and one without – will be forced to follow different trajectories (thus perceiving a 'personal' trajectory), yet the latter will have a trajectory that is limited in scope.

Trial 2 onwards explored discrimination based upon both the technological capabilities of the visitors' mobile phones and upon the visitor profile as defined by the information supplied during the coupled interaction at the *Registration* couple. The heterogeneity of the personal mobile device has been previously identified as a fundamental, potentially problematic issue (Issue 6, p.94) that needs to be considered while designing coupling environments, while it was also stated that the visitor's profile provides a useful handle for the personalisation of experiences, given that different people (demographically) tend to have different interests.

Restricting by technological capabilities of the mobile device

Configuration 1 contained two couples that relied upon the visitor's mobile device having camera functionality; the *Registration* couple in fact required particularly specific camera functionality by which the device can capture images facing towards the visitor (typically used by mobile phones with video-calling functionality; see Figure 52) as opposed to the more common ability to capture images from a camera pointing away from the user (typically used for snapshot applications).

Figure 52 Secondary, front-facing camera type required for full coupled interaction at Registration coupling opportunity

During trial 1 users were given only mobile phones with both rear and front-facing cameras to use, chosen specifically to be suitable for all couples in the environment, thus although the *Registration* installation was initially defined as having a "hard" requirement for a secondary camera no discrimination was actually possible. All mobile devices were also sufficiently capable of capturing images of a quality suitable for the *World Map* coupled interaction (where data matrices needed to be "scanned" and decoded using the mobile device).

From trial 2 onwards a variety of mobile phone models were made available for users to use, all of which had a more common rear-facing camera, but only three quarters of which had the front-facing camera. Half of these remaining "full-featured" mobile phones also functioned extremely poorly at producing images of the data matrices at the *World Map* suitable for decoding.

Figure 53 User attempting to scan a troublesome matrix: trying to reduce glare (left); flattening the matrix (middle); another user photographing the attempts (right)

In fact while the older mobile phones such as the Nokia N91 introduced for earlier trials (notably with lower resolution cameras) performed well, typically decoding data matrices with >50% success, the more modern Nokia N96s' high resolution camera (and to a lesser extent that of the Nokia N95s) output fell foul to motion artifacts that reduced their effectiveness in the hands of some users to nil.

Gateways

In all configurations of the coupling environment the *Registration* couple was the only possible coupling opportunity for the visitor having just entered the coupling environment. All other couples had narrative dependencies that directly included the *Registration* experience, or another experience that did.

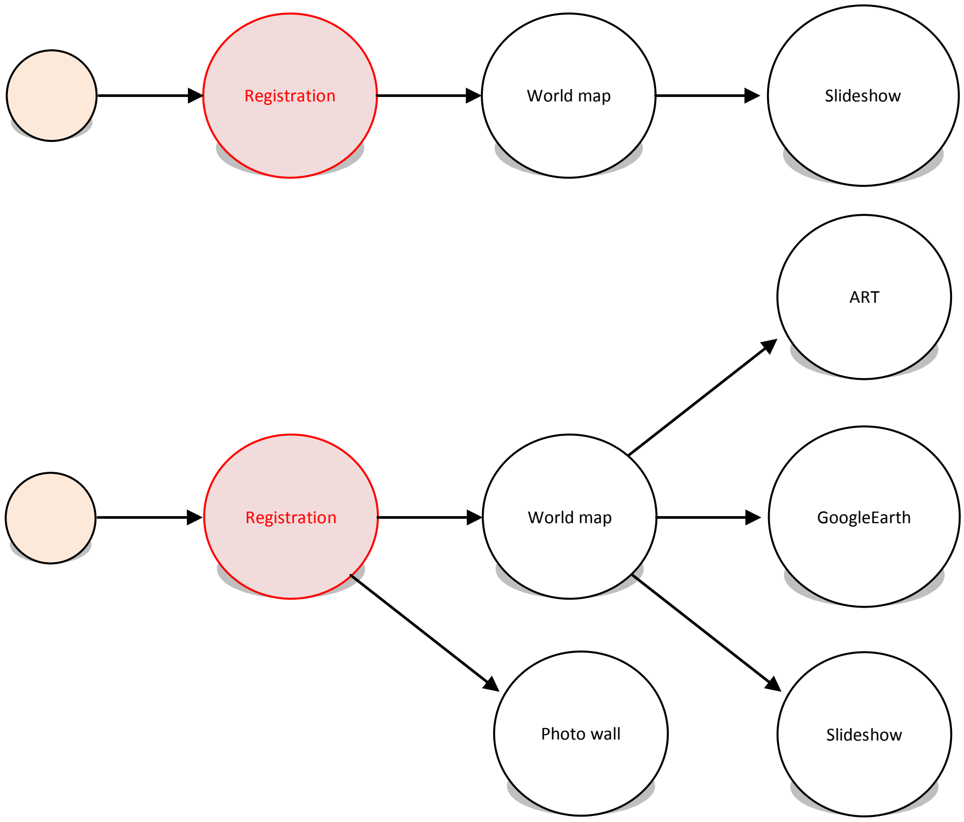


Figure 54 Narrative dependencies in configuration 1 (top) and configuration 3 (bottom)

As such the *Registration* couple can be referred to as a *gateway* experience, a metaphor that aptly reflects the fact that visitors must “pass through” the *Registration* experience in order to reach other couples, and also leads to the consideration of the problems that may be caused if, for some reason, this coupling opportunity is closed. The narrative dependency diagrams in Figure 54 illustrate clearly the *Registration* couple’s position as a gateway throughout the variations of the coupling environment configurations.

A closed gateway effectively forms a barrier, restricting the visitor to all couples prior to the gateway in the narrative of the coupling environment. *Temporary* closure of a gateway coupling opportunity – the role of a *concealing* mechanism – is an effective design strategy as this forces visitors to engage in the coupling opportunity’s narrative predecessors, rewarding them for doing so with progression; concealment is discussed in section 0. *Permanent* closure of a gateway opportunity, via a *restriction* mechanism, must be a carefully-made strategic decision by the coupling environment designer. Clearly in the trial environments, the closure of the *Registration* coupling opportunity to certain visitors would have meant that these visitors could couple with *no* further devices in the environment. As such restricting mechanisms, i.e. not advertising the availability of the *Registration* coupling opportunity, against those visitors whose mobile phones failed to meet the *Registration* couple's “hard” requirement for a secondary camera was infeasible, and instead the coupled interaction at the *Registration* needed to be made adaptable to accommodate a greater heterogeneity of mobile devices. Two types of adaptation of the coupled interaction have been explored in order to accommodate ‘unsuitable’ devices: bypass and alternatives (Figure 55).

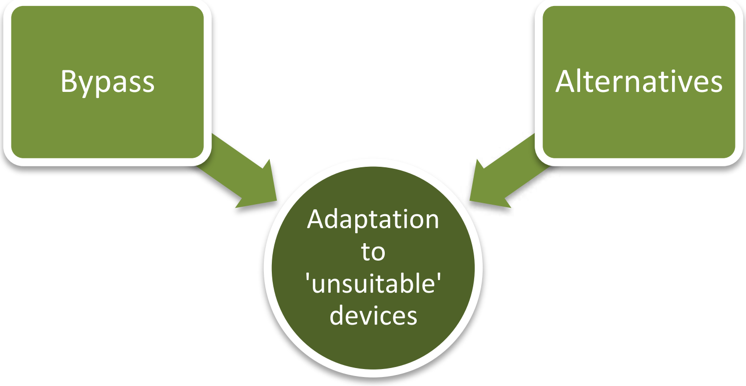


Figure 55 Types of adaptation when restriction is undesirable

Bypass

In response the coupled interaction at the *Registration* was altered following trial 1 to provide a limited experience to those visitors with mobile devices without a secondary camera: in these cases the visitor would be prompted to enter their name and age, as all visitors would be, but would then skip the steps during which their photograph was captured through the mobile device. As a result these visitors would not have a photograph registered as part of their profile in the context database. This limitation has only a relatively minor impact upon the remaining course of the visitor's experience, particularly in comparison to an all-out block on further experiences: in the trial environment the visitor's photo was simply used to allow situated displays to “greet” the visitor upon coupling, thus while a degree of the personal nature of the coupled interaction was lost without the visitor photo the visitor's progression to other couples was not restricted. This adaptation of the *Registration* couple meant that the requirement for a secondary camera was reduced to “soft”[45], indicating that lack of this capability would result in an *open but limited* rather than a closed opportunity for coupling.

[45] See installations.* in appendix 10.2 for the technological requirements of the couples in the final trial

Alternatives

The *World Map* coupling opportunity was another key gateway in the coupling environment. As stated previously the coupled interaction at this couple required the use of the primary camera of the mobile phones. All mobile phones used in all trials had primary cameras and were thus registered as having that capability in the context database upon entry to the environment, yet some cameras were incapable of performing to the required standard. There were no tests (regarding how *capable* a present camera was) built into the short profiling phase that occurred before the capabilities of a mobile phone were registered, thus the performance could only be determined through use. Unlike in the case of the *Registration* couple, the step requiring the mobile phone's camera was pivotal to the coupled interaction at the *World Map*: if no data matrices could be decoded then no progression could be made past the *World Map* as any further coupled interaction at other couples required the mobile to have knowledge of the encoded content of at least one of the matrices.

Once the Nokia N95s and N96s were introduced (trial 3 onwards and trial 5 onwards respectively) users became frustrated at times with their seeming inability to scan the data matrices on the *World Map* successfully. Unlike at the *Registration* where the system knew in advance whether a visitor’s mobile would allow a complete experience, the system did not know whether the mobile could accurately capture a data matrix, thus the mobile needed to fail before the system became aware. Since this process was a necessity to allow progression, rather than bypassing the step an *alternative* means of acquiring the content of the data matrices without using the camera needed to be provided.

Adaptation of the *World Map* couple involved the subtle alteration of the data matrices such that they included a (human-readable) numerical code. After three subsequent failed attempts to scan matrices the mobile client would inform the visitor that they should inspect a matrix closely to find the code, then type it into the mobile phone. Doing so would give the same results as a successful scan of the matrix. In the relatively unlikely (in the case of the trials, impossible) event that a visitor's mobile did not have a primary camera, the client would have defaulted to this behaviour initially.

Another example of alternative coupled interaction is implemented in the test-bed at the *Google Earth* coupling opportunity. The intended coupled interaction utilised motion sensing capabilities of mobile phones to translate the movement of the mobile phone into directional controls of the *Google Earth* visualisation projected on the situated display; only a small number (at most 3) of the mobile phones used in any one trial would have this capability (the

Nokia N95) thus in trial 5 in which the coupling opportunity was implemented there were 2 and 3 phones (in the first and second session respectively) that could not control the interaction in this manner. Instead, users with "differently-abled" mobile phones could control the interaction using key-presses (keys 2, 4, 6 and 8 replacing two degrees of tilt). Again, no key steps were bypassed via this alternative interaction, thus there were no long-term effects (i.e. beyond the *Google Earth* couple) on further interaction.

Bypassing a portion of coupled interaction does not necessarily cause long-term effects, nor does the provision of alternative coupled interaction necessarily guarantee that further coupled interaction is unaffected, instead it is important to raise the fact that these two solutions are available, each are more or less suitable in particular situations, and that when making a choice a designer must consider both the effects on later interactions and upon the current interaction. If there is no significant negative long-term effect of bypassing an infeasible portion of interaction and any alternative interactions are difficult to implement, unwieldy or contrived then this strategy would be preferable. In either case, these approaches allow restrictions to be implemented on portions of coupled interaction at each couple: rather than blocking access to a coupling opportunity *completely*, access is *limited*. The knock-on effects of literally closing (i.e. proactively denying) access to a particular coupling opportunity, i.e. blocking access to subsequent suitable couples, should always be fully considered.

Restricting by visitor profile

Previously discussed were a number of systems such as Hippie, CRUMPET and Magitti that alter their behaviour according to visitor profile. The common goal of these is to provide a more suitable experience by restricting the interactive possibilities of the user to those that are deemed suitable, in the same way that interactions were restricted according to the technological capabilities of the visitor's mobile phone as described previously. During trial 4, museum professionals stated that "personalisation [according to visitor profile] is the holy grail of interactive museum design".

From trial 2 onwards the age registered for each visitor in the context database (during coupled interaction at the *Registration* couple) was used to restrict coupled interaction at the *World Map*, *Slideshow* and *ART* couples. In all cases, visitors were classified as either children or adults, the threshold being set at 15 years of age; the *World Map* returned one set of facts for adults and another for children, the *Slideshow* produced slide-shows drawing from a common set of slides and music (for both adults and children), a set exclusively for adults and a set just for children, while *ART* visualised objects from a set for adults and a set for children.

As with technological restrictions in the trial environment no couples were actually closed based upon visitor profile, i.e. restrictions based on visitor profile or technological profile do not affect the exploration process, but coupled interactions were limited.

Unlike a mobile device's technological capabilities the visitor profile in the trial environment is supplied by the visitor rather than being sensed directly by the system. Since the system is assigning relevance based upon this information and upon an idealistic notion of an adult's and a child's interests the system relies upon the visitor being truthful about himself. In reality many visitors took the opportunity to create an alter ego (Q25-26), rather than an accurate representation of themselves, or wanted to see if the system was ‘clever enough’ to spot a blatant lie (Q27-28).

> *Q25: “I would have been embarrassed to put my real age – I didn't know who might see it later on” trial 4; interview*

> *Q26: “It's like a game isn't it – I wanted to make a good character, not just be boring” trial 3; interview*

> *Q27: “If it's going to ask me then of course I was going to have some fun with it!” trial 3; interview*

> *Q28: “I wanted to see if it would let me put something that obviously wasn't true – you know, like I was a baby” trial 5; interview*

A number of users even attempted to manipulate the snapshot taken during the *Registration* interaction, e.g. hiding themselves, placing objects in the camera's view, posing with other visitors, and so on.

A number of the images registered for users during the trials are shown below in Figure 56.

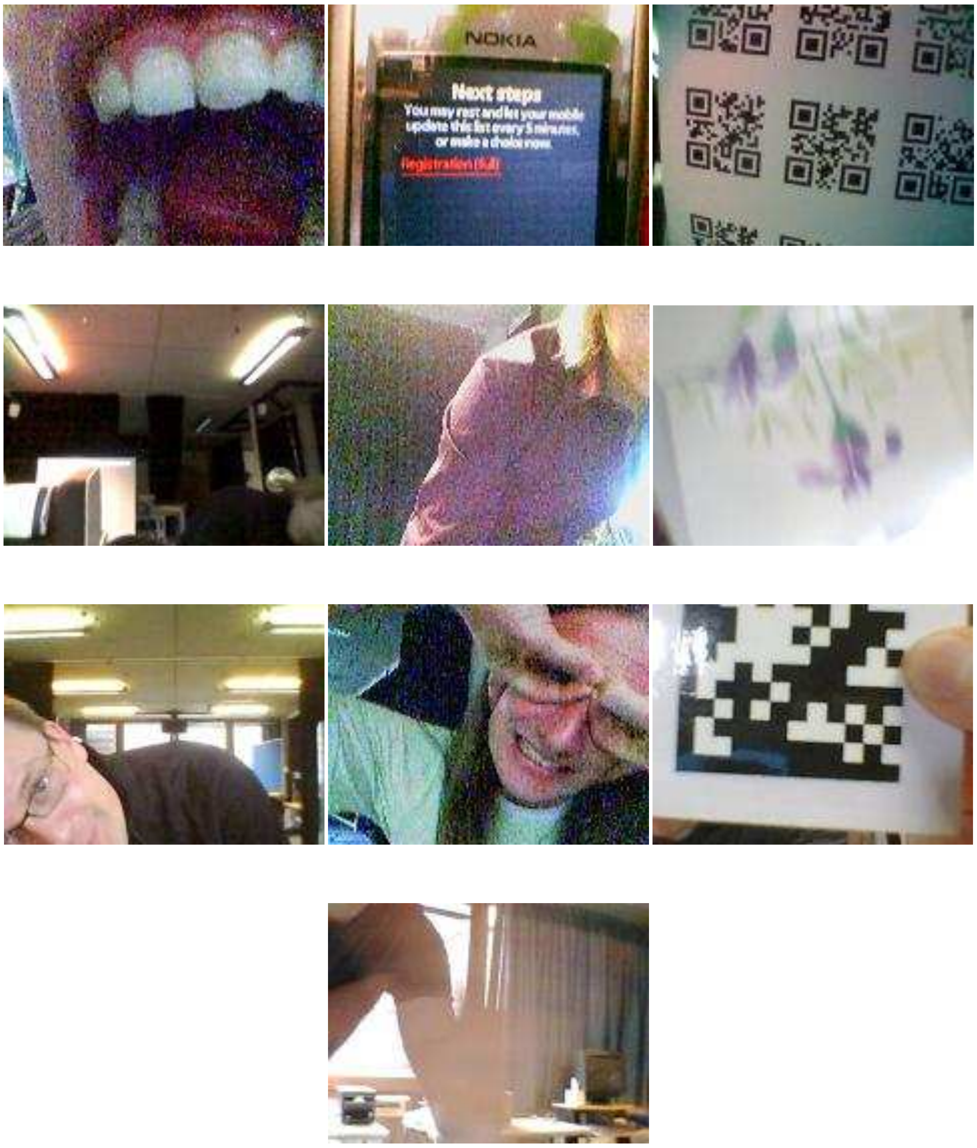


Figure 56 Playful visitor self-portraits

In addition, while the *Registration* coupled interaction could involve a group (although with only one visitor driving it) specifying an “age” for the group was a conceptually ambiguous task. Most groups, while having no problems providing a name and photo that represented the group as a group, would defer to the participant for the group's “age”. In one interesting case the group entered their age as the sum of the ages of the participant and the two by-standers comprising the group.

Several visitor profile photos from users interacting on behalf of a group are shown in Figure 57 below.

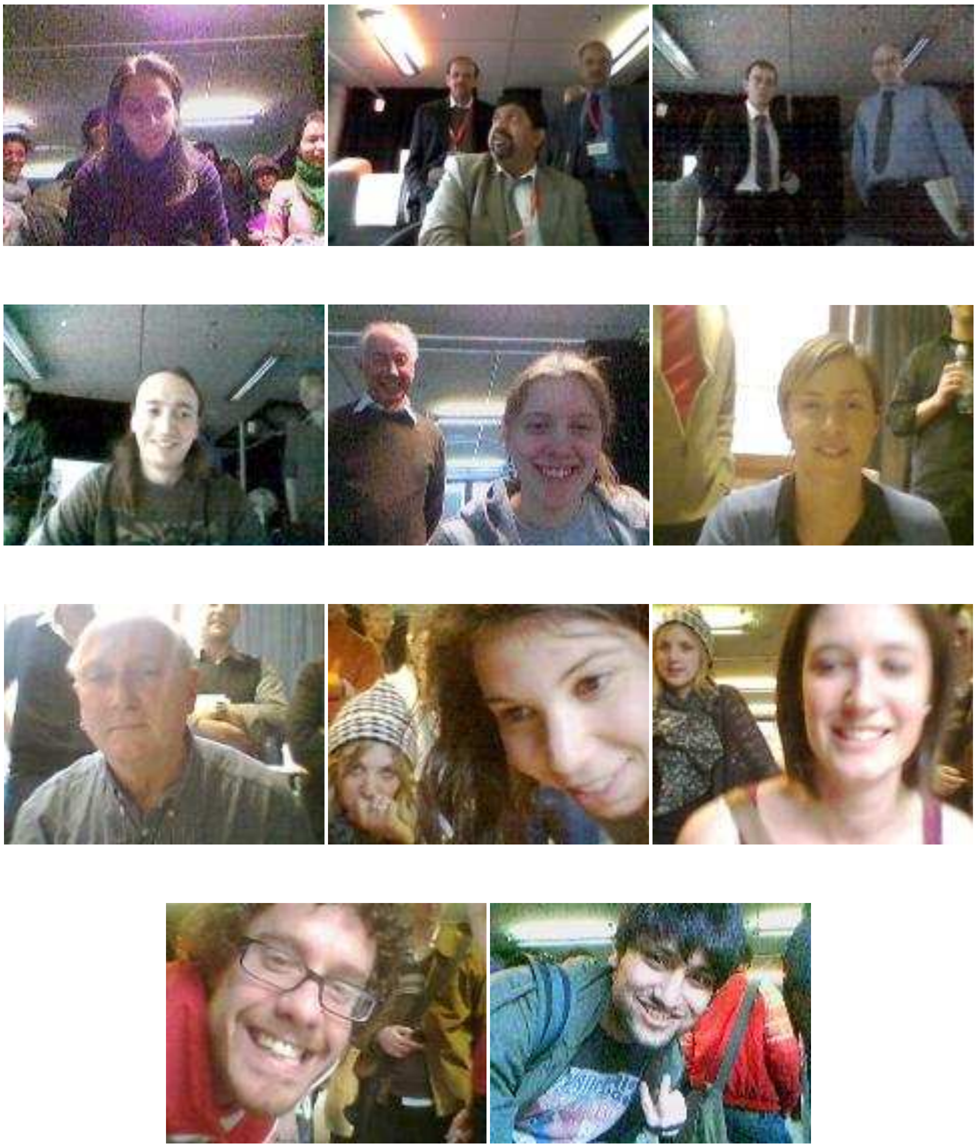


Figure 57 Visiting group self-portraits

The visitor profile was clearly neither objective nor specific. This then begs the question as to whether later coupled interactions should have been restricted based upon visitor profile data, at least in a fashion that attempted to do so objectively. In reality there were no cases of users claiming that the content to which they were restricted was unsuitable for them, thus it becomes difficult to form a grounded response to this question. There might be major issues given less generic content or experiences, in which cases the combination of "objective" restriction mechanisms based on assumptions (or logically determined context) may give rise to unsuitable experiences, the opposite effect to that the designer may hope to achieve. It may be suggested that the designer carefully consider how group identity is reconciled with visitor profiles – the test-bed infrastructure is built upon the assumption that one visitor has one mobile phone and one profile, yet in the trials groups shared mobile phones; the groups themselves negotiated around this issue by creating visitor profiles that represented the group yet it can be seen, in the resulting ambiguity of the age attribute, that there are some attributes of a group profile that need to be handled differently in comparison to an individual visitor.

Dynamic visitor profiles

One unintended emergent feature of the trial environment was the ability for users to return to the *Registration* coupling opportunity and re-register with a different visitor profile. There were no blocks in place to prevent visitors from returning to already experienced couples – on the contrary this was intended behaviour for later couples such as the *World Map* – thus (while even discouraged due to the way in which couples were prioritised during advertising) curious users discovered that re-registration was possible (Q29-33). Not all of these users saw any major significance in this ability beyond refining their visitor profile, yet those that had also realised that their registered age would affect some coupled interactions saw this ability as an opportunity to lift the visitor profile-related restrictions (Q31-33).

Q29: "I didn't know whether I was supposed to do it again but I figured I'd see what happened. I guess it was a cheat but it was funny to be able to change my name half-way through" trial 3; interview

Q30: "I was glad that I could take my photo again – the first one wasn't great!" trial 4; group discussion

Q31: "We knew that age was a factor … once we tried to go back to the Registration *and it worked we tried to get to those children's slides" trial 5; interview*

Q32: "The first time round I didn't really take the Registration *seriously, but then I found out that it actually mattered so I went back to do it properly" trial 5; interview*

Q33: "I wanted to see all the objects [at the ART *couple] so I went back and registered like him – the one I saw who got those choices. I didn't get it right first time – I still was too old, so I had to go back again" trial 5; interview*

6 of the users in trial 5 were observed exhibiting this tactic, 4 of whom did so to bypass the visitor profile-related restrictions, while 3 of these learnt the tactic by observing another user. Interestingly, while 4 of the users learnt the tactic by observation, half of these did not learn the details of the tactic, i.e. the threshold separating “child” and “adult” profiles, and thus needed to return to the *Registration* couple more than once (Q34): both users originally registered as adults (24 and 21 years old), and then re-registered as 16 year-olds, assuming that this would be young enough. One then went back to the *Slideshow* coupling opportunity, while one went to the *ART* coupling opportunity, before both realising that their re-registered age had made no difference.

> *Q34: “Working out the* Registration *was good fun – I knew I could probably ask someone else how to do it but that would've been cheating” trial 5; interview*

These incidents highlight *appropriation* of features of the system by the users (Dourish, 2003), i.e. adaptation of or improvisation with a technology to “get the job done” (Dix, 2007); appropriation is often seen in interactions with novel technologies where there are fewer or less well-grounded interaction metaphors for users to draw upon – in such situations the designer may be more likely to incorrectly assume the interpretation of the user, making it important to include the user in the design process in order to react to (to capitalise or correct) appropriation. The observations above also draw attention to the fact that appropriation, as with expected uses of the system, may be observed and repeated by others.

ii. Concealing mechanisms

Concealing mechanisms temporarily limit interactive possibilities. Narrative dependencies have been previously discussed as a means to direct visitors along particular paths through the coupling environment, i.e. to shape the visitors' trajectories. Each coupling opportunity's registration in the context database includes records representing the other couples that must be completed before the coupling opportunity will be advertised to a visitor[46]. In contrast to restrictions, the visitor is denied access to couples that are available only at a later point in the environment's narrative *until* their personal trajectory has reached that point in the narrative: in this way couples are only temporarily *concealed* from the visitor rather than the visitor’s access being permanently restricted. This potentially enforces variety amongst

[46] See storylines.* in appendix 10.2 for a snapshot of the dependencies in the trial 5 coupling environment

visitors' trajectories only *temporarily*, since all visitors – if they explore fully enough – might progress completely through all narratives and thus reveal all the concealed couples.

Over the course of the trials it has become clear that the system plays a key role in not just enforcing a narrative structure on the trajectories of the visitors, but in enforcing that structure in a manner that is *acceptable* to the visitors. In implementing restrictions there is no notion of a balance of control between system and visitor; in concealing mechanisms there is a grey area in which the balance between system and visitor exists, shifts and governs the method and extent to which couples are concealed. This balance will be discussed following a brief reflection on the mechanisms implemented to enforce the narratives in the trial environments.

Completing goals

From trial 1 onwards the test-bed implemented a notion of *completion* during coupled interaction - once coupled interaction progressed to a certain step the experience at that couple was "completed". Once an experience was completed any couples requiring that experience as a narrative dependency would be advertised to the visitor during exploration rather than being concealed. Practically speaking, every instance spawned by an installation inherited the functionality to register a "completed experience" for a particular visitor in the context database[47] - these records were then considered by the context server in conjunction with the narrative dependencies of each coupling opportunity when generating suitable adverts for a visitor. In this manner, narrative dependencies and proactive denial by the system combine to form narrative fail-safes.

At the couples in trial 1, a particular coupled action progresses the narrative. In the case of the *Registration* couple, the coupled interaction would be deemed completed when the visitor's profile had been registered in the context database; at the *World Map* once one of the data matrices had been successfully scanned the experience was "completed"; at the *Slideshow* one slide-show needed to be viewed.

By requiring that the coupled interaction reach a particular point the visitor is forcedto do more than simply arrive at the coupling opportunity, couple, then quit and immediately try to move on to the next opportunity – in such a situation the visitor would simply receive the same adverts again. There was no evidence of such attempts to skip couples in trial 1, partly due to the nature of the users, but more so due to the orchestration approach (direction) and

[47] See completeexperiences.* in appendix 10.2

pace of the overall experience in the coupling environment (discussed further in section 7.2.2). In addition, completion at the *World Map* and *Slideshow* occurred very early in coupled interaction at those couples, thus there was little chance to fail to complete the interaction unless a visitor ended coupled interaction literally as soon as the couple was formed. At the *World Map*, for example, all users would scan one matrix simply because they were instructed to at which point the experience was “complete”; no users were observed arriving and decoupling before scanning *any* data matrices. Also, as has previously been mentioned, the mobile phones used in trial 1 were particularly capable of scanning the matrices, thus no users had a chance to become frustrated enough over their first scan to end coupled interaction prematurely.

There was one case of unintentional premature decoupling in trial 1: in this case the user had previously observed another user during their coupled interaction at the *Registration* opportunity, watching the participant remove their mobile phone from the fixed assembly holster to initiate decoupling when the coupled interaction had finished. When the bystander went on to become the participant they were quick to remove their mobile phone from the holster as soon as they entered their name and age, not realising that they still had a step of the interaction remaining (taking the photograph), thus decoupling before the experience was “completed”. The user, despite being concerned about whether they had “broken” the experience, was immediately directed to re-couple with the *Registration* and restart the experience.

In later trials the variety of means to complete experiences increased, in terms of both the actual actions that completed experiences and in terms of how far through coupled interaction this completion action would occur. The development of the *World Map* couple over the course of the trials illustrates this well: while in trial 1 there were 3 data matrices, any of which when scanned would complete the experience and allow the user to move on to the next opportunity, from trial 2 onwards the number of data matrices increased, including the original 3 in addition to a number of others. More importantly, only the original 3 when scanned would cause the experience to be completed, allowing the users to progress – if any other data matrices were scanned the user would receive a fact about the relevant geographical location to which the matrices were attached, but would not yet be able to progress further beyond the *World Map*. The reasons for this were twofold: first to increase the variety of interaction possible at the *World Map* to combat some of the perception of linearity expressed by users in trial 1 (discussed further in section 7.2.2), i.e. to allow visitors to differentiate their experiences somewhat, and secondly to introduce an element of exploration, i.e. to encourage visitors to work to achieve progression to the next couples (exploration to find content has often been linked to a greater sense of value in the consumption of that content, e.g. (Izadi et al., 2002)).

In addition, a new coupling opportunity was added in trial 2 - the *Photowall* - access to which was dependent not solely upon completion of particular couples, but also upon a particular task being completed while the visitor is exploring the environment (i.e. decoupled). In this case the visitor is required to take a photograph while exploring: once the visitor had done so the *Photowall* would be advertised to the visitor as normal.

Users no longer completed experiences at the couples simply by coupling, as had essentially been the case in trial 1 – completion of experiences became a non-trivial task, the difficulty of which would, intentionally, vary between visitors thus increasing the variety of visitors' personal trajectories in terms of both the duration and sequence of coupled interactions, without restricting particular visitors to particular experiences. The resulting behaviour of users became similar to that resulting unintentionally from the ability to re-register with a different age; in actuality due to the ability to re-register, the restrictions intended to be placed upon visitor's interactions via their registered age were *not* restrictions but instead simply concealed particular interactions. Analogies can be drawn between, for example, the users giving Q31-33 who tried out different possible ages in order to experience all possible content at later couples with those giving Q35-38 who returned to the *World Map* to explore for further actions that would reveal further interactions at the *Slideshow*, *ART* and *Google Earth* couples.

> *Q35: "I wasn't exactly sure how many different tags I had to scan before I got all the different slides and 3D [objects] but I knew it was quite a few so I kept going back" trial 3; interview*

> *Q36: "I thought I'd got all of them on the first go; I saw some people coming back so I thought I would try and avoid that – they were like ants marching back and forward" trial 5; interview*

> *Q37: "I was a bit blasé at the start; it took me a while to cotton on to what the link was between the [*World Map*] and the others, but once I did I had to scan all those things" trial 4; interview*

> *Q38: "It was annoying actually – funny annoying – because every time I left the [*World Map*] someone shouted out that they were interacting with a different country so I had to go back twice. Then someone just made one up and I spent ages looking for*

it, scanning all those different tags. It's a pity my geography isn't a bit better!" trial 3; interview

Interestingly, while the development of the *World Map* encouraged more exploration of that particular couple, recognition that taking a photograph revealed the *Photowall* exhibit encouraged users to explore the mobile client for more ways to unlock further couples. While 8 of the users in trial 5 managed to reveal the *Photowall* opportunity and all except one took multiple photographs, 3 of these claimed in interviews to do so explicitly to test whether more opportunities (either for further coupled interactions at the *Photowall* couple, or for completely new couples) would be revealed by doing so. Several users who had previously paid little directed attention to the mobile client went on to systematically try every command to try to reveal further opportunities. One user even tried a few combinations of key-presses to see what would happen:

Q39: "I thought that there might be cheat codes like in computer games – you know the old ones where you pressed a certain combination and things happened. They didn't though" trial 5; interview

Hubs

In contrast to the *Registration*'s role as a *gateway* to all further couples, the *World Map*'s role is not just as a gateway, but as a *hub* from which visitors may explore many branches of further coupled interactions. Couples that act as hubs would feature *directly* in multiple other couples' narrative dependencies, as the *World Map* did in the trial environments.

This is clear in the sample snapshot of the context database's *storylines* table taken during trial 5 in Table 25 below where the *World Map* accounts for 3 of the 5 dependencies.

instanceName	prerequisiteInstance Name
Slideshow	WorldMap
WorldMap	Registration
Art	WorldMap
GoogleEarth	WorldMap
Photowall	Registration

Table 25 Narrative dependencies in trial 5

This is a contrast to the *Registration* which features directly only twice in the table, but indirectly precedes *all other* couples, as can be seen in the narrative dependency diagram in Figure 58.

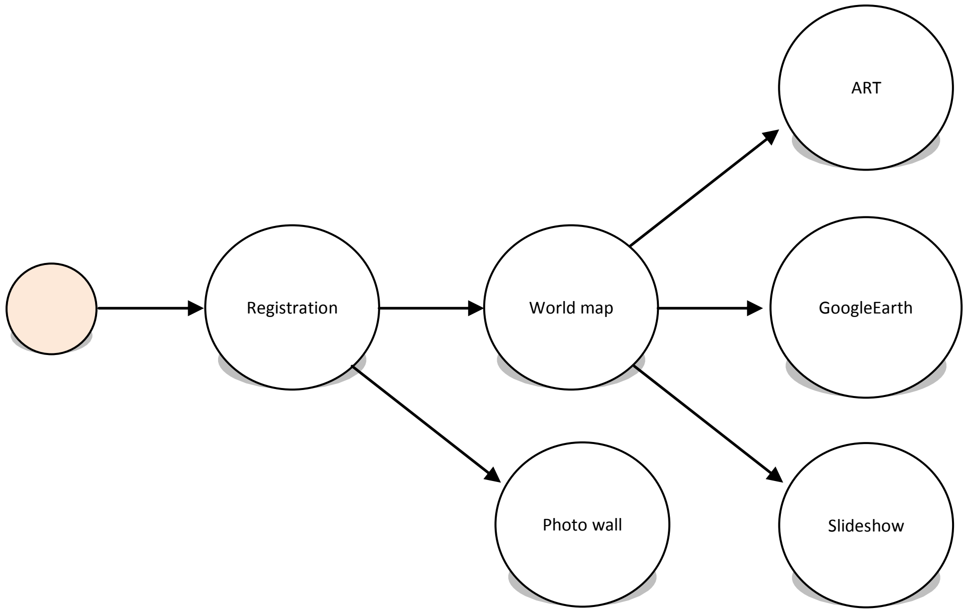


Figure 58 Narrative dependencies in trial 5

The behaviour observed during the trials in which users moved backwards and forwards between the *World Map* and other couples, returning and re-experiencing the *World Map* coupled interaction, has previously been discussed. Users engaged in this behaviour due to the fact that there were three data matrices at the World Map that could be scanned that each added new, different coupled interactions at the *Slideshow*, *ART* and *Google Earth* couples, thus if a visitor did not scan all three key matrices on their first visit to the *World Map* then they would need to return if they wished to experience all coupled interactions at the subsequent couples. A user that *had* discovered all three key matrices on their first visit, or indeed a user that did not feel the need to find, or did not realise that they *could* find more matrices, did not need to return to the *World Map* as all three dependent couples – *Slideshow*, *ART* and *Google Earth* – would be revealed during the exploration process following decoupling from the *World Map*. For most users this was not the case, and the majority moved backwards and forwards between the hub and its dependent couples at some point during their experience.

In trial 1 users that returned to the *World Map* would tend to be those that felt that they could or should scan only one data matrix at a time at the *World Map*. As there was only one coupling opportunity following the *World Map* – the *Slideshow* – there was only a limited chance for the return-to-hub behaviour to emerge. Instead, the behaviour become increasingly apparent as the additional data matrices were added to the *World Map* and multiple couples became available following a "completed" experience at the *World Map*. There appeared to be two variations of the return-to-hub behaviour, whereby users would either a) find key matrices at the *World Map*, then work their way through all newly-available couples before returning to the *World Map* and repeating the process, or b) find key matrices at the *World Map*, then visit one new opportunity, then return to the *World Map*, then visit a different new opportunity, and so on. This latter variation was much less systematic and led to confusion on behalf of several visitors who could not judge which coupled interactions remained to be experienced at the different couples:

> *Q40: "I lost track of what I got after I went back [to the World Map] the third time; there was already a queue at the slides so I didn't bother trying to work it out any more" trial 3; interview*

> *Q41: "I don't think any of us were really sure about whether there was more to see at the [*Slideshow*] – I think we felt like we were walking around in circles" trial 2; interview*

This behaviour was only evident in trials 2 and 3 in which the adverts presented to the visitors via the mobile client were not prioritised beyond indicating any couples were currently full to capacity with other visitors. Instead, adverts would remain in the order in which they were originally received, and while the *Registration* coupling opportunity would often be advertised with the lowest priority (as it was often engaged by other visitors) the *World Map* advert remained at the head of the list (as it would never reach full capacity), thus users often stated that they felt that they were supposed to revisit it:

> *Q42: "I think it kept asking us to do more at the [*World Map*]; [another member of the group] wanted to try all the other [couples] but I thought we should follow what it was suggesting" trial 2; interview*

> *Q43: "It was odd that the phone kept telling me to go back to the [*World Map*]; I don't know if there was a goal there that I didn't really understand but it seemed pretty insistent" trial 3; group discussion*

Based on the trials it seems that while gateway couples enforce narratives and remove complexity from the exploration process, hubs *add* complexity while introducing the possibility for variety amongst visitors' trajectories. While the complexity introduced by the *World Map* hub seemed poorly managed in earlier trials, resulting in comments such as Q40-43, there were no such issues in trials 4 and 5 in which already visited couples are given a lower priority than as yet unvisited couples (i.e. the adverts for the visited couples are listed below those of unvisited couples). In this way the *World Map* cannot rise to the top of the adverts presented to the visitor again until they have visited all its dependants (unless all of these lack capacity).

7.2.2 Pace and balance of control

The thesis has referred several times previously to the *pace* of the users' experiences and to the *balance of control* over their trajectories between user and system. This section expands now on these two issues which are both strongly related to the mechanisms supporting visitor exploration.

i. Dictated and immediate choices

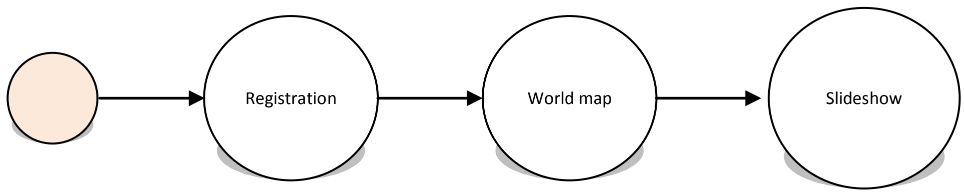


Figure 59 Narrative dependencies in trial 1

In trial 1 the test-bed exercised a strong control over the trajectories of the users through *direction*. Of course, due to the linearity of the narrative enforced in the trial (see Figure 59) there appears to be little opportunity for individual diversity, as evidenced by the durations of experiences tabulated in

User ID	Total experience duration (seconds)
1	740
2	802
3	800
4	770
5	690
6	709

7	887
8	626
9	800
10	599
Mean	742.3
SD	83.6

Table 24 on page 175, yet these highly-similar times and the qualitative feedback from the users point to an issue separate to that of the linear narratives. A linear narrative should not by itself ensure that visitors have similar trajectories, either in terms of overall duration (where it would be expected that different visitors at least spend differing periods of time between experiences) or paradoxically in sequence[48]. Statements by test users from trial 1 do point, however, to a perception of over-control:

Q44: "I am intelligent – why do I have to let the mobile keep telling me when to move?" trial 1; interview

Q45: "It was OK but everything was a bit rushed – I wouldn't have minded a breather" trial 1; interview

Q46: "There wasn't really any chance for me to do what I wanted to do – it was all decided for me, right?" trial 1; interview

It should be noted that direction in the scope of the test-bed meant that users were never given a choice about which coupling opportunity they would visit next. Importantly the exploration process in this first trial was fundamentally different from that of the other trials, firstly due to the fact that there is no *understanding the environment* or *choice* on behalf of the visitor (the context server determines which couples are suitable then the visitor's mobile client initiates navigation to the "most" suitable), and secondly due to the fact that the system's direction occurs immediately after decoupling from the previous coupling opportunity, thus the visitor is continually either interacting with a couple or on the way to the next couple. There is no slack built in to the process for the "breather" desired by the user giving Q45. The intention was to investigate such a combination of *immediate* direction in order to determine whether there was any value in ensuring that coupling environment experiences

[48] It is important to emphasise again that even "linear" narratives in the test-bed are only linear *in one direction* - there are no restrictions on movement *backwards* through the narratives.

were as efficient as possible. Particular sequences of coupled interactions can be imagined for which this may be acceptable, but they have not been found in the trial environment.

Linearity of narrative need not mean that every aspect of the trajectory of the visitor through the coupling environment is controlled. Even without the use of the differentiation mechanisms discussed previously it is important that a *perception* of visitor control is built into the experience. It can be suggested that this breathing space between stages in the progression through the environment is vital to provide to the visitor this sense of control over the experience. Indeed, based upon observation of informal trials before and after trial 1 it seems that this slack would be particularly important for visiting groups – trial 1 did not assess this hypothesis.

ii. Selection and search

As a response to the feedback from trial 1, a direction-based approach to exploration was set aside in favour of two other techniques supported by the test-bed: *selection* and *search*. Also as a result, understanding the environment and choice became distinct steps in exploration. Rather than decoupling then immediately receiving directions to the next coupling opportunity, users would be given a choice to either rest (whereby the mobile client would take no further action until the user chose one of the other two options), search for couples (at which point the mobile client would request and visualise a list of relevant adverts from the context server), or select an opportunity, via a main screen in the mobile client (see Figure 60 below).

Figure 60 The main exploration screen of the mobile client in trial 4

Figure 61 ***World Map*** **and** ***Slideshow*** **couples with data matrices for selection (top); example of selection data matrix (bottom)**

If the user chose to select an opportunity they would be instructed by the mobile client to find a data matrix attached to the situated device with which the user wished to couple (see Figure 61 above) and then the mobile client would provide the user with a means to scan the matrix. The resulting decoded ID (representing a particular coupling opportunity) is sent to the context server which determines whether or not the coupling opportunity is relevant to that visitor, returning either a positive or negative response. Upon a positive response, navigation is skipped (as the visitor is already at the location of the coupling opportunity) and coupling begins. On a negative response the mobile client informs the visitor that they cannot access the coupling opportunity, for whatever reason.

When searching for relevant couples, the adverts returned and listed by the mobile client were categorised as either suitable or suitable but currently fully-engaged (see Figure 62 below). These adverts were then listed with suitable adverts at the head of the list and full adverts at the tail.

Figure 62 Advert visualisation in trials 2-3 for suitable couples (left) and full but otherwise suitable couples (right)

The decision to introduce search and selection mechanisms for exploration was based on the desire to give the visitor a greater degree of control over both the *direction* and *pace* of their trajectory through the coupling environment, the former being deemed significant due to the introduction of branches in the narrative (see Figure 63), and the latter due to the feedback from trial 1.

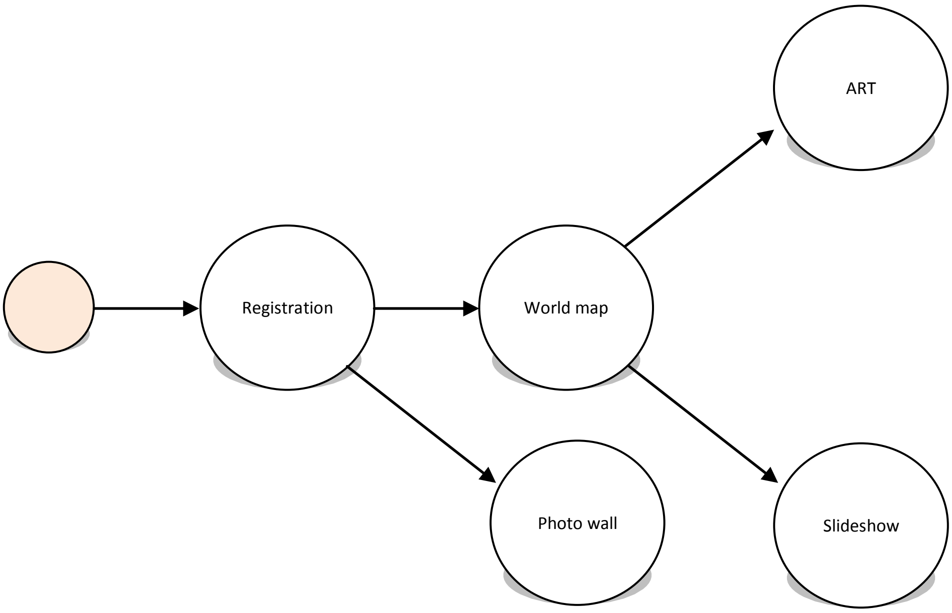


Figure 63 Narrative dependencies in trials 2-4, illustrating branching

Non-coupling points-of-interest

A complication that became clear during trial 3 was the bottleneck effect of low capacity couples. In trial 3 there were 5 visiting groups exploring and using the environment concurrently; the *Registration*, *ART* and *Slideshow* couples all had capacities lower than five (1, 3 and 1 respectively[49]) and each, on several occasions, caused bottlenecks where bystanders were waiting for a chance to couple. Several participants remarked afterwards that they felt rushed, not by the system but by bystanders:

Q47: "I felt like I had to hurry up because they were starting to queue" trial 3; interview

Q48: "You were all being quiet too – looking a bit bored – so I thought I should probably skip the last few slides" trial 3; group discussion

Q49: "I saw that everyone was already at the Slideshow *so I just stood back – I had already seen all the other ones on the list" trial 3; interview*

To alleviate this issue and to introduce further diversity to the trajectories of the users additional situated points-of-interest (POIs; previously mentioned in *Populating the context database* on page 309) were introduced into the coupling environment in trial 4. These POIs were information displays, services and landmarks that may be of interest to the visitor, but to which the visitor did not need to couple their mobile device. The context server registered these POIs when it was initialised and users could request adverts for POIs through an alternative button while exploring (see the option "Show other points of interest" in Figure 60). Q50-53 focus upon the perception of the POIs within the coupling environment:

Q50: "I liked the mix of the exhibits; you could go off to one of the not interactive ones to calm down a bit – the Slideshow *got a bit hairy at times, especially if you weren't quite as good at using it as the others" trial 4; group discussion*

Q51: "The extra stops were great for putting it on hold; I wasn't so much interested in what was there as being able to step back and watch what was going on elsewhere" trial 4; interview

Q52: "I think you would definitely need these little stops if there were more of us […] to spread us all out a bit" trial 4; group discussion

Q53: "The big list of things to do was really good – now that I look back it seemed like there was lots going on because we were all off in different directions. You had more to talk about with other people too because you'd all seen the place a little bit different" trial 5; interview

[49] See installations.capacity in appendix 10.2

A general consensus appeared to be that users often appreciated the POIs as a means to control the pace of the experience, i.e. to legitimately use the breathing space created by relevant couples being full to capacity. Despite the ability to rest at any point following decoupling (i.e. by not choosing to either search or select couples) the majority of users still expressed the opinion that they felt they *should* be doing something as soon as they finished one coupling experience, even if no further couples were accessible. This is an interesting contrast to trial 1 where the users felt like they had no control and thus could not do anything *but* follow instructions, while in trials 2-4 the users felt that even though they had control (no users suggested that the system was controlling *them* in trials 2-4) that they should be trying to work their way through the environment. Statements such as Q50-52 suggest that POIs were used as *filler* experiences in order to add slack to the users' trajectories. It is particularly interesting to observe that users felt a strong obligation to be actively exploring to fill time when no couples were accessible rather than filling their time by conversing with or observing one another. This is not to say that these activities did not occur (social behaviour is discussed specifically later in chapter 8), but that the unexpected "filler" behaviour was equally prevalent.

The view may be hazarded that the users in trials 2-4 had too much responsibility for orchestrating their own trajectory (in comparison to trial 1 where they clearly had too little), without possessing the ability to fill the periods between coupling experiences effectively.

No such perceptions were observed in trial 5 – at no point did any users in these trials state that they felt controlled (as they had done in trial 1), nor that they felt that they should be doing *something* to fill gaps in their experience. With regards to the advertising process there were few changes from trial 4 to trial 5:

- as previously, only adverts for suitable (Figure 64 left) and full-but-otherwise-suitable adverts were listed (see Figure 64 middle where the fully-occupied *Registration* opportunity is given the lowest priority, and if clicked would deny the visitor access), but these adverts were also marked and reduced in priority on the list if the couple had already been visited (see Figure 64 right where the *World Map* and *Registration* opportunities are displayed at the tail of the list as they have already been visited) based upon feedback suggesting the users desired a reminder of their previous activity in the environment;
- adverts for POIs and couples were merged into one list, with adverts for POIs given a lower priority than those of couples (see Figure 64 left, where the *Storychart* and *CoffeeMachine* as POIs are listed below the *Registration* couple), thus searching for

POIs and couples became one action (resulting in only one button to initiate this on the mobile client: see Figure 65)

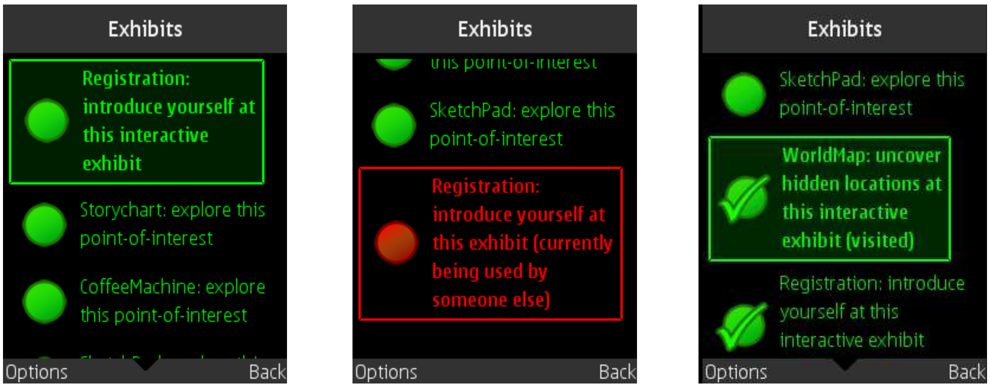


Figure 64 Various adverts listed in the mobile client in trial 5

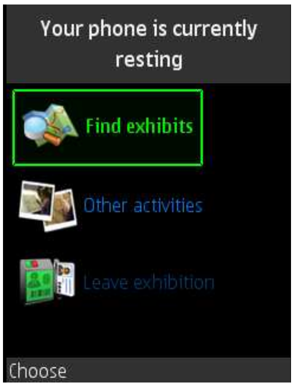


Figure 65 The main exploration screen of the mobile client in trial 5

Users in trial 5 in fact made no reference to the pace of the experience and expressed little opinion on the control exerted by the system over the adverts exposed to them; this is a stark contrast to earlier trials were these were common subjects of discussion both amongst users' post-session and during interviews. This general change in perception cannot be attributed to any of the changes made to the advertising visualisation, nor can it be suggested that a change in time at which adverts were pushed to or pulled by the users was responsible as this was not altered: users were still responsible for pulling adverts whenever they wanted following decoupling. Instead a *significantly* improved understanding of the differentiation mechanisms at play in the coupling environment on behalf of the users can be credited in trial 5 with improving their sense of purpose, ownership of trajectory and enjoyment of their experience, i.e. that visitors understood the links between couples and thus had a strong sense of purpose and goals. The chapter continues now by describing the key changes to the environment responsible for this improved understanding.

7.2.3 Visibility and accountability

For differentiation mechanisms that have a visible effect on personal trajectories to be accepted by visitors, or more accurately for the impact of these mechanisms to be accepted, the mechanisms themselves must be visible, such that the mechanisms are understandable and accountability can be apportioned appropriately.

In trial 1, users were well-aware of the mechanisms at play shaping their personal trajectories, or indeed the lack of differentiation mechanisms. As such there was no confusion; negative perceptions of the system revolved around the clear but overwhelming system control. A general confusion or lack of purpose amongst users emerging in trials 2-4 was a result of the introduction of differentiation mechanisms without a full consideration of the need to ensure that they were understandable.

In trials 2-4 many users realised that there were differentiation mechanisms at work in the environment – many of the quotes discussed in previous sections attest to this fact, and 39/42 users responded via the questionnaire that they were "aware that [their] actions at certain exhibits affected what actions were possible for [them] at other exhibits" – yet the majority of these failed to understand either the actual *mechanism* or the intended *purpose* of the mechanism.

A good example of the former is the development of the *World Map* coupling opportunity from trial 2 to 5. As briefly described in *Completing goals* on page 191 there were initially only 3 data matrices to scan, each of which would open access to the subsequent coupling opportunity – this combined with the fact that users had no chance to choose their couples meant that there was essentially no concealing mechanism to understand. Over the course of trials 2-4 the number of matrices was gradually increased from the original 3 to these plus an additional 10 matrices that would give immediate coupled feedback in the form of a new fact when scanned but would not "complete" the experience and thus would not reveal access to subsequent couples.

Figure 66 Data matrices at World Map in trial 2; 3 key matrices (bottom) are similar in appearance to additional matrices (top)

The intended impact of this change was to encourage exploration of the interactions possible at the *World Map*; in trial 2 the additional printed matrices had the same appearance (beyond the matrix itself), as shown in Figure 66 above as it was assumed that differentiating the matrices visually would render the task as trivial as in trial 1. In reality users in trial 2 largely failed to understand the impact of their actions as evidenced by the quotes below:

> *Q54: "I'm not sure what I did at the [*World Map*] to get to the next one. Well I know I had to scan the tags – I think we had to scan a certain number?" trial 2; interview*

> *Q55: "I'm glad she [a member of the visiting group] knew what she was doing – when I had a go first nothing seemed to happen; I don't think she did anything different but she was obviously better at it than me" trial 2; interview*

An important oversight in the design of the mobile client in trial 2 was the lack of feedback during the scanning process as to the difference between the scanned matrices: users did not know until they decoupled whether they had scanned any of the 3 key matrices, thus the mechanism governing the concealment of the subsequent couples was unclear.

In trials 3 and 4 varying matrix appearances were experimented with (in trial 3 varying the colour and in trial 4 varying the size), while immediate feedback was also given when the users scanned one of the 3 key matrices before they received their fact regarding the scanned location that they had found "a special tag that has unlocked additional opportunities for interaction in the exhibition". Q56-57 below neatly represent the effect of these changes which was to make the mechanism clear, but to apparently further ambiguate the conceptual purpose of the coupled interaction.

Q56: "I think we got that certain barcodes would let us go on to the next exhibit but I don't really know why – actually I thought the interesting facts were with the [non-key] barcodes" trial 3; interview

Q57: "It was pretty clear that there were a few special tags; once I found that the little ones [the non-key tags] didn't give me that pop-up on the mobile then I just went straight for all the special ones. I didn't get why they were special until someone pointed it out to me later – it didn't ring a bell when I got Kenya and Cuba at the Slideshow *that I had found them earlier at the [*World Map*]" trial 4; group discussion*

Further feedback indicated that the increase in data matrices scanned by each user meant that few users could or would remember which locations any key matrices scanned were attached to. In trial 1 users would typically scan only 1 or 2 matrices in one coupling with the *World Map* and thus would tend to remember which locations the tags were attached to when they then moved on to further couples; as such, when coupled interaction at later opportunities was then related to the same location that was scanned, the users understood the relationship between the two. In trials 2-4 these conceptual links would not be made.

To make clearer the reason for scanning tags at the *World Map*, it was necessary to introduce a more explicit key metaphor into the experience. Upon coupling with the *World Map* exhibit, the visitor's mobile would ask the visitor to read a poster attached to the surface of the map which explained that upon scanning certain matrices the visitor would receive a key linked to the scanned location that could be carried to further exhibits to unlock new experiences related to that location. When any key matrix was scanned the visitor would receive immediate feedback informing them that a key for the location had been transferred to and stored in their mobile phone, as well as an indication of how many other keys remained to be found; when the first non-key matrix was scanned the visitor would receive immediate feedback informing them that, in this case, they would only receive a fact, not a key and that they should keep scanning more matrices until they find a key. Upon decoupling, the visitor would receive a summary of their finds, i.e. how many keys they had left to find, and instructions regarding how to view the keys stored in the "wallet" on their phone (accessible via the "Other activities" menu, as shown in Figure 67 below). The notion of the carriable key was enforced at the *Slideshow* and *ART* couples where visitors were told during coupling what interactions they had unlocked using their keys, and reminded which keys they actually had. Upon decoupling from these exhibits they were further explicitly reminded about whether or not there were unfound keys remaining at the *World Map*.

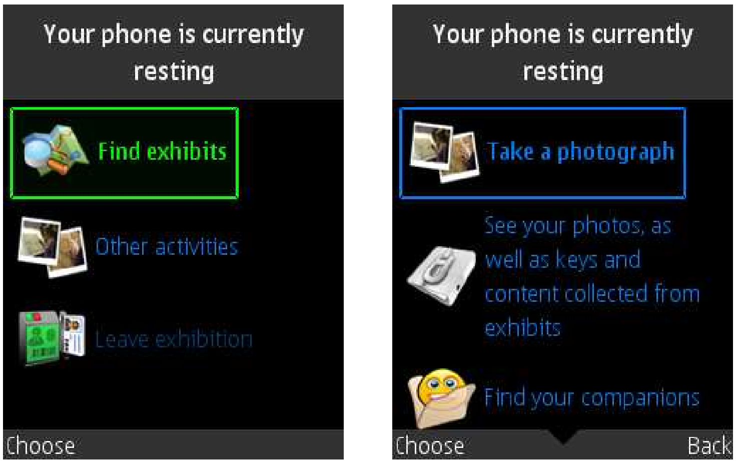


Figure 67 Accessing the photography functionality of the mobile client in the "Other activities" menu (right) via the main exploration screen (left)

These changes in trial 5 significantly improved the understanding (and engagement) of the users regarding the mechanism.

Statements such a Q58-59 below emphasise this change.

> *Q58: "I thought it was great that you could carry the locations over from the [*World Map*] to the [*Slideshow*] – it was like bringing a sample over to a microscope to look at it more closely" trial 5; interview*

> *Q59: "I really got the idea of the wallet – it made it pretty obvious how to get to all the slides and the 3D stuff that other people had because I just had to go back to the [*World Map*] and grab it" trial 5; interview*

i. Revealing issues with mechanisms through staging of coupled interaction

A complicating factor emerging in trials 2-4 (where multiple visitors experienced the coupling environment concurrently) was the way that aspects of the differentiation mechanisms were revealed through the staging of coupled interaction. At all couples, users (as bystanders and fellow participants) observed participants during coupled interaction. Observation also led to exacerbation of the confusion over the understanding of the mechanisms and their purposes.

In trial 2 where the *Photowall* coupling opportunity was first introduced a similar approach was taken to that of the early *World Map*, whereby the concealing mechanism at play (in this case the need to take a photograph in order for the *Photowall* opportunity to become relevant and thus revealed) was hidden entirely: users were required to discover serendipitously that capturing a photograph via the mobile client revealed the *Photowall* opportunity. Users could of course see the *Photowall* situated display while exploring the environment, yet users only became aware that the display was a potential coupling opportunity (as opposed to simply a publicly-situated but private display) by observing others coupled to and engaging in coupled interaction with it:

> *Q60: "You know I thought that the [*Photowall*] was just another demo you had set up; the photos on it didn't really look like the kind of photos I would take. I only got it when [another user] walked over to it and started add stuff" trial 3; group discussion*

> *Q61: "There was so much going on in the space anyway – I don't think you really took any notice of anything unless the mobile told you to go there. We didn't bother with the [*Photowall*] until we saw those lot go and put a photo up" trial 3; group discussion*

Unfortunately for the bystanders, observing the coupled interaction at the *Photowall* did not necessarily reveal the secret to accessing it: coupled interaction lasted only an instant during which time the *Photowall*'s display was simply updated with the photographs taken by the coupled visitor. Several users, as represented by Q62-65, never understood how the participants gained access to the *Photowall*, and in a few cases (such as Q63-64) did not understand that the new photographs on the situated display had been taken by and transferred from the participants.

Q62: "I'm not sure how [another user] added that photo – it was a nice idea but maybe I couldn't do it with my phone?" trial 4; interview

Q63: "The photographs looked really good – we couldn't find out how to do it though, because you couldn't just use the camera like normal" trial 3; group discussion

Q64: "Was it like a randomiser? There weren't any people in the photos so it was quite hard to tell" trial 2; interview

*Q65: "I guess they came from the [*Registration*] – maybe some other people found out how to put their registration photos on the [*Photowall*]?" trial 3; group discussion*

The fact that the option to capture photographs was, to use the words of several users: "hidden", in the second level of the mobile client UI did not make serendipitous discovery of the concealing mechanism likely. For trials 2-4 the *Photowall* remained the realm of only the very curious (who found the mobile client's photography functionality), the shrewd observers, or those that the participants later shared their expertise with. The *Photowall* achieved the intended aim of staging the visitors' photographs, but failed in that only a minority of the visitors understood that they could use it to stage *their* photographs. A simple but evidently effective solution to this issue was to make explicit the mechanism via the situated display: by telling the visitor who stumbles upon the situated display that it is a device to which they can couple their mobile, and how to reveal it (see Figure 68 below) a degree of serendipity is retained (the visitor must first "stumble upon" the situated display), but the purpose of the coupling opportunity is made clearer, thus encouraging wider use.

Figure 68 Snapshot of the *Photowall* situated display UI indicating to the visitor how to reveal access to the coupling opportunity

Significantly, staging of coupled interaction also emphasises the relative restrictions placed upon different visitors' personal trajectories. A comparison that clearly illustrates this effect is that of the *World Map* (where age restricts the facts available to the participant) to the *Slideshow* (where age restricts the slides available to the participant); in the former, despite the participants sharing a common input space (the map surface), output is personal (via the mobile client), therefore the feedback that shows the effects of the restriction is not staged and participants (unless collaborating) are not easily able to compare one another's feedback; in the latter, both the single participant and all bystanders experience the same feedback from the participant's coupled interaction, i.e. the feedback is staged for all to see, thus bystanders can compare the participant's coupled interaction with their own (past or future) coupled interaction and easily determine if any restriction mechanisms are at work.

Return trips to the *Registration* coupling opportunity to eliminate this restriction helped, unexpectedly, to alleviate the issue of the restriction being staged, yet this option is not always available, thus it is important to consider the negative impact of staging coupled interactions that make visible the effects of any restricting mechanisms. The restrictions based on the technological capabilities of visitors' mobile phones are a good example of such issues; in this case the visibility of the restriction was increased at the *World Map* as users could clearly see when others were forced to manually enter the codes of the data matrices when their mobile phone's camera was not able to scan them (the alternative coupled interaction, as discussed in *Restricting by technological capabilities of the mobile device* on page 184). Feedback from users that could not scan the matrices indicated in some cases that they felt embarrassed and/or left out by having to interact with the map in this way alongside other users:

Q66: "I felt bad when I couldn't scan them – I think the others thought we were cheating" trial 3; interview

Q67: "You know it was like we didn't have to work so hard, but I suppose if the phone can't do it then it can't do it. We still felt a bit cheap to do it like that though in front of them" trial 4; group discussion

7.3 Key findings and reflections

Personalised trajectories lead to benefits for all but require a strategy for ownership

The discussions in this chapter have revolved around the concept of **ownership of trajectory**. In order to afford a sense of ownership in the context of the coupling paradigm three requirements must be met:

1. *Mechanisms for differentiation* exist such that the visitor may see evidence of their control over their trajectory in the differentiation amongst trajectories of all visitors,
2. Visitor *understands how to progress* through the environment and utilise those differentiation mechanisms, and
3. Visitor is able to *control the pace* of that progress.

The results of various trials led to the conclusion that the shift from a common, shared trajectory through an environment to *personal unique trajectories* leads to a greater engagement (as opposed to experience by proxy) and enjoyment of the experiences within the environment. A greater personal engagement in the experience and the space in which the experiences occur will be the overriding aim for both the visitor to the coupling environment and of the designer of the coupling environments (whether commercial educational and/or otherwise), thus knowledge of how personalised trajectories may be provided and how a sense of ownership of those trajectories may be afforded is a function of the framework presented in this thesis.

It is possible to summarise now how these three requirements may be met in the design of a coupling environment in order to

a) allow a visitor to gain a sense of ownership over *their personal trajectory* while constrained by narrative, and

b) enable a visitor to instil a greater sense of ownership in *other visitors*.

7.3.1 Differentiation mechanisms are a necessary design feature

Restriction and concealment both facilitate personalised trajectories but restriction is detrimental while concealment encourages exploration

Differentiation mechanisms have been presented: features of the system that allow visitors to shape their own trajectory and differentiate it from that of others. Mechanisms have been categorised as those that either *restrict* or *conceal* couples, relating to whether the conditions upon which they deny access are static or dynamic and hence whether they deny access to couples permanently or temporarily respectively.

As an alternative to restricting access, couples may adapt to heterogeneity of visitors

It was found that while restricting mechanisms enforce differentiation amongst visitors' trajectories, and appear to be a solution to the need to support heterogeneous mobile devices, they *limit* the possibilities for an individual's progress through a coupling environment, thus limiting the potential for experiencing the environment. It may be suggested that no couples should be denied to a particular visitor permanently based upon conditions that they can do nothing about (e.g. their mobile's capabilities); alternatives to creating a couple that simply cannot be experienced by a particular type of visitor, or by visitors with a particular type of mobile, are to create *alternative* coupled interactions at those couples to cater for those visitors, which may include bypassing non-essential steps in coupled interaction or adapting existing steps. Essentially **observations of the trials would not support advocating the use of restricting mechanisms, but would suggest that couples are designed to be adaptive to the heterogeneity of visitors and their devices**.

Concealing mechanisms add challenge to encourage visitor progression

Strictly speaking, concealing mechanisms do not enforce differentiation amongst visitors' trajectories as they do not permanently deny access to couples; instead they offer the visitors the chance to make varying choices and overcome the temporary barriers to accessing couples at varying paces, thus **allowing the visitors the chance to differentiate their trajectories**. Concealing mechanisms set goals for visitors that, when completed, reveal couples: the goals may require actions during exploration (e.g. taking a photograph to reveal access to the *Photowall* couple) or during coupled interactions (e.g. scanning a key matrix at the *World Map* to reveal access to the *Slideshow* couple). Observations have shown that concealment mechanisms are much more closely aligned with the goals of the coupling paradigm as they act to **encourage the visitors' personal engagement in and exploration of the environment, adding an element of challenge to the environment's narrative structure**.

7.3.2 The means of progression must be transparent

Making the causality and boundaries of differentiation mechanisms visible encourages personal progression and the open transfer of knowledge and observation between visitors

While it has previously been stated that concealing mechanisms add an “element of challenge” that is beneficial as it encourages progression, observations also raised a need for transparency within the coupling environment such that visitors can enjoy that challenge. Indeed the trials have shown that ‘challenge’ is not analogous to difficulty and that visitors will be encouraged to continue engaging with the environment by being posed many simple understandable challenges (as this provides variety) but will be discouraged by serendipitous or ambiguous barriers.

Ambiguity leads to protective behaviour that limits the progression of others

The thesis has discussed how hiding the goals for differentiation mechanisms can cause those mechanisms to form more permanent restrictions for visitors, and that **serendipitous *and* unexplained completion of those hidden goals is often unsatisfying**. Protective behaviour was observed amongst visitors when the goals are ambiguous as visitors who have completed those goals strive to retain that ‘upper-hand’. This type of behaviour may be distasteful to the environment designer as, like the restricting mechanisms limited an *individual’s* trajectory, **protection limits the trajectories (and hence engagement in the environment) of *others***.

It is important to emphasise that serendipity is not wholly unwelcome: serendipity within *understandable* mechanisms can *encourage* engagement (and in the case of the coupling environment, progression). An everyday illustration of this can be found in rich experiences of music using the shuffle feature of music-playing devices and online radio services, shown to be “inspirational and transformative” when the music played is left to chance (Leong et al., 2005), particularly when users do not have strong preferences over the nature of the experience (Leong et al., 2008). While not discussed in great detail in this chapter, the *Google Earth* couple allowed observation of these positive reactions to serendipity first-hand: here users would be played Last.fm’s current most popular track from different countries as the user ‘flew’ across the globe – unlike at the *Slideshow* where each adult or child had access to the same content respectively, it was quite possible that each user of the *Google Earth* couple would be played different songs as the content of Last.fm changed. Here users understood why their content was different from one another, and enjoyed the uniqueness and serendipity of their experiences.

In order to increase the transparency of differentiation mechanisms the designer must consider how visible their mechanisms' *causality* and *boundaries* are. Causality is the visitor's ability to define what actions complete a goal; a clear example during the trials of a lack of visible causality was the mechanism that concealed the *Photowall* couple: when the *Photowall* situated display had no features to identify that it was a part of the environment and taking a photograph gave no immediate feedback that it had revealed access to the *Photowall* users had little reason to suspect that they had either completed the goal or that there was even a goal to complete. By adding text to the situated display indicating that it was part of a potential couple and what the action to reveal it might be, as well as adding feedback on the mobile to indicate that the couple had been revealed when a photo was taken, the users then indicated that the mechanism was clear and there was a marked increase in engagement with that couple.

The boundaries of a mechanism are relevant when a mechanism's goal may not just be completed, but may be satisfied to *different extents*. In the case of the mechanism that concealed the *Slideshow*, *ART* and *Google Earth* couples, i.e. scanning the key data matrices at the *World Map*, scanning one data matrix 'completed' the goal and revealed the three dependant couples, but would only allow access to one part of the content available at those couples. Users needed to scan *all three* key matrices to access all the content, yet until the final trial there was no indication to the users that there were three key matrices – a fact that was difficult to ascertain themselves given that there were many more than three data matrices on the *World Map*. Frustration was observed over whether or not users had found as much content as they could – frustration relieved by feedback introduced in the final trial that indicated through the mobile client whether or not they had found all the key matrices upon decoupling from the *World Map*.

Transparency encourages users to share knowledge and thus aid each others' progression

In later trials when differentiation mechanisms were relatively more transparent, more-beneficial sharing behaviour was observed: as the goals to be completed became more trivial to understand defending knowledge of the mechanisms became less attractive and instead users tended to try to gain the status of 'experts' by *transferring* knowledge to others. **The**

designer might wish to encourage this form of behaviour as it increases social interactions amongst familiar visitors[50] and encourages the progression of other visitors' through the environment. While familiar and unfamiliar visitors would observe one another in order to understand differentiation mechanisms, familiar visitors would also discuss the mechanisms with one another. In either case observation would take place to learn the differentiation mechanisms, not to experience the coupled interactions by proxy. Although learning by observation is far from a novel phenomenon, especially with regards to technology (it is also referred to as "over the shoulder learning" (Twidale, 2005), emulation (Huang and Charman, 2005) and a range of other terms), the trials have shown that it is often a necessity for users in novel coupling environments, but that observation of ambiguous interactions may do more harm than good.

7.3.3 Orchestration must allow the visitor control over pace of exploration

Orchestration by the system should exercise direction when necessary, but tend to offer a greater degree of freedom to the visitor to shape their trajectory, while also offering the means to legitimise breaks in exploration of the environment

Over the course of the trials the users' responses to a range of orchestration approaches – from direction to selection – were observed. A major impact of the orchestration approaches on the users' broader experience was to increase or reduce the users' sense of control over the pace of their trajectory through the environment. Observations showed that there is no one orchestration approach that provides a suitable solution for managing visitor exploration but that there are several considerations that shape what approach should be employed in which situations.

Users may appreciate a greater level of control as they gain confidence

As discussed in the next chapter, visitors gain a sense of confidence in interacting within the environment as their trajectory progresses. **As the visitor's confidence grows, so does their desire for greater control over the pace of that progression, while during the initial stages of a visit the visitor desires reassurance which can be provided through more direct orchestra-**

[50] As discussed, it was not found that social interaction amongst unfamiliar visitors was increased – this may not be a dissatisfactory consequence given that it may be suggested that a significant portion of visitors would not want to initiate interactions with strangers and equally would not relish advances from strangers.

tion of their trajectory by the system. In practice this is reflected by offering no choice early on, and steadily adding degrees of responsibility: the trials revealed that users were reassured by immediate *direction* to the *Registration*, then being introduced to the concept of *search* by being prompted to initiate a search to find the *World Map* (but hiding the POIs that represent an overwhelming range of choice at that stage), then being allowed to search without limiting the results (i.e. showing all suitable couples and POIs). Employing *direction* once the users had carried out their own *search* and choice was perceived as hurrying the users through the environment. Discussing this gradual introduction in terms of narrative it is beneficial to suggest that **the first few experiences are linked in a linear narrative while branches (if not concealed) are only introduced after the visitor has had a chance to engage with a couple and has moved between two couples**.

Users need to legitimise resting when given control over the pace of their progression

Even though orchestration approaches such as *search* offer the visitor control over the pace of exploration the visitor can still be compelled to progress faster than they feel comfortable with: despite search being a pull-based technique, thus allowing users the opportunity to simply rest and not use the mobile client, users felt uncomfortable waiting too long without searching. **Users were found to have a need to 'legitimise' resting periods between couples**, i.e. to use the mobile for something, even if not for coupling – the introduction of POIs (points-of-interest that visitors could use the mobile client to guide themselves to) appeared to provide this legitimacy, allowing users to explore without needing to commit to a coupled experience. The trials show that **non-couple POIs are a beneficial design feature, not just to provide these filler experiences, but also to increase the visitors' familiarity with exploration via the mobile phone and indeed to enrich the visitors' experience of the environment**.

Chapter 8 - a second chapter relating observations - relates and discusses social interactions within the trials, the features that affect these interactions and the implications of these observations.

8. Coupled interaction

This chapter considers how the *configuration of a coupling environment* may contribute to reducing social awkwardness. In the previous chapter it was argued that encouraging social interactions amongst visitors at situated devices may well be an aim of the environment designer as this promotes progression through the environment. This chapter considers the observations of discussions, direction-giving and collaboration, presenting the design features of the couples that contributed to useful social interactions. It addresses the social dynamics of the visiting group as a consideration of the environment designer and presents implications (both positive and negative) for the visitor experience of groups sharing a single mobile device, relating to their need to share the experience of controlling and receiving feedback during their visit, and for establishing group identity.

In this chapter, as in chapter 7, the key elements from the trials are presented, in this case in terms of the overall environment configuration and the ways in which the visitors experience interaction as a social phenomenon. Each of the key sections in this chapter will refer back to the various studies where the elements discussed were observed.

8.1 Environment configuration and couple arrangement

8.1.1 Environment configuration

Key literature such as (Brignull and Rogers, 2003) and (Agamanolis, 2003) have previously identified encouraging a passer-by to become a participant as a key difficulty in the design of public display technologies. Embarrassment or social awkwardness is cited as the most significant barrier issue stopping *potential* users from becoming users. There are fundamental differences between the public technologies considered in such literature and the couples this thesis considers. The coupling environments of the sort created for the trials have *four key characteristics*:

1. **Narrative links act as progressive lures, driving a desire for further interactions:** links between the content of the experience at previous and subsequent couples encourage the visitor to progress from one coupling opportunity to the next.
2. **Progression through the environment is understandable but challenging:** when progression through the environment is understandable, i.e. the causality and boundaries of progression are clear, yet the possibilities for progression are still rich visitors are more inclined to continue seeking further progression.
3. **Multiple couples build confidence at couples:** over the course of a number of coupled interactions, visitors gain an understanding of the interaction between the mobile device and the situated devices and learn what to expect, reducing apprehension over further coupled interactions.
4. **Staging of the coupled interaction of others develops a sense of solidarity amongst visitors:** by observing others engaging in coupled interaction a visitor may understand the interaction and gain a sense that their own coupled interaction is more conventional.

In the trial environments social awkwardness was visible at the *Registration* coupling opportunity. A number of users were observed tentatively engaging in the use of the *Registration*:

Q68: "I wasn't sure whether I was doing it how it should be – it seemed to work right but this is the first time I've done anything like it" trial 2; interview

Q69: "I sort of expected other people to watch me – I was doing some pretty weird things with the phone. I'm sure a I saw at least one of them lot [passers-by] gawking at me" trial 1; interview

Bearing the four characteristics of coupling environments in mind: at the *Registration* the users had yet to experience coupling or coupled interaction, or to witness other participants in the environment, while the participant was naturally the focus of attention for any bystanders or passers-by. Observations suggest that the awkwardness arising from a lack of experience and lack of a sense of solidarity was magnified by the exposure of the coupled interaction to non-participants.

In contrast the *Slideshow* and *Google Earth* couples represented much more exposed stages for coupled interaction yet less awkwardness was observed, as described in more detail in later in this chapter: this points to the four characteristics of the coupling environment configurations listed previously as vital in removing the social awkwardness associated with interaction with public technologies.

8.1.2 Arrangements of the Couple

Within the coupling environment couples were implemented with three distinct arrangements (see Figure 69 below), each provoking particular social behaviour.

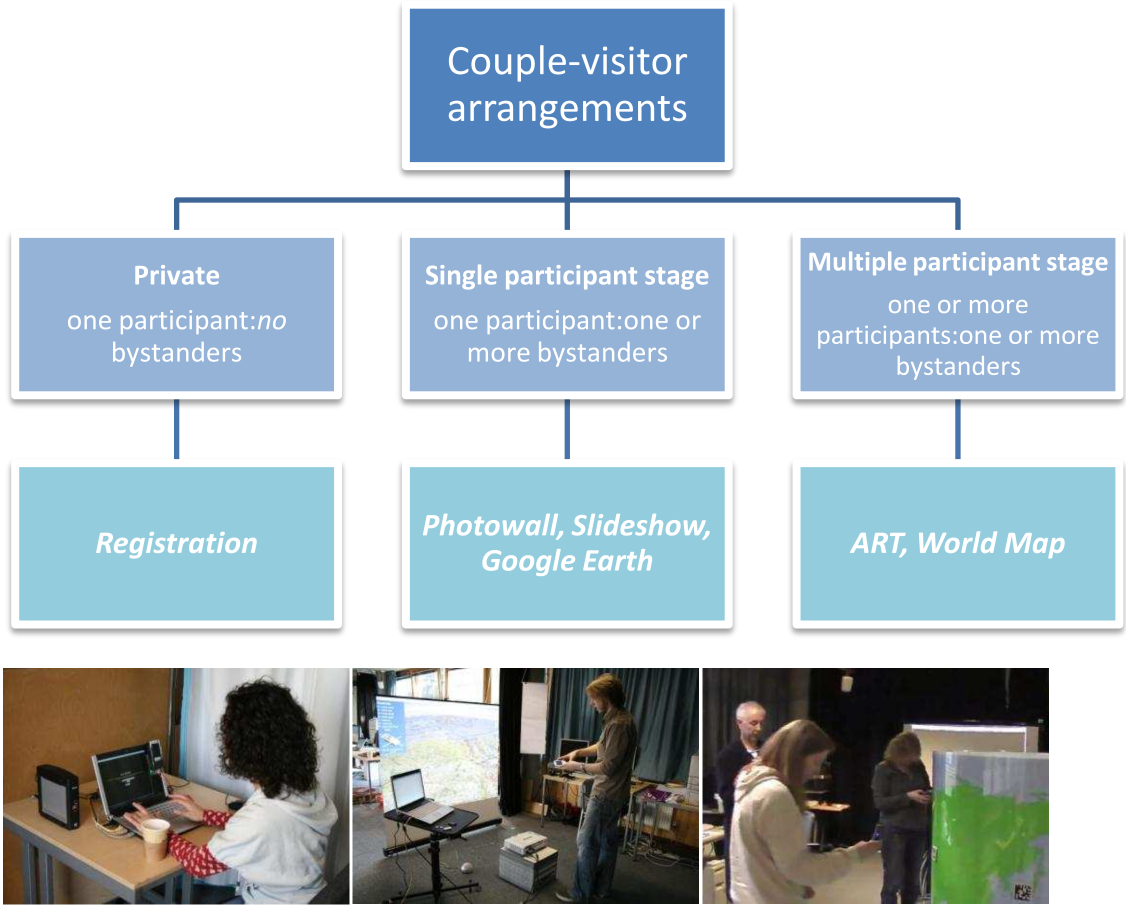


Figure 69 Different couple-visitor arrangements

i. Private couples

The *Registration* couple was designed with the aim of discouraging group use in order to provide the privacy to allow a visitor to enter personal details. Situated technologies were chosen that resulted in a coupled experience that was effective (by providing more comfortable means of input and feedback) at a scale (below body-size) that encourages a perception of personal use.

In the trials three key issues with this design approach were observed:

- *Perceptions of staging* - being publicly situated, even a form factor suited to personal use was perceived by users as being staged;
- *Impersonal input* - users often tended to provide invented personal data, or that of a caricature, and thus were unconcerned with privacy;

- *Visiting groups* - many participants experienced the couple as a member of a group, thus the couple also *needed* to support group experiences.

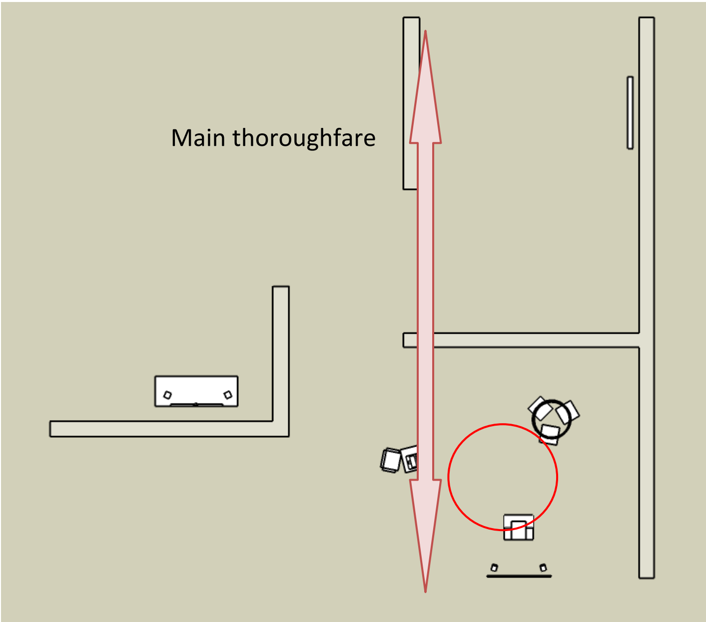
Perceptions of staging

Users in trials 1-4 were observed exhibiting feelings of exposure much more than those in trial 5 and would point towards the location of the *Registration* opportunity within the environment as a strong candidate for this change in perception rather than factors such as the scale or form of the couple. In addition to Q69 the following (from a different user) illustrates the issue of exposure particularly well:

> *Q70: "When I was registering lots of people kept walking past – I think some of them had phones too but I didn't want to look around too much. It was quite off-putting because I wasn't sure whether I was doing the right thing and obviously I was attracting some attention" trial 1; interview*

This user was not actually being actively observed by any other visitors or non-visitors, i.e. there were no bystanders, yet a number of non-visitors had walked past and glanced at the user. The possibility of being watched was a significant source of awkwardness for the user.

In trials 1-4 the *Registration* was positioned centrally, such that subsequent couples were clearly visible to reduce the difficulty of navigation (see Figure 70 (top) below); in trial 5 the *Registration* was positioned together with the *World Map* but physically and visibly separate from other couples (see Figure 70 (bottom)) and thoroughfares as these couples provided the users' introduction to the environment.



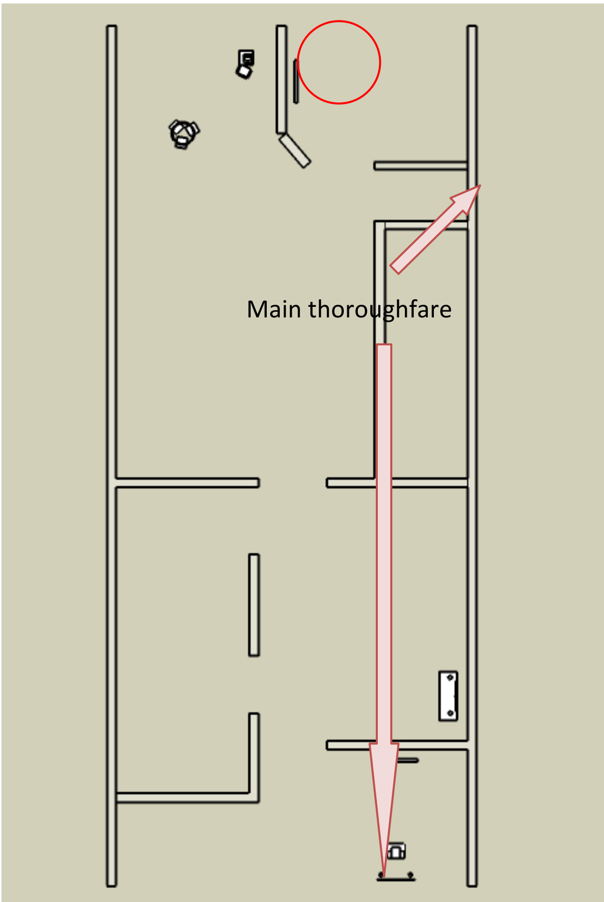


Figure 70 Various placements of the Registration coupling opportunity: trial 1-4 (top); trial 5 (bottom)

The isolation of the *World Map* and *Registration* offered users a chance to gain experience of the first coupling opportunity in a less visible situation, but also encouraged observation of the coupled interactions of concurrent visitors at the *World Map* from the *Registration,* raising an early sense of being a part of an larger ongoing group activity. With a high capacity for couples, the *World Map* also tended to have a high number of participants and a low number of bystanders (as bystanders most often accumulated while waiting for a chance to participate), thus to a new visitor at the *Registration*, most nearby visitors appeared to be engaged with their own coupled interactions (or navigating away to other remote couples) rather than waiting and observing. Quotes 71-73 below from trial 5 give a sense of this:

> *Q71: (in response to apparent rush to leave the* Registration*): "It seemed quite busy at the [*World Map*] – people looked like they were having fun there – that's why I was rushing a bit at the* Registration*!" trial 5; interview*

> *Q72: "I liked how the first two [couples] were set apart from the rest – like an introduction. I felt a bit scared of the technology to begin with so I liked that I knew I wasn't out in the firing line straight away" trial 5; interview*

> *Q73: "I could watch the others at the [*World Map*] while I was [at the* Registration*] – I actually did it really slowly so that I could learn what to do next" trial 5; interview*

Impersonal input

The intention of the *Registration* was that subsequent couples could adapt their interactions to each visitor, based upon assumptions about their interests related to their age. The integrity of this aim rests upon the further assumption that visitors will be truthful about their age; it then follows that visitors would be more comfortable entering personal information, such as their age, in private.

The majority of names entered during the coupled interactions at the *Registration were* truthful, yet the profile of *ages* entered at the couple[51] are different from those given through the post-experience questionnaire. A selection of users from later trials was asked whether they had qualms about entering their real personal information during registration, and two reasons emerged:

[51] the ages used to build the comparative illustration are those entered during each visitor's *first* visit to the *Registration* coupling opportunity; any return visits are ignored

- As stated in the previous chapter, some users enjoyed making an *alter ego*, thus entering an imaginary age (and often also name) that would typically be either extremely high or low; while
- other users pointed to the *perception of staging* at the *Registration* as a reason for their untruthfulness.

The first reason would suggest that measures to provide privacy are unnecessary. The latter points to a need to either afford privacy to a much higher degree (i.e. by situating the coupling opportunity in a private location), or alter the interactions to explicitly encourage the visitors to create an alter ego, rather than a truthful personal profile.

5 of the users suggested that they would have been more likely to give truthful information had they been made more clearly aware of the implications of their choices. These users were all participants in earlier trials (trials 1-3); having received this feedback, additional information was added to the situated display during the *Registration* coupled interactions, informing the visitor that the information that they had entered would be used to adapt later experiences to be more suited to them. This did not appear to significantly affect the truthfulness of the users. It may be best in public coupling environments to allow visitors to create alter egos and provide a means for visitors to *change* their alter egos during their experience (as discussed in *Dynamic visitor profiles* on page 189) once the aspects of the coupled interactions that are adapted based upon those alter egos become clear to the visitors.

Visiting groups

An oversight during the conception and implementation of the *Registration* coupling opportunity was the support for visiting groups. The coupling opportunity was clearly designed for one participant, to the extent that it prompts for one name, one age and one photograph. As previously discussed, the visiting groups during trials often found their own ways to reappropriate the design of the couple, entering group names, group ages and producing group photos (see Figure 57 on page 188); of course given that these processes were not implemented to support these behaviours some groups were confused over how to behave.

Given that a sizeable proportion - if not a majority of visitors - would be expected to visit as part of a group rather than as an individual hindsight would suggest that couples, even 'private' couples - unless designed for a very specific effect - should always be conceived as supporting a group first and individuals second.

ii. Single participant staging couples

Like the *Registration* coupling opportunity, the *Slideshow* and *Google Earth* couples had capacities for only one participant concurrently, but unlike the *Registration* these couples stage the participant's coupled interaction to bystanders.

Both the *Slideshow* and *Google Earth* couples attracted bystanders who were waiting for a turn to couple or who simply observed. Both couples utilised the same technologies, however the technologies are arranged differently: in the case of the *Slideshow* bystanders were separated from the participant by the participant's chair (leading to a *passive* audience of bystanders), while at the *Google Earth* couple there was no such barrier (leading to an *active* audience).

Passive bystanders

At the *Slideshow* the participant was prompted by their mobile client to sit in a large solid wing-back chair from where they controlled the interaction with the body-size situated display using their mobile phone like a TV remote control (see Figure 71 (right) below).

Figure 71 Audience-conductor enforced by physical layout of the Slideshow

While the chair was originally chosen to enhance the 'watching TV' metaphor for the coupled interaction at the *Slideshow*, it had a more significant effect upon the social dynamics between the bystanders and participant, appearing to enforce the separation of the participant as controller or *conductor* of the coupled interaction and the bystanders as the *audience*. This separation was clearly observed in both the activity of users and in their inhabitation of the space at the couple, where bystanders never stepped within the boundary of the interaction space as delineated by the participant's chair (see Figure 72 below).

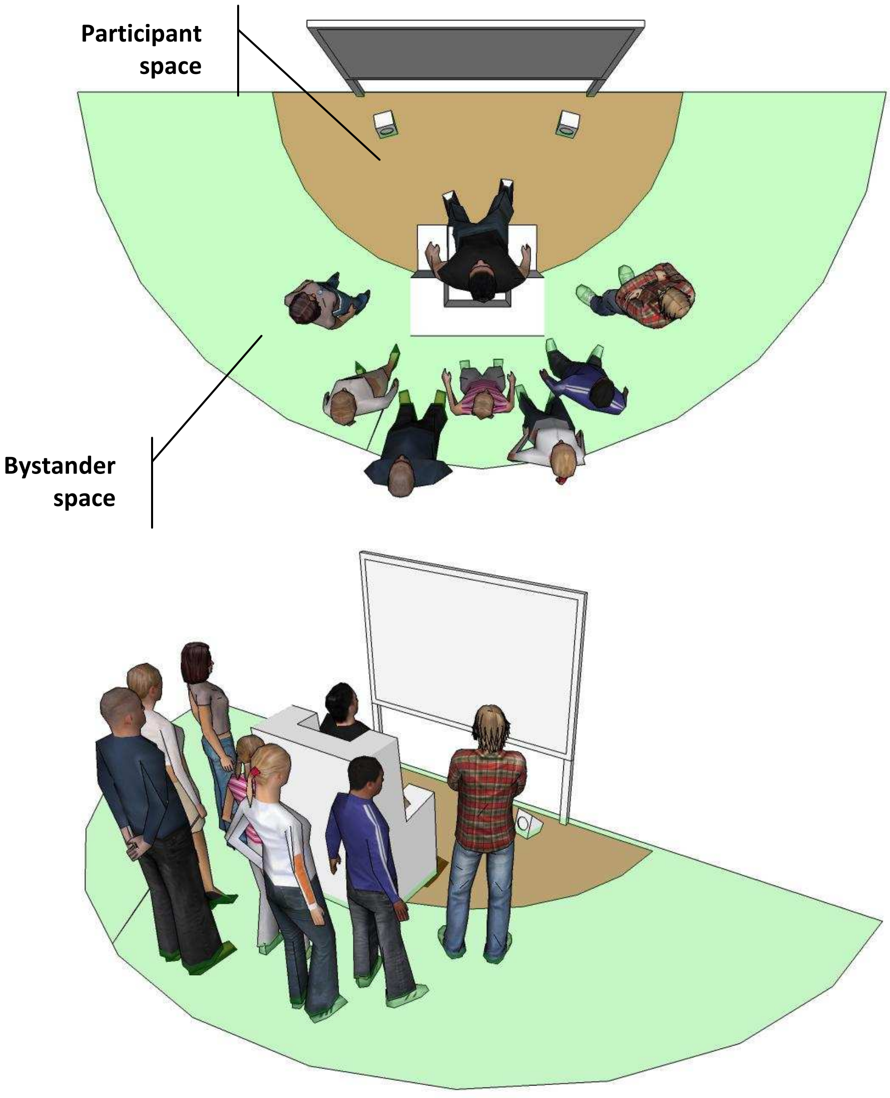


Figure 72 Chair at Slideshow separating bystanders and participants

Comments from the bystanders indicated a perceived role of the chair as both barrier (Q74:) and gathering point (Q75:):

Q74: "You just naturally stand behind that chair – I would've felt out of place if I went and stood next to it" trial 2; interview

Q75: "It was a like a bar – we all went and stood there, leaning on it and watching what was going on. It was a place to catch your breath" trial 3; group discussion

Bystanders at the *Slideshow* would typically either observe or comment on the content of the *Slideshow,* depending on their familiarity with the participant or the other bystanders. A bystander unfamiliar with either would typically only observe, while a bystander familiar with the participant or other bystanders would offer comments or begin discussions with the participant or other bystanders respectively.

Many users would assume the role of conductor with comfort; in this role the visitor would naturally be expected to experience an increasing sense of awkwardness as the number of bystanders increased. To explain this, the discussion may be turned again to the conductor's chair as a barrier. From the participant's perspective the chair formed a very tangible barrier, rendering it difficult for them to see the audience unless they turned in the chair. The participant could of course hear the bystanders' voices but there resulted relatively little social interaction between participant and bystanders.

Q76: "From the seat you felt that everyone else was talking amongst themselves – it's all kind of background murmuring after a while. I remember one of them [a by-stander] really shouting at one point to get my attention" trial 3; group discussion

Q77: "I was actually ignoring some of the discussion going on back there. I was listen-ing and I could tell that they wanted me to speed up a bit – I think they wanted a go – but I just pretended like I wasn't [listening]" trial 3; interview

The only significant exception to this was observed within a family group where the conductor (a parent) explicitly requested direction from the other family group members having taken over control from one of the children. This behaviour was of course well-supported – the bystanders could see the situated display in order to give directions – but simply was not encouraged at the *Slideshow*.

Active bystanders

The participant's chair at the *Slideshow* bestowed a socially-elevated status to the participant, but there was no such segregation of participant and bystander at the *Google Earth* couple. The photographs in Figure 73 below shows a participant and bystander during trial 5. Unlike at the *Slideshow*, bystanders would often walk up to the projected display and observe the display and participant, on several occasions obstructing the view of the participant. The users exhibited none of the clearly defined conductor-audience separation.

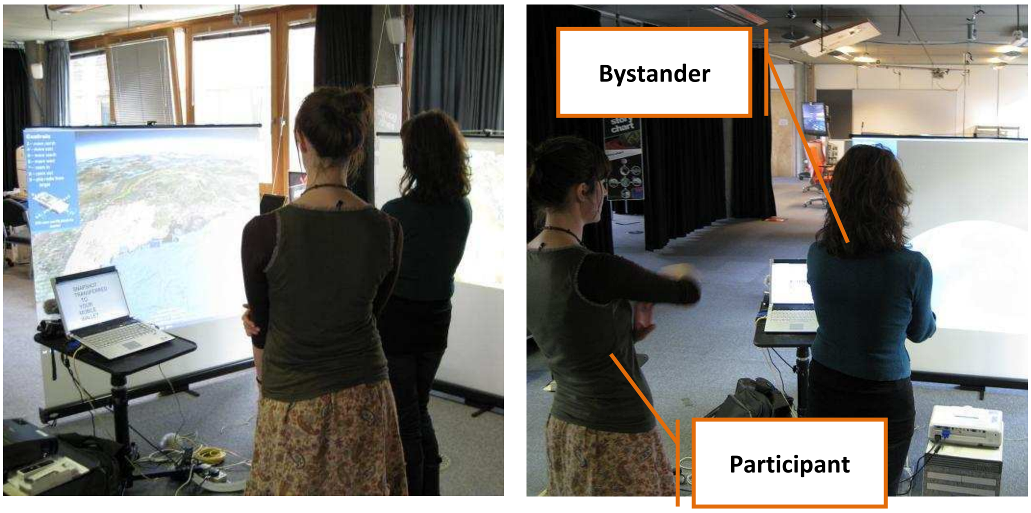


Figure 73 Bystander standing between the participant and the situated display

As at the *Slideshow* the coupled interaction of the participant made them conspicuous; in the case of *Google Earth* the exposure (at least in the case of those utilising the Nokia N95s) was through the physical nature of the coupled interaction, tilting and rolling the mobile phone to control the situated display. In the majority of cases the participant's motions were exaggerated – some walking or skipping energetically around the interaction space to control the display. The coupled interactions thus clearly differentiated them from the bystanders yet the bystanders did not show the same degree of deference towards the participant as they did at the *Slideshow*. It has already been stated that bystanders rarely attempted to direct the pace or direction of the coupled interaction at the *Slideshow*, especially when unfamiliar with the participant, yet at the *Google Earth* couple this was relatively common behaviour. Figure 74 below shows a bystander directing the participant to investigate the parts of the globe that she (the bystander) found interesting. In this case the participant and bystander were familiar with one another, yet also observed were bystanders unfamiliar to the participant intervening in order to point the participant towards particular points-of-interest or to make a comment – behaviour that never occurred at the *Slideshow*.

Figure 74 Bystander directing the participant's coupled interaction

No ill-feeling was observed on the part of the participant as a result of bystander intervention. In contrast the interventions were often a welcome addition to the experience as bystanders would share information – stories, experiences or opinions - about the locations being viewed on the situated display. The *Google Earth* coupling opportunity appeared to be a particularly suitable platform for encouraging this type of group behaviour as – by itself – the Google Earth visualisation provides very little engaging content (beyond a view of the landscape[52]), instead offering a geographical frame of reference for the discussion of the participant's and bystanders' personal knowledge. The following episode occurred during trial 5 while two bystanders observed a participant interacting with the *Google Earth* couple.

Episode 4

Bystander 1 is familiar with the participant, while bystander 2 is a stranger to both. Bystanders 1 and 2 arrived almost simultaneously a couple of minutes after the participant had coupled her device to the *Google Earth* situated display.

[52] The participants had no means of accessing the interactive content that may be overlaid on the landscape via the Google Earth desktop application.

Q78:

Participant: “Look this is really good; I haven't used Google Earth before – I didn't know it was like this”

Bystander 1: “What are you looking at? Is that England?”

Participant: “Yeah”

Bystander 1: “I thought so – it looks like London”

Participant: “How did you guess that? It's just [a suburb of London] – I'm trying to find my house”

Bystander 1: “Have you found the right road?”

Participant: “No, it's difficult – it all looks different from up here (referring to the bird's-eye view of the Google Earth visualisation)”

Bystander 1: “It's near to [a London rail station], right? So over there …”

Bystander 1 walks up to the situated display and points to the station.

Participant: “That's what I thought, but I didn't recognise the roads”

Participant manipulates the visualisation, moving the POV over the station pointed to by bystander 1.

Bystander 1: “You must recognise that big roundabout? It's huge”

Participant: “Not really. There's a big Tesco's around here somewhere”

Bystander 2: “I know which one you mean – I actually used to walk to that station”

Participant: “Oh really? Do you live near to it?”

Bystander 2: “No – I used to work at [a company]”

Participant: “Oh that's close!”

Bystander 2: “I don't know that roundabout either but there was a park ...”

Bystander 2 also walks over to the display and motions westward. The participant moves the POV to the west.

Bystander 2: “Maybe go a bit faster – I think I walked quite a long way to get to the station from the park”

Participant: “I have to zoom out”

Bystander 2: “Wait – there it is I think; zoom back in”

Participant: “Oh I know this one – it's not too far away. My brother used to go with his friends there. It isn't a nice park”

Bystander 2: “Yeah it's not the sort of place you'd go of a Sunday for a stroll”

Bystander 1: “Maybe I should leave you two to reminisce ...”

Participant: “It's just a bit weird, you know – a six degrees of separation moment!”

Bystander 2: "Yeah, it all seems a bit more compact looking at it like this – I was sure I'd walked much further. Go that way (indicates north) and you can see my old work"
trial 5; observation

The episode illustrates well a typical group interaction at the *Google Earth* couple where the role of conductor is *transient*, being transferred between bystanders and participant[53], and where users created their own group experience by relating (and staging) their own personal experiences using the Google Earth visualisation as a means of providing a shared frame of reference.

While most participants (even those unfamiliar with the bystanders) appeared comfortable interacting with the couple, there were noticeably more participants at the *Google Earth* coupling opportunity that appeared apprehensive in comparison to the *Slideshow*. Indeed, two participants were witnessed in trial 5 ending their coupled interaction very quickly once more overbearing bystanders arrived, deferring to these bystanders by freeing the coupling opportunity for a bystander to take over. While reasons have already been suggested for this, i.e. the lack of a clearly defined separation between interaction spaces, resulting in a lack of authority and increased exposure of the participant, user feedback also hinted at this perceived exposure:

*Q79: "I was enjoying playing with the [*Google Earth *couple] until too many other people turned up; I felt a bit silly just aimlessly exploring in front of them" trial 5; interview*

Q80: "I didn't mind the other two watching what I was doing [at the Google Earth *coupling opportunity] – they seemed as interested as I was but then when they start arguing over what to look at next I just didn't want to be in the middle any more" trial 5; interview*

Momentary coupling

As yet undiscussed in this section is the *Photowall* 'couple', which also had a defined capacity of one visitor. On reflection it is difficult to refer to the *Photowall* as a couple as a visitor's mobile is coupled with the situated display only long enough for any new photographs to be automatically transferred to the display and the user plays no part in this, hence there is no coupled interaction. Instead, the *Photowall* is a useful case for a comparison of couples with

[53] Transience is also seen within visiting groups, as discussed later in section 8.2.1.

less interactive public technologies. At the couples in the trials social behaviour emerged around and alongside the ongoing coupled interaction; at the *Photowall* there was no ongoing coupled interaction to feed this social interaction, only the remnants of previous coupled interactions in the form of photographs left on the *Photowall* display, as captured in Figure 75 below.

Figure 75 Bystanders observing a photograph left by a previous participant on the *Photowall* situated display

When there is no ongoing coupled interaction for bystanders to observe there is no clear indication that the situated device is a part of the coupling environment. There is also no spectacle to retain the attention of the bystander for any length of time: observation would suggest that often the social interaction between users at a coupling opportunity and observation of the 'performance' of the participant was in fact *more* interesting to the bystanders than the content of the couple. This was emphasised at the *Photowall* where bystanders that did view the photos tended to do so very briefly and would comment that the number of photos was relatively small and were often ambiguous or uninteresting.

The *Photowall* also failed to encourage either purposeful or repeat visits by participants that may have driven social interaction. Since coupled interaction at the *Photowall* could reveal no further branches of the narrative, and the content being added by other visitors (although frequently renewed) was not compelling, a number of users suggested that there was no reason to return to use or observe the *Photowall*.

When questioned about changes to the *Photowall* that might have attracted them to return again, users most frequently suggested that they should have been able to interact with the situated display, not just to add new photographs, but also to navigate back through the older photographs that, in the test-bed implementation, were simply lost. This suggestion would appear to be a sound one as it would afford coupled interaction, providing the attractive 'spectacle' evident at couples.

iii. Multiple participant staging couples

The *World Map* and *ART* couples both accommodate multiple simultaneous participants, while also staging their coupled interaction to bystanders and passers-by. Variations between the behaviour at these two multiple participant couples were observed due to the difference in the way the participants receive feedback: at the *ART* couple the users receive feedback from the single situated display (*sharing* the feedback), while at the *World Map* the feedback is delivered through the users' mobiles (providing *personal* feedback).

Shared feedback

The interaction space at the *ART* couple is small, forcing multiple participants to interact side-by-side and the feedback from the interaction is delivered through the situated device such that users share one another's feedback. The capacity of the coupling opportunity was limited to 3 in order to avoid overcrowding of the space.

In earlier trials there was no intention to design the couple to provide benefits to the participants for cooperating; however since the interaction space was intimate there was an almost ubiquitous conversation amongst participants at the *ART* couple in order to discuss both the virtual objects exposed through their coupled interactions, and the interaction itself. The episode below illustrates this collaborative behaviour at the *ART* couple in earlier trials:

Q81:

Participant 1 (having watched participant 2 holding their mobile very still within the interaction space): "You know you can move it around … tilt it like this"
Participant 1 demonstrates how to tilt the mobile to tilt the virtual object.
Participant 2: "Ah OK I didn't really get the instructions – that's nice. Oh wait it disappeared … no I just tilted too far I think"
Participant 1: "What countries do you have on your one?"
Participant 2: "What countries?"

Participant 1: "Yes – if you look at your phone it tells you what countries you have"

Participant 2: "Oh right. I really didn't read the instructions did I? Are these the ones I found back there [at the World Map]?"

Participant 1: "I think so. You have more than me – I don't have Kenya"

Participant 2: "At least I did something right!"

Trial 3; observation

In later trials (4-5) the extended functionality of the ARTECT software was used to more explicitly encourage collaboration between the participants. Via ARTECT it is possible to afford additional feedback when participants move the markers displayed on their mobiles close together, e.g. when two participants place their mobiles close together a web-page is displayed on a second situated display showing a clue regarding the narrative of the coupling environment (see Figure 76, Figure 77 and Figure 78 below).

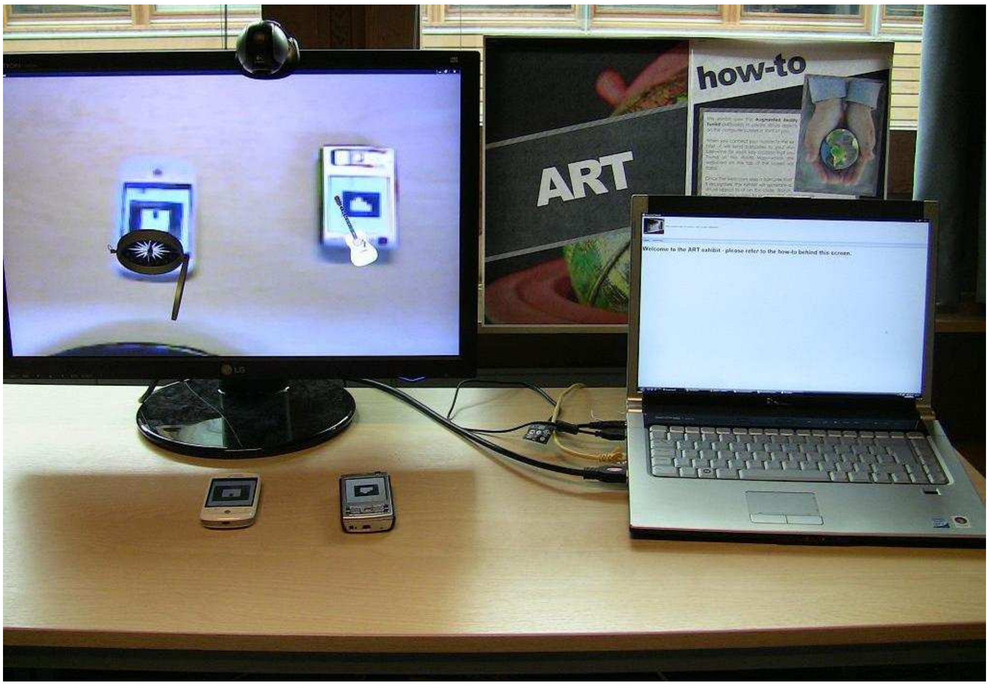


Figure 76 Two mobiles placed separate from one another within the ART interaction space

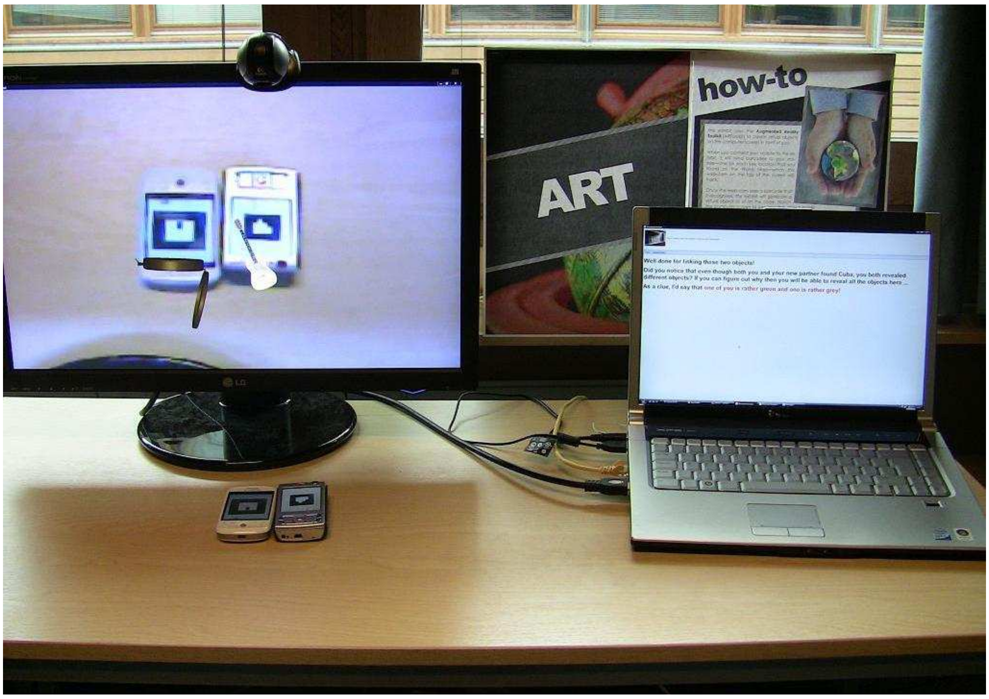


Figure 77 The two mobiles placed close to one another

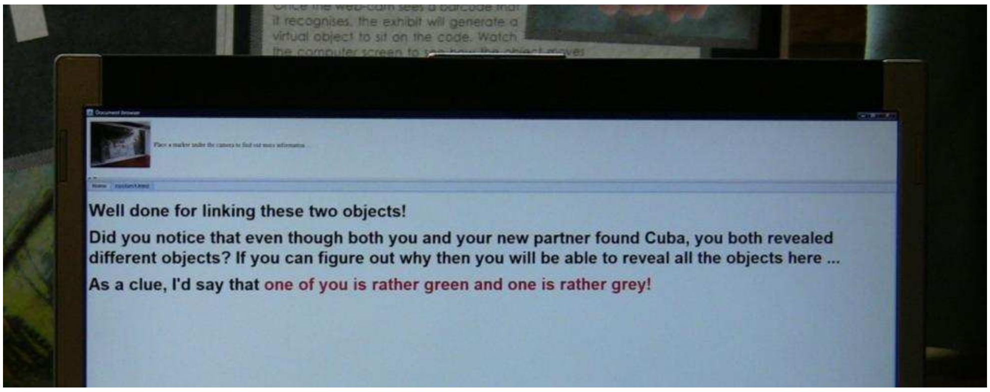


Figure 78 Resulting clue displayed on the second situated display

In trial 4, this mechanism was left unexplained with the hope that users would discover it for themselves. Having observed earlier instances of users bringing their mobiles together within the interaction space it was determined that this serendipitous discovery would occur frequently enough. This confidence in the benefit of serendipitous discovery was misplaced, as had been the case with *World Map* data matrices and *Photowall* concealing mechanisms, discussed in *Visibility and accountability* on page 205.

To combat this, similar efforts were made to make the mechanism clear. In fact during trial 5 on three occasions participants delayed their decoupling in order to wait for other users to couple so that they could collaborate to reveal the content concealed to them as an individual participant. A significant impact of this collaborative mechanism is the encouragement of social and coupled interaction between *unfamiliar* users in contrast to the *Slideshow* and *Google Earth* couples which did not appear to dramatically increase social interaction between unfamiliar users. Two pairs of users were questioned who engaged in collaborative behaviour at the *ART* coupling opportunity despite being unfamiliar with one another, in order to ask them to describe their collaboration:

> *Q82: "Someone stepped up later than me and looked a bit confused even though I was working it like a pro – I felt sorry for them because I'd just spent a few minutes working it out myself so I let them in on how to do it" trial 5; interview*

> *Q83: "It was nice to have another person doing the same thing right next-door – really reassuring" trial 4; group discussion*

Building lasting collaborative relationships

One of the collaborative relationships was witnessed extending beyond the *ART* coupling opportunity; in this case the participants went on to decouple simultaneously and continue as a pair, returning to the *World Map* and working together to find and scan the key data matrices that each had yet to find. In fact this pair realised that, by collaborating at the *World Map*, they could then return to the *ART* couple as a ready-made pair and reveal all the possible additional content at that coupling opportunity without having to find a new partner.

It might not be beneficial to further intervene with design measures to encourage the building of these long-term collaborative relationships, particularly with measures that *require* individual visitors to form and maintain such relationships beyond a single coupling opportunity, simply because the maintenance of the relationship may become tiring and contrived. By observing the sole unfamiliar pair that did maintain their relationship it was found that the two users were well-matched in their pace of coupled interaction and exploration, and in their interests, and thus the social relationship was as strong as the common desire to reveal more coupled interactions. The users were also candid when it was clear that they had revealed all the hidden clues at the *ART* coupling opportunity and that they wished to continue to explore the environment individually – when interviewing the pair separately after the session, they verbalised the concern:

*Q84: "I was glad that he didn't make it awkward because it was obvious that we didn't need to go back to the [*World Map*] again but I felt a tiny bit obliged to follow him. We had fun but I wanted to try some stuff by myself so it was good that we could just say bye and go our separate ways" trial 5; interview*

Q85: "It was a little bit weird – like at the end of a first date, you know – where you weren't sure exactly whether you should just leave or make an effort to keep the conversation going. I think we were both happy to end it there though. We still chatted a bit when we walked past each other!" trial 5; interview

Collaborative goals at couples that form part of a narrative allow long-term relationships to be formed between visitors in order to more effectively reveal hidden coupled interactions, but it is important to explore whether enforcing the building of such relationships may lead to relationships that feel contrived or that visitors feel an obligation to uphold beyond the point where their benefit has been exhausted.

Personal feedback

In contrast to *ART* the *World Map* couple provided private feedback via the visitor's mobile device – visitors shared a common physical interaction space yet only the visitors' control (input) interactions were directly exposed to one another, i.e. users could observe one another scanning particular data matrices, but could not see the results. Unlike at the *Slideshow*, *Google Earth* and *ART* couples where both the user input and couple feedback were staged for other participants and bystanders, only the participant's input was staged at the *World Map*.

In the cases where participants were individuals (i.e. not a part of a visiting group) this led to a *lack* of collaborative behaviour – users were focussed upon their own coupled interaction and were concerned with other users only to determine which matrices they could scan without interference. Social interaction almost always occurred within visiting groups. Through post-session interviews evidence of the benefits to the users of feeling part of a common activity was observed:

*Q86: "It was ... relaxing, I think is the best way to describe it, to see a few other people doing it [interacting with the *World Map*] at the same time – you felt you were doing the right thing, especially when others had a problem with some of the [data matrices]" trial 4; interview*

*Q87: "Funny how quiet it was at the [*World Map*] right? You could hear everyone laughing at the other stations but at this one everyone was concentrating quite hard and it was we were like the hard-working students … or factory workers" trial 5; interview*

Observation between participants did occur, but it was opportunistic in manner, happening when one participant staged their personal feedback by vocalising it. This was most commonplace when there were visiting groups interacting with the *World Map* – since the feedback was delivered via the mobile device it was difficult for members of a visiting group beyond the participant to read the facts displayed, thus the participant most often shared the facts by reading them out aloud (alternatively, but more rarely, the participant would pass the mobile around the group). Several participants were observed over the course of the trials listening in to other participants as they did so; this was most evident in trials 2 and 5 where there were mixtures of unrelated visiting groups and individuals. This might not be considered collaboration, but similar behaviour was observed amongst participants with social connections who on a number of occasions – particularly during trials 3 and 4 – would actively read out the feedback to one another.

It may be argued that both the *World Map* and *ART* offer useful examples of very different methods for providing *personal* control and feedback while in interaction spaces that allow *collaboration*. *ART* appears to encourage collaboration more explicitly so than the *World Map*, by placing personal feedback in a shared output channel, but users have been seen achieving the same end result at the *World Map* by staging their personal feedback for others. The visitor-couple arrangement of the *World Map* is significantly more scalable with regards to the capacity of couples that could be supported, acceptably, concurrently. At its peak, the *World Map* was observed in use by 5 participants simultaneously (during trials 3 and 5), with additional bystanders. There were no conflicts or interference amongst this number of participants and bystanders, the large interaction space and nature of the coupled interactions allowing participants to almost subconsciously manage themselves in order to utilise the space without conflict. Indeed it is a particular characteristic of the coupled interaction at the *World Map* – that control and feedback are asynchronous, allowing a visitor to scan a matrix, then step back from the couple to view the feedback – that affords participants this opportunity, whereas participants within the interaction space at *ART* felt (even though not technically the case) that they must maintain their position in that space until they wish to decouple. As such the interaction space at *ART* is much less fluid, and the coupled interaction more intense – described by one user, who experienced *ART* alongside one other participant and 3 bystanders, as “hectic” - in comparison to that of the *World Map*, that has been described as “relaxing”.

Providing aid

Interestingly, the only examples of participants engaging in coupled interactions with one another's mobile devices on their behalf were observed at the *World Map*. This form of collaboration was entirely unplanned and emerged due to previously raised issues with the scanning mechanism and the staging of the resulting interactional difficulties. In a small number of cases (once in trial 2, twice in trial 3, twice in trial 4) one participant scanning data matrices in the stead of another participant who had requested assistance was observed. When questioned, the participant who was aided consistently stated that they had observed the other participant being more successful than themselves. Consider the following quote:

> *Q88: “He was just better at it than me wasn't he? I was just wasting time and he was running around getting all of them. Seemed like a waste of time me doing it even though it was a bit embarrassing asking for help” trial 3; interview*

Such collaboration did in some cases cause a degree of embarrassment, where asking for aid appeared to be a last resort in order to progress. Of course in real public environments there are often additional social support structures in place: museums, galleries and shopping centres all have staff simply to be ready-at-hand to aid visitors, while other types of environment will have an information point or help-desk where such help can be more actively sought. It might be argued that support from an authorised ‘help-giver’ or expert (who might be expected to know more than the user) is less socially embarrassing than receiving help from another user, yet observation of another event run during the same period that the trials were being run[54] led us to believe that this might be even more embarrassing, as the help-givers were obvious to bystanders, thus the act of being given help was also obvious to all. During the event the approach was altered and the helpers were asked to wander the site, acting like visitors, offering to ‘chip-in’ if necessary as though they were another visitor who had just recently used the couple. While some users were still clearly ill-at-ease with accepting help while using the couple, there was a markedly-improved reaction to help given (as if) by another user in comparison to a designated helper.

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[54] *Rivers Baghdad*, described in section 9.3.4ii, where staff were employed to be ready to help users understand and interact with a couple similar to the *Google Earth* couple

Introduction of the 'three strikes' feature (whereby a visitor continually failing to scan tags is offered an alternative means of controlling the interaction), was an attempt to remove the need to ask other participants for help, yet as related in *Revealing issues with mechanisms through staging of coupled interaction* on page 209 the differences between this alternative form of control and the scanning of the data matrices also publicly revealed that those users were having difficulties, causing an equally significant sense of embarrassment. While coupled interaction at other couples may have been as difficult, if not more difficult and novel as at the *World Map*, all coupled interactions could (particularly by the final trial when instructions had become much less ambiguous) be quickly learnt; at the *World Map*, regardless of how well the users understood the input mechanism, their actual success depended (to the users, apparently arbitrarily) upon the success of their mobile's camera. A concession may therefore be made that the coupled interaction at the *World Map* suffered not due to a lack of a suitable 'alternative' interaction technique for some visitors, but because the conceptually-sound primary interaction technique was poorly implemented across users' devices (and across different moments in the use of the same device).

The important lesson here (repeating that of the previous chapter) is that if a coupling opportunity stages coupled interaction then variances between visitors' interaction must stand up to comparison by the visitors, by being consistent and understandable. If it is not clear to a visitor why they cannot successfully interact with a couple even though they appear to be acting in the same manner as another successful visitor, exacerbated by these disparities being publicly exposed, the visitor will become dissatisfied. In the absence of a design that is perfectly understandable and usable by all, the solution is clearly more complex than simply choosing to allow participants to help one another, offering support structures (e.g. in the form of staff), or developing a range of different interaction techniques: during the *Rivers Baghdad* event it was found that while the majority of visitors appeared to prefer not to be helped by a designated ‘helper’, older users (who are potentially more familiar with such support structures) did not react badly to such intervention. Of course this may also vary across cultures or genders, and thus how to best provide this support remains an open question.

8.2 Intra-group roles during coupled interaction

Thus far occasion references have been made to visiting groups, but these have not focussed in detail upon how the coupling paradigm and the configuration of the coupling environment and couples impact upon the social dynamics of the visiting group. Visiting groups during the trials consisted of family groups, groups of friends and groups of peers with looser social connections (the museum professionals). In each case when a reference is made to a visiting group this refers to multiple visitors sharing a mobile device.

This relatively brief section looks at control and the consumption of feedback as *transient* or *shared* roles evident in the visiting groups, illustrating characteristic intra-group interaction.

8.2.1 Transient control

Control of coupled interaction and the consumption of feedback during coupled interaction are the main concerns of visitors while coupled. An individual visitor has responsibility for the control and consumption of feedback from their own coupled interaction, yet this is not the case within a visiting group. In every couple the single mobile device is the means of controlling the coupled interaction thus individual responsibility for control is placed upon one member of the group.

The responsibility for control within visiting groups was rarely given to one particular member of a visiting group for the entire duration of the group's visit, but would more often than not be transferred between members of the group, i.e. this role was *transient*. There did not appear to be an order to the transfer of control amongst groups – in almost all cases the participant would pass over control to a different group member after one coupling experience – interviews with groups suggested that the cycle of coupled interaction and exploration leant itself naturally to such turn-taking behaviour. In some cases this turn-taking took place *during* the coupled interaction, e.g. several groups were observed passing the mobile device between members while the mobile was coupled with the *World Map* – interestingly this was less often the case at both the *Slideshow* and *ART*. In the first case, group members not in the role of participant appeared to feel equally restrained by the presence of the 'conductor's chair' (as discussed in *Single participant staging couples*), despite being a part of the participant's visiting group. In the latter case a number of users made statements (such as that below) suggesting that they felt that they could not remove the mobile from the *ART* interaction space (i.e. within the view of the web-cam) to hand it over to another group member for fear of ending the coupled interaction.

> *Q89: "I wanted to pass it over to [another group member] but we were scared that it would break it; the object disappeared when I took it too far away – it felt a bit delicate so we decided that I would keep hold of it" group discussion; trial 3*

Of course this was not the case, but the synchronous nature of the control and feedback at the *ART* couple suggested a need to continuously control the interaction.

i. Bystander control

There was one exception to the informal sharing of control amongst group members which occurred in one of the family groups in trial 2. Within this group the parents rarely took a directly controlling role but strictly enforced an equal sharing of the control between the two children, again agreeing on a turn-taking system whereby control was switched after each decoupling. A parent took control on only two occasions: in one case to put an end to an argument between the children over who should take control (i.e. to reinforce the turn-taking), and in another to demonstrate to the children how to interact with a couple, i.e. to act as an expert within the group.

Through the fleeting mention of this observation an allusion is made to a concern of a portion of the museum professionals: potential conflict over control within groups. The mention is brief here because, despite this concern, only this one episode of conflict was observed which was mediated swiftly and successfully by the parents. The concern was founded upon the potentially elevated status bestowed upon the member of the group using the mobile device; in reality the only instance of conflict – that observed between the children in the family group – occurred at the *Slideshow*, where the children fought, not necessarily over control of the mobile device, but evidently over who should *sit in the conductor's chair* and control the mobile device. The *Slideshow* is the key example within the trial environment of a visitor-couple arrangement that segregates the participants and bystanders, and indeed the only example of a negative perception of this segregation by bystanders.

Of course a user did not need to be in possession of the mobile device to exert influence over the coupled interactions. How bystanders can influence the coupled interaction, particularly at the *Google Earth* coupling opportunity, has previously been discussed, yet instructions from bystander group members to the participant group member were the most common source of this bystander intervention. Bystanders gave instructions to the participant due to varying paces of observation and varying interests – this is as true of unconnected bystanders as it is of bystanders of the same visiting group as the participant, yet social conventions provide a barrier of sorts to such direct instruction by unfamiliar bystanders. This social barrier is less evident between familiar visitors, especially those in a visiting group where the bystanders evidently felt that they had a right to *influence*, if not control the coupled interaction, despite not holding the mobile device. It may be suggested in fact that the conflict experienced within the family group was due to a lack of a more mature understanding of the ways in which a bystander might influence the participant's coupled interaction: for the children, being the participant in the interaction appeared to be the *only* way to engage in the coupled interaction (Q90), while other visiting group users used verbal and gestural direction to have some influence over the coupled interaction (Q91), while respecting the participant's right to their 'turn' in control.

Q90: "I wanted to sit in the chair [at the Slideshow*]. It meant she'd have a better go than me – everyone got to tell me what to do on my go [at the* World Map*] so it wasn't really my go. Probably only half a go" trial 2; group discussion*

Q91: "I think he [the participant] was concentrating harder on following what we were all yelling at him to do – it was so funny by the end because we were more in control than he was – yeah he was our puppet!" trial 3; group discussion

8.2.2 Shared feedback

In contrast to control, feedback during coupled interaction occurred (with the notable exception of the *World Map* couple) via the situated device and thus could be consumed by more than just the participant simultaneously, regardless of which member had possession of the mobile device. As such the responsibility for consumption may be described as a *shared* role of the visiting group members, not one bestowed by the mobile device.

The *World Map* is an exception to this rule due to the feedback being delivered via the mobile device, thus encouraging only the participant to consume it directly. In cases of visiting pairs it was possible (if the pair were comfortable with being physically close) for both the participant (i.e. the controlling visitor) and the bystander to view the mobile display, but in larger groups this was not possible.

In the latter case the groups developed two strategies for sharing this individual feedback:

- *taking turns* to view the feedback by physically passing the mobile device between members of the group (in a similar manner to the transfer of control amongst members), or
- *staging* of the feedback by the participant verbalising the feedback for the other group members (as described in *Personal feedback* on page 239).

8.3 Key findings and reflections

The key finding of the work was the identification of ways in which configuration of the coupling environment can reduce social awkwardness and arrangement of the couple may facilitate useful social interactions. Apprehension within the coupling environment causes visitors to behave in ways that are not anticipated by the environment designer, reducing the benefit that the environment provides to both the designer and the visitor. The observations have shown that this apprehension relates to:

- utilising the coupling environment in front of other visitors,
- interacting with other visitors, and
- sharing the experience with other visitors within a visiting group

To maximise the engagement of the visitor in the environment, this apprehension must be minimised. In summary this may be achieved, through:

- *four key design characteristics of the configuration of coupling environments that can contribute to reducing the social awkwardness* that typically reduces a user's engagement with public technologies.
- comparison of couples designed to be 'private' compared to those designed to be 'public', the situations in which either are required, and discussion of *how the arrangement of these couples contributed to encouraging or discouraging social interactions*
- How the needs of visiting groups emerged and *how their characteristic social dynamics came to be supported*.

8.3.1 Environment configuration can reduce social awkwardness over the course of the visitor's trajectory

Particular configurations of the coupling environment reduce social awkwardness over the course of a visitor's trajectory – increasing the chance and extent of visitor engagement - but require a sympathetic introduction

Four characteristics of coupling environments help to reduce social apprehension

Users may be apprehensive over interaction with novel technologies, particularly when those interactions take place in public. The Sociologist Goffman provides some concepts that draw on dramaturgy that are relevant to this summary, particularly given certain terminology used in this thesis, e.g. the 'staging' of coupled interaction. Firstly Goffman describes how an individual's actions in public occur on a 'stage' in front of others, i.e. the individual is an actor performing for an audience (Goffman, 1959); the actor's actions are likely to be tailored such that the actor highlights the aspects of themselves that they feel are most impressive or positive, i.e. that their ideal self-image is conveyed to the audience. As such the individual's actions in public may well be different to those in private, i.e. off-stage, where the acting persona disappears (or alters). Extending this Goffman argues that social interactions therefore contribute to the 'face' of the individual, which may not match with an individual's ideal self-image: if interactions cause an individual to appear to fall short of the image they are attempting to project they will 'lose face' and potentially be embarrassed (Goffman, 1956). If this is applied to interaction with novel publicly-situated technologies it can be suggested that users may be apprehensive about engaging in interactions that might expose weaknesses in their interacting ability or understanding to their audience.

In countering this apprehension, coupling environments (a *sequence* of couples) have unique benefits over disparate publically-situated devices. Four characteristics of coupling environments have been identified that lead to a distinctive reduction of the social awkwardness often observed in users of situated public technologies:

1. **Narrative links act as progressive lures, driving a desire for further interactions:** links between the content of the experience at previous and subsequent couples, enhanced by differentiation mechanisms that reveal further couples once an experience has been completed encourage the visitor to progress from one coupling opportunity to the next.
2. **Progression through the environment is understandable but challenging:** when progression through the environment is understandable, i.e. the causality and boundaries of progression are clear, yet the possibilities for progression are still rich visitors are more inclined to continue seeking further progression.
3. **Multiple couples build confidence at couples:** over the course of a number of coupled interactions, visitors gain an understanding of the interaction between the mo-

bile device and the situated devices and learn what to expect, reducing apprehension over further coupled interactions.

4. **Staging of the coupled interaction of others develops a sense of solidarity amongst visitors:** by observing others engaging in coupled interaction a visitor may understand the interaction and gain a sense that their own coupled interaction is more conventional.

Each of these characteristics either reduce the chance of loss of face by increasing the chance of successful interactions (most often by making the means of interacting more understandable), or by increasing the benefits (most often progression through the environment narrative or availability of new experiences) over the risk of face loss.

The coupling environment increasingly affects a visitor over the course of a visit

A visitor entering the environment will have not yet experienced multiple couples in order to gain understanding, or have begun the environment's narrative to be encouraged to progress, or have witnessed other visitors interacting with couples, thus the new visitor will naturally be the most apprehensive. Such apprehension has previously been described as being witnessed in the trial users at the *Registration* coupling opportunity (the first couple in all trials). In response to this the suggestion is that it may be beneficial for **the coupling environment to cater to the new visitor by providing a sympathetic introduction**; such an introduction would feature couples that:

- *Are simple to understand* regarding the purpose and nature of their coupled interaction such that a persistent fear of the novelty of coupled interaction is not instilled in the visitor;
- *Are not visibly exposed* to visitors other than those directed to them, requiring both situation off visitor thoroughfares, and input and output that does not create a spectacle of a participant's coupled interaction;
- *Provide a view of other visitors* engaging in coupled interaction, such that the new visitor can gain confidence and understanding by observing others before moving on to interacting alongside those more experienced visitors.

Steps were taken to progress the *Registration* couple towards such guidelines: the coupled interactions were entirely novel for all users, yet were also very clearly explained and were not time critical, resulting in a rewarding coupled experience while introducing the users to the concept of using the mobile phone as a tool; in later trials the *Registration* was also moved well away from visitor thoroughfares (into a 'dead-end' space), with a visible connection only to the *World Map* coupling opportunity – the next opportunity in the narrative, and one at which participants tended to be focussed on their own coupled interactions rather than observing their surroundings.

By exploiting the four characteristics and paying particular attention to the initial couples in the visitors' trajectories the designer may **increase both the chance that visitors will engage in coupled interaction, and the time that a visitor spends engaging once coupled**.

8.3.2 Arrangement of a couple may encourage beneficial social interactions

While there are specific limited needs for private couples, couples should most often be arranged so as to maximise the opportunities for coupled interactions to be observed

The need for non-staged ('private') couples is limited. In the coupling environment there was one couple designed to be private – the *Registration* – where the provision of visitor profile information caused apprehension amongst users in the trials, not as originally suspected due to background fears of identity 'theft', but due to the visitors' apprehension over how that information – if staged - might be perceived by other visitors.

Location of a couple has a greater impact on perceptions of staging than scale or arrangement

Despite reducing the scale of the couple to reduce the chance of observation by other passers-by or attraction of bystanders, participants still expressed a perception that their coupled interaction was exposed. In response visitors often registered using an 'alter ego'. Referring back to Goffman's notions of face, these alter egos allowed users to circumvent potential loss of face by preparing either ideal (positive) personal data for exposure to the public, or personal data that was so far removed from reality that the audience could not possibly believe that it was an accurate representation of the user. It was found that placing a couple away from areas where other visitors congregate (couples and thoroughfares) is much more effective than particular choice of scale or coupling metaphor at reducing the users' perception of exposure. Indeed the need for visitors to enter truthful personal information was questioned: considering the difficulty that a designer might have to go to in order to ensure the truthful provision of personal information, and then to accurately base restriction mechanisms upon that information, visitors might be encouraged instead to create alter egos. By doing so, apprehension over providing real information would be lessened, exhibitionism would be explicitly supported and, as has previously been discussed, group identity might be better supported. Private couples also clearly do not serve to allow bystanders to observe actions of the participant and therefore aid their own exploration of the environment.

Physical arrangement can be used to manipulate the social interactions at the couple

The majority of couples staged the participants' interactions, be they individual participants or multiple participants. Rather than bestowing a degree of superiority upon the participant in the manner of a totem, the mobile device acts to expose the participant as the centre of the spectacle in staged coupled interaction, allowing discussion, direction and collaboration to encourage the engagement and progression of both participants and bystanders. Coupled interaction that was physical in nature – that of the *ART* and *Google Earth* – was witnessed attracting bystanders, who then showed little tendency to defer to the participant as the conductor. Instead the participant provided a focal point for the bystanders' comments and directions. In contrast the physical form of the *Slideshow* – specifically the conductor's chair – accounted for the distinct deference shown by bystanders at that coupling opportunity. Between these two extremes the *World Map*, through its shared interaction space, fostered a sense of common interaction without encouraging collaboration, thus providing a socially rewarding experience without requiring the individual to exhibit themselves.

Segregation facilitates more extended personal coupled interactions

Having attracted bystanders, the physical arrangement and form of the couple may then segregate those bystanders from the participant, resulting in a passive audience suiting more personal rather than social forms of coupled interaction. However, deference from bystander to participant or segregation of the two will not be the universal aim of the designer. The effect of the *Slideshow*'s physical form and configuration served the type of coupled interactions supported at that couple well as the coupled interaction at the *Slideshow* is by its nature more personal. Users interacted with the couple at highly varying rates and for equally varying durations, choosing to pay more attention to varying parts of the content. Previous coupled interactions also had dramatic effect on the amount of content available to each individual user, thus bystanders were likely to experience conflicts of pace or content. Instead the physical form of the couple shields the participant from the bystanders allowing on the one hand the participant to focus upon their own coupled interaction without feeling obliged to appease the bystanders, while also allowing the bystanders to observe and leave as they please without experiencing apprehension over interrupting or invading the personal space of the participant. On the other hand, the physical configuration and form of the couple does not literally prevent interaction between the participant and bystander, as evidenced by observed social interactions amongst visiting groups and between bystanders socially familiar with the participant. The participant is merely given a greater leave to enjoy their own coupled interaction without obligation, unless desired, to the bystanders.

An open interaction space suits those couples that aim to encourage social interaction between users at a couple

The *Google Earth* and *ART* couples offered far less in terms of purely consumable content, yet provided platforms for very rich collaborative or social interaction – particularly at the *Google Earth* coupling opportunity, much of the ‘experience’ arose from discussions between the participant and bystanders about the locations being viewed on the situated display. Although participants could and did spend long periods of time interacting alone with the couple, the longest and richest experiences were collaborative and social in nature. Such experiences would have been stifled by a physical configuration such as that at the *Slideshow*, and thus the suggestion is to create fluid interaction spaces when the coupled interactions benefit from the intervention and addition of bystanders (or indeed, as at *ART*, other participants). A lack of physical constraint on both the participant’s mobile and on the movement of the visitors allowed bystanders to move into the participant’s interaction space and instruct the participant or lead the social interaction. This type of configuration does rely upon social conventions in order to mediate this fluidity; there was no overbearing interference by bystanders in the coupled interactions of unfamiliar participants, yet new social relationships were formed as a result of the participant’s coupled interactions. The *Google Earth* and *ART* couples with their accommodation for social interaction provided a much more sustained benefit to the bystanders that they attracted, in comparison to the *Slideshow*.

8.3.3 It is important to consider supporting the need for experience-sharing amongst visiting groups

The designer should utilise the cyclical nature of interaction in the coupling environment to facilitate turn-taking within groups, avoiding barriers that prevent turn-taking and allow turn-taking to be enforced socially

It is essential for the environment designer to support visiting groups as well as individuals. While the individual experiences all exploration and control/feedback during coupled interactions themselves, these elements of the user experience are delivered (partly or completely) via the mobile device and therefore only one member of a group can hold the mobile at any one time: **there must be an element of turn-taking within a visiting group in order for all members of the group to share the experience**. Of course where feedback occurred via the situated display rather than the mobile client the feedback could be shared amongst the group, thus avoiding the need for turn-taking.

Interaction in the coupling environment is cyclical, facilitating turn-taking in groups

Interaction in the coupling environment consists of various cycles, thus lending itself to turn-taking within the group. At a high level, exploration and coupled interaction form a cycle, where group members may swap roles before coupling and/or after decoupling such that turns are taken to couple and explore respectively; at the level of coupled interaction, several couples had coupled interaction that consisted of cycles, e.g. at the *World Map* group members could swap roles after each matrix was scanned. Even where cyclical coupled interaction existed, groups engineered alternative means of sharing the mobile device: at the *World Map* where (uniquely) the feedback was delivered via the mobile device, the group member in possession of the mobile device either physically passed the mobile device around the group to share feedback, or broadcasted that feedback by reading out the facts delivered through the mobile to the entire group.

Certain arrangements pose a barrier to turn-taking

Beyond a lack of cyclical coupled interactions the arrangement of the couple may pose other barriers that may prevent experience-sharing within groups. A segregation of bystanders and participant was caused by the physical arrangement of the *Slideshow* couple, and although this did not extend to preventing verbal interactions with some visiting groups it did serve to prevent group members switching roles in what was a clearly cyclical coupled interaction. The lack of physical space at the *ART* couple as well as confusion concerning how the mobile could be manipulated in that space, particularly that passing the device between users might cause the devices to decouple, created apprehension preventing groups from switching roles at the couple. The designer must evidently consider:

- whether the physical arrangement of a couple *segregates the participant and by-standers* such that the mobile device cannot be passed between group members, and
- whether the arrangement of the couple implies to the participant that passing the mobile device to a bystander may *cause the mobile and situated devices to decouple*.

Turn-taking can be socially enforced rather than being orchestrated by the system

Finally turn-taking was found to be enforced socially within groups and thus did not require orchestration by the system, beyond providing the necessary cyclical interactions: **it is beneficial for the designer to take a hands-off approach to enforcing turn-taking**. Conflict over the sharing of the experience was observed only in one group – a family group – where order was quickly imposed as it would be outside the coupling environment, by the parents. Orchestration by the system would require an added layer of complexity to the user experience that would be detrimental given that social mechanisms for enforcing fair (or at least acceptable) turn-taking already exist.

9. Final discussions

This final chapter concludes and reflects upon the exploration of coupling presented in this thesis. In section 9.1 the work conducted is summarised; section 9.2 presents the key findings resulting from this work; section 9.3 states the contributions made by the thesis; finally section 9.4 indicates the opportunities for future work based upon the thesis.

9.1 Summary

This thesis argues that there are an increasing number and variety of devices situated in public spaces yet interactions with such devices are impersonal and subject to social apprehension. It was proposed that the personal mobile device might provide a means to make better use of environments containing disparate situated devices through the combination (coupling) of mobile and situated devices. The thesis argued that coupling could:

1. **facilitate personalised interactions** (as the mobile device identifies its owner and acts as a personal input/output device) with those situated devices
2. **extend the computational capabilities** of the situated device through the addition of the input, output and storage capabilities of the mobile device
3. **link sequences of interactions with different situated devices** providing rich, cohesive experiences across an environment

The thesis has shown that coupling allows paths to be taken through these environments, building a compelling user experience out of sequences of coupled interactions at different situated devices. It has identified the benefits of this type of user experience and has produced guidance for designers of coupling environments to achieve these benefits.

The work began by considering relevant previous work to ground the thesis, identifying that although there was a lack of work considering multiple situated devices in public, there was a body of existing work considering combinations of mobiles with single situated displays (MP-PDs) and also physical input devices in situated sensing systems (TUIs). Chapter 2 explored the TUI concept as encompassing the 'couple' which itself encompasses the MP-PD; useful categories were isolated to allow a comparison of existing examples of combinations of mobile and situated device.

In chapter 3 attention shifted to the environment in which resources – such as public devices – might be situated. Previous work exploring technology as a means of mediating the exploration of physical spaces to find resources was reviewed to learn how situated devices within an environment might be located and linked using the personal mobile device.

The review of existing mobile-situated combinations and exploration allowed the proposal and elaboration of a core model of interaction within a coupling environment in chapter 4. This elaborated model consisted of a cycle of exploration and situated interaction and serves to map the design space of coupling in order to isolate parts of the space that are interesting and require further investigation. Several design questions were raised regarding both exploration and situated interaction, leading to the identification of a number of design issues. These design issues were intended to steer the implementation of a test-bed, the trialling of which would elicit increased knowledge about the benefits of the coupling concept and how to design environments so as to achieve those benefits.

Chapter 5 and 6 presented the implementation of the test-bed, consisting of six couples, a range of orchestration approaches, three environment configurations and a set of five user trials intended to facilitate thorough exploration of the design issues.

Finally, observations of the user trials were presented from two perspectives: in the first (chapter 7) observations of the individual user experience, discussed as the user trajectory through the coupling environment, were reflected on to explore how the extent to which a trajectory is different from others is related to both the individual's appreciation of the experience, and to how the individual might have a beneficial impact on the experience of other visitors. **Differentiation mechanisms** were presented: features of the system that allow visitors to shape their own trajectory and differentiate it from that of others. Mechanisms were categorised as those that either *restrict* or *conceal* couples, relating to whether the conditions upon which they deny access are static or dynamic and hence whether they deny access to couples permanently or temporarily respectively. Observations were also presented regarding the effects of these two mechanisms and of different orchestration approaches on the user's enjoyment of their experience.

In chapter 8 observations were presented of social interactions at couples, discussing how the arrangement of a couple affects the social interactions encouraged at the couple, how the configuration of the environment may reduce the social awkwardness typically associated with interactions with novel technologies in public, and finally how groups sharing a single mobile device can and need to be supported in coupling environments.

9.2 Key findings

The work of this thesis involved iterative prototyping in close collaboration with users. A series of formative studies were undertaken to shape the research and key elements of the resulting framework. Findings from thesis studies and the framework can be considered in two themes:

1. Through support for narrative and personal orchestration, coupling environments afford **personalised trajectories**. By designing to afford these personal trajectories the visitor has both a more enjoyable personal experience and seeks to improve the experiences of others
2. Coupling environments tend towards staged interaction, supporting **social experiences**; the step-by-step nature of a visitor's trajectory through the coupling environment lends itself to gradually introducing visitors to staged, social coupled interaction such that the benefits of these interactions can be enjoyed while the social awkwardness of interacting in public is reduced

9.2.1 Personalised trajectories

The thesis has shown that the shift from a common shared trajectory, i.e. where each visitor's experience follows the same path through an environment (where users are happy to observe each other rather than experience for themselves), towards unique trajectories encourages greater personal engagement in interaction at the couples and a greater enjoyment of the user experience. Significantly the findings suggest that this is only true if three requirements (resulting in a sense of ownership of the personal trajectory) are met by the design of the coupling environment: the environment must provide **differentiation mechanisms** that are **transparent**, and the system must share control over **orchestration** with the user.

Of the two types of mechanism to allow users to differentiate their paths, restricting mechanisms (section 7.2.1i) were found to limit the possibilities for an individual's progress through the coupling environment, but more significantly these limitations are staged so that users can compare with one another encouraging a negative perception of discrimination. In all cases these perceptions could be lessened: coupled interactions that originally were restricted to certain users (based on the capabilities of their mobile) could instead be adapted to different visitors such that all could experience every couple to some degree.

Observations taught that concealment mechanisms act to encourage rather than limit the visitors' exploration of the environment, adding an element of challenge to progression through the environment's narrative. Additionally it was found that 'challenge' is not required to be difficult in order to provide this encouragement: in fact users enjoyed many easily-understandable challenges, and were discouraged by unexplained progression or overcomplicated challenges. Indeed if the differentiation mechanisms are ambiguous, those visitors that do progress have a tendency towards protecting their achievement, thus limiting the progression of others. In contrast, goals that are more trivial to understand reduce the advantage gained by completing them, thus encouraging users to share their expertise quickly to be seen as a (temporary) leader or expert; in this way the individual encourages the progression of others rather than limiting it.

The pace of the user's trajectory – affected by the system's orchestration approach – was found to be another key factor in the enjoyment of the user experience. Even in environments with linear narrative and a lack of differentiation mechanisms, users found satisfaction in being able to control the pace at which they progressed along the resulting similar trajectories by searching for couples rather than being directed or receiving updates. However, the trials showed that even when users had total control over the pace of their progression they still perceived a degree of expectation, i.e. an onus to keep exploring even if not explicitly required. Users were observed to be more comfortable using the mobile to explore to find non-couple locations at which they could 'legitimately' rest, rather than simply stop using the mobile.

9.2.2 The social experience

Social apprehension has been traditionally seen as a barrier to user engagement with public technologies, thus to maximise the engagement of the visitor in the environment, this apprehension must be minimised. At various points in the trials the users exhibited social apprehension in response to:

- Utilising the coupling environment in front of other visitors
- Interacting with other visitors
- Sharing the experience with other members of a visiting group

Four characteristics of coupling environments have been isolated that lead to a distinctive reduction of the social awkwardness often observed in users of situated public technologies:

1. Narrative links act as progressive lures, driving a desire for further interactions
2. Visitors are encouraged to explore further when progression through the environment is understandable but offers variety
3. Experiencing multiple couples builds confidence at subsequent couples
4. Observing coupled interaction develops a sense of solidarity amongst visitors

These qualities assert an increasing affect on a visitor over the course of a visit to a coupling environment thus it is important to consider how the coupling environment could cater to the new visitor by providing a sympathetic introduction. An early couple (where a visitor's apprehension is high) could:

- Be the simplest to understand
- Not stage the visitor's coupled interaction to bystanders
- Provide a view of other participants engaging in coupled interaction

An increase in both the chance that visitors will engage in coupled interaction, and the time that a visitor spends engaging once coupled was observed when the four characteristics of coupling environments stated above were exploited.

Additionally, the trials have shown that as the visitor's confidence grows not only does the visitor's eagerness to explore grow, but the visitor also desires greater control over the direction and pace of their trajectory. It was found that the approach to orchestrating a visitor's trajectory needs to adapt as this desire grows, exerting control (in the form of direction) at the start of the user's visit, while providing more choice and the ability to control when progression occurs (through search) later in the user's visit.

Figure 79 below relates the user's confidence during earlier and later stages of their trajectory to the major coupling environment design decisions:

User	← Earlier	***Stage of user's visit***	Later →
	← Lower	***User confidence***	Higher →
Design	← Direction	***Suitable orchestration approach***	Search →
	← Private	***Suitable exposure of coupled interaction***	Staged →
	← Simpler	***Suitable complexity of coupled interaction***	More complex →

Figure 79 Relating user confidence to design decisions

In addition to positioning couples out of view in order to provide new visitors a sympathetic entrance to the environment other means of ensuring private coupled interaction were explored. However in the exploration of couple design it was found that both reducing the scale of a couple (as per the *Registration*) and physically segregating the participant's interaction space from that of the bystanders (as per the *Slideshow*) had little power to reduce the sense of staging perceived by users. Instead the physical arrangement of the couple was shown to be able to provide various forms of staging that suited different types of coupled interaction. The physical segregation of participant and bystander at the *Slideshow* encouraged bystanders to observe without interrupting the participant's experience – this was suitable as the content was rich and thus 'spoke for itself' while requiring sustained attention from the participant; in comparison there was no segregation at the *Google Earth* couple, which benefitted greatly from the social interactions between participant and bystanders that were encouraged from the fluid interaction space, given that the *Google Earth* couple has no 'content' of its own.

Finally, it became clear that the cyclical nature of interaction in the coupling environment allows the sharing of experiences by members of visiting groups to be facilitated through turn-taking. Group members swapped roles before coupling and/or after decoupling such that turns were taken to couple and explore respectively, while group members also swapped roles during coupled interaction where the coupled interaction involved cyclical interactions. Despite providing the necessary cyclical interaction the arrangement of the couple may pose other barriers that may prevent experience-sharing within groups, i.e.

- a physical arrangement of a couple that *segregates the participant and bystanders* may prevent the mobile device from being passed between group members, and
- the arrangement of the couple can imply to the participant that passing the mobile device to a bystander may *cause the mobile and situated devices to decouple*.

Finally turn-taking was found to be enforced socially within groups and thus did not require orchestration by the system: beyond providing the necessary cyclical interactions and ensuring that the couple's physical arrangement does not prevent the passing of the mobile between members, and so the designer may take a hands-off approach to enforcing turn-taking.

9.3 Contributions and implications

The major contributions of the work are a balance of **design framework and principles** that map possibilities for the designer and provoke consideration, an exemplar **software infrastructure** implemented in order to demonstrate application of the framework, **user studies** that provide illustrative examples of the benefits of design guided by the framework and the formative process by which the framework was shaped, and **dissemination** of the research to the wider research community.

9.3.1 Design framework and principles

A design framework and guiding principles have been presented, extending aspects of existing theory and grounded in observations of user trials. Key components of the framework are:

i. Model of user behaviour

The model of behaviour in coupling environments (chapter 4) describes a novel cycle of exploration and situated interaction providing a means to discuss and generalise the actions of visitors to coupling environments.

Work involving exploratory behaviour using the mobile device has previously considered environments with situated resources that can be visited and that might have varying suitability depending upon visitor profile; exploration of a *coupling* environment (section 4.2) is novel in that suitability also depends upon the capabilities of the mobile device and the capacity for the situated device to combine with a particular number of visitor's mobiles. Also novel is that fact that the mobile can literally prevent the visitor from experiencing a situated device – visitors cannot stumble across and use any situated device at will.

ii. Orchestration

Rich narrative structures that allow users to progress through a coupling environment at varying paces and to varying degrees may be facilitated by differentiation mechanisms (section 7.3.1) and enforced by advertising and providing access to the situated devices through the mobile. This approach to enforcing narrative structures provides a new and interesting model of control over the user experience that changes over the course of the experience whereby the system makes the final decision over suitability of user choices, yet provides an increasing variety and the freedom for users to control the pace of their exploration: in this way exploration at the pace most comfortable to the users is encouraged. This requires a mixed approach to orchestration (section 7.3.3) in which users are gradually given more control over their own progression through the coupling environment utilising various techniques: first through direction (push-based system control) and finally through search (pull-based user control).

iii. Measures for facilitating beneficial social interactions

The framework presents four key design characteristics of the configuration of coupling environments that can contribute to reducing the users' social awkwardness over the course of a visit (section 8.3.1) – these regard the novel nature of coupling environments as *sequences* of publically-situated devices that the visitor progresses through and identify the benefits that this configuration may bring; in comparison previous studies of publically-situated devices have considered only the disparate installation.

The framework also extends previous work to explore the arrangement of the technology in an individual couple, showing how physical segregation of participant and bystanders, as well as the choice of channel through which feedback is delivered and control exerted, each affect the type of social interactions that a couple may promote (section 8.3.2).

9.3.2 Software architecture instantiated to demonstrate framework

Also presented was the implementation of a test-bed that consisted of six couples in various configurations (chapter 5), underpinned by a software infrastructure that demonstrated the instantiation of the framework (chapter 6). The infrastructure demonstrated suitable system architecture to support the application of orchestration approaches, guidance of the users between locations via dynamically-generated photographic trails and generic couple functionality that could be extended to support a variety of coupled interactions at different situated devices.

9.3.3 User studies

Formative user studies shaped the framework and revealed novel aspects of the user experience for study, including:

- While restricting mechanisms enforce variety amongst visitor trajectories they also limit the possibilities for an individual's progress through the coupling environment, and these limitations are staged so that users can compare with one another encouraging a negative perception of discrimination (section 7.2.1i).

- Facing visitors with many simple, understandable challenges that must be overcome in order to progress encouraged an individual to explore the environment, yet this also encouraged individuals to interact with one another to share expertise and help one another to progress (section 7.3.2).
- The location of a couple has a more significant impact upon the feelings of exposure of a visitor when engaged in coupled interactions than design features of the couple, e.g. the scale or form of the couple. Placing a couple away from other situated devices and thoroughfares reduces these feelings of exposure, yet placing a couple near another couple allows an apprehensive user to observe others also engaged in coupled interactions, thus reducing the perception of their own behaviour as unconventional (section 8.3.1).
- The desire of users for direction by the system (to reassure and reduce complexity) early in their experience reduces over time; as a user gains confidence in using their mobile for exploration of the coupling environment and to couple with situated devices, they desire a greater control over their own progression. This results in a need for different types of orchestration at different stages in their experience rather than reliance upon one approach (section 7.3.3).

9.3.4 Dissemination

An early overview of the framework itself was presented and discussed, focusing upon the core model and the observations of trial 1, at an international workshop (Bedwell and Koleva, 2007). The framework has also been exploited during various public deployments beyond the five trials described in this thesis.

i. Orchestration of user experiences

One of the core elements explored over the course of the thesis work was the notion of orchestration of user experiences by the system to provide coherence. Beyond the trials, orchestration was explored through the development of two urban experiences run for members of the public in Nottingham city centre: *Future Garden* and *Anywhere-Somewhere-Everywhere*.

Future Garden (Schnädelbach et al., 2006) was a mobile-driven mixed-media tour that led participants around a fading marketplace in the city centre, providing them with experiences of both the site's history and plans for its future. The experience extended the use of photo-trails in the test-bed to support movement by using 1st-person-perspective videos that the participants followed from point to point (indicated by numerical markers painted on the streets, as shown in Figure 80 below).

Figure 80 Markers on the streets in *Future Garden* to aid movement

As such, particular routes were prescribed between points (as the videos were not dynamically generated as the photo-trails in the test-bed were) – indeed this was desired in order to provide particular experiences while moving between the different experiences (e.g. to see particular views). As with Anywhere-Somewhere-Everywhere, participants appreciated the fact that the movement between locations was as much of an experience as the experiences at the locations. Beyond prescribing the routes, participants were given freedom to select the next experience from any of the different locations (Figure 81 right) – there were no narrative dependencies that the participants had to satisfy.

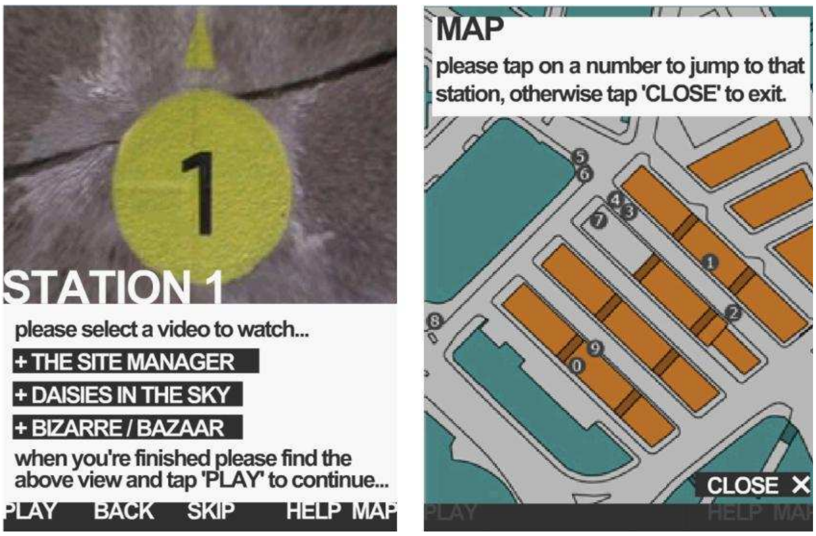

Figure 81 Screenshot of the *Future Garden* mobile UI after a participant has reached location 1, offering choices of media relevant to the location (left); UI showing map of site, offering choices of all the experiences (right)

In the absence of any other systematic means of orchestrating their own tour, participants tended to follow the numbering of the stations (which resulted in a tour with the least amount of walking); the implication of this was that many participants followed the same route, and the locations numbered highest received fewest visits (as a number of visitors ended their experience earlier, due to the length of the content at some locations). Participants were keen to find any sort of authoritative structure to act as a framework for their exploration of the site, and occasionally appeared apprehensive that they had simply missed instructions that might have told them how to go about or reason about a structure.

Anywhere-Somewhere-Everywhere (Bedwell et al., 2009) was an orchestrated mixed-media tour of Nottingham, combining various types of experience (from short videos to physical exploration of sites and one-to-one dramatic performances) located around the city centre. The visitor was led on a path between a number of these locations by a performer, who communicated with the visitor via mobile phone conversations during which the pair would decide on the next location and the performer would give verbal directions if necessary. There was no fixed narrative structure for these paths through the city, so each visitor – depending upon the choices advised by their performer – could take their own unique path.

Figure 82 Visitor experiencing a personal location-based performance

Although coupled interactions did not take place at any of the city centre locations analogies may be drawn to the trajectories of the users in the user trials (chapter 7): as in the coupling environment, the city centre locations only had a capacity for a certain number of visitors at any one time, and were of varying accessibility to visitors (e.g. some sites requiring physical exploration were unsuited to less active participants), thus each location had a different relevance to a visitor. Unlike in the coupling environment user trials the system did not orchestrate the choices defining the users' trajectories; instead the human performer was tasked with determining which locations were most relevant to their visitors and advising them accordingly (Figure 83).

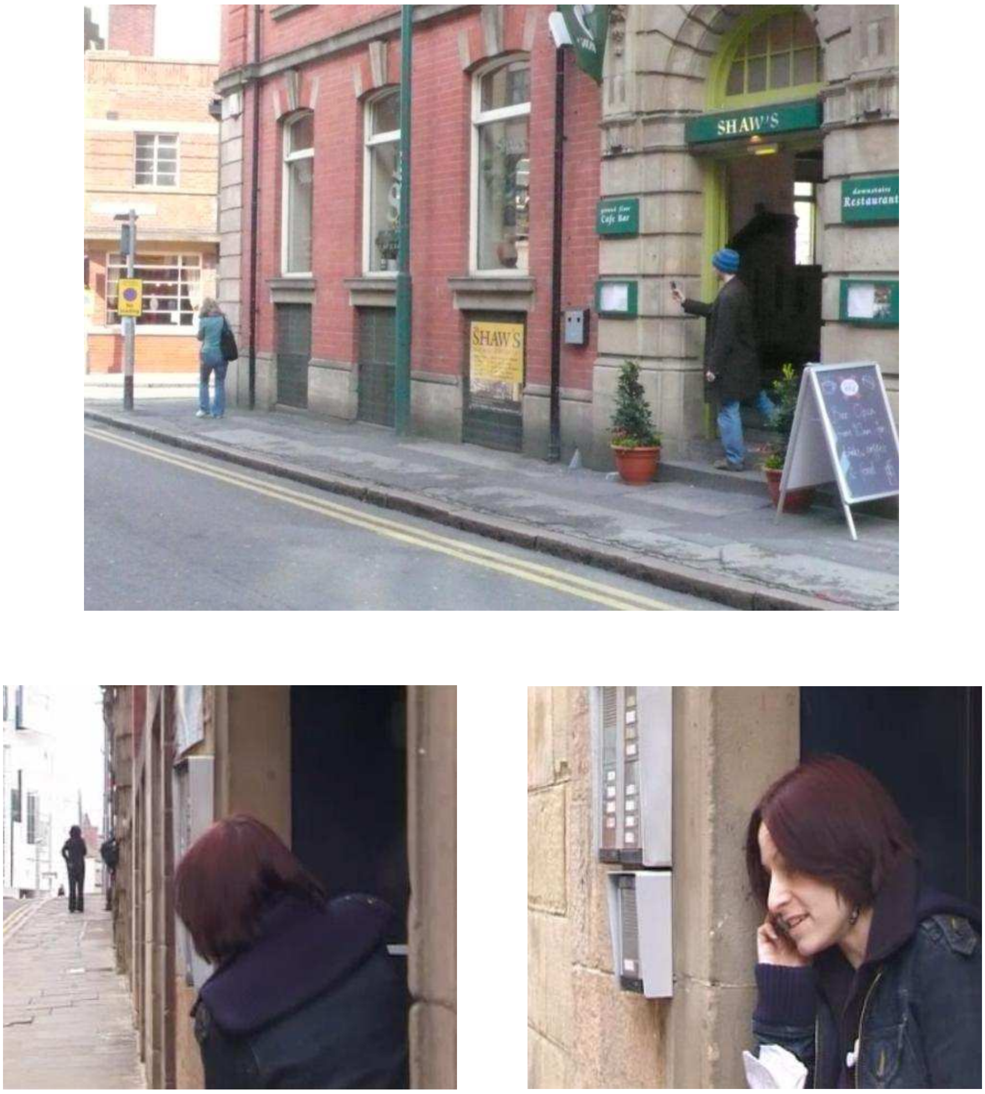

Figure 83 Performers orchestrating experiences: a performer following and photographing a visitor (top); performer hiding from a visitor (bottom left) then calling them to discuss which location to visit next (bottom right)

The performers were provided with a mobile interface that summarised the relevant information that the system *could* determine, e.g. the current free capacity of the locations (see Figure 84 below), whilst placing the onus on the performer to determine other information (e.g. the interests of the visitors).

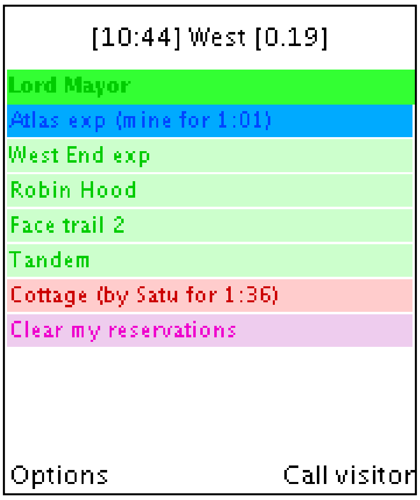

Figure 84 The orchestration mobile client showing various locations and their current capacity; green indicates free capacity, red indicates no capacity and blue indicates the location currently occupied by the orchestrator's visitor

The event ran for a week with 3 performers orchestrating 40 visitor experiences in total. Despite being initially unfamiliar with Nottingham the performers were found to be able to provide their visitors with highly-cohesive experiences, such that the visitors did not perceive their visit as a sequence of disparate location-based experiences linked together by walks through the city, but instead enjoyed a single coherent experience during which they formed a social bond with their performer. Participants stated that they enjoyed the engagement with their orchestrator as much as the location-based experiences. In contrast, users that took part in trials in the coupling environments referred only to the coupled interactions when discussing their experience, feeling a need to legitimise not hurrying directly from one coupled interaction to the next. This indicates that while the coupled interactions in the environments followed a cohesive narrative, building upon one another and encouraging progression from one to the next, the broader user experience (including movement between couples) could be more cohesive. It also raises an interesting question that will be explored as future work: how much of the orchestration conducted by the system in the thesis' trials might be conducted by visitors for one another, and how would this affect their experience of the coupling environment – is a human touch required to produce truly cohesive experiences, or at least experiences that are *perceived* as cohesive?

ii. Coupled interactions

While *Anywhere-Somewhere-Everywhere* explored orchestration, a new couple was also developed and publically-deployed as part of the *Rivers Baghdad* project[55] in Benjamin Franklin House museum in London which was also used by approximately 40 visitors. An installation that combined two large projected displays situated side-by-side with a Nokia N95 was created to allow the user of the N95 (via the mobile's motion sensor) to control the two displays (Figure 85). At the first situated display the user controlled a Google Earth visualisation of Baghdad which had been annotated with 3d water drops placed at various locations around the city; by tilting the mobile to centre the visualisation on a water drop the user could then press a key on the mobile to launch a piece of content (either an image, web page or video) associated with the water drop's location on the second display (Figure 86).

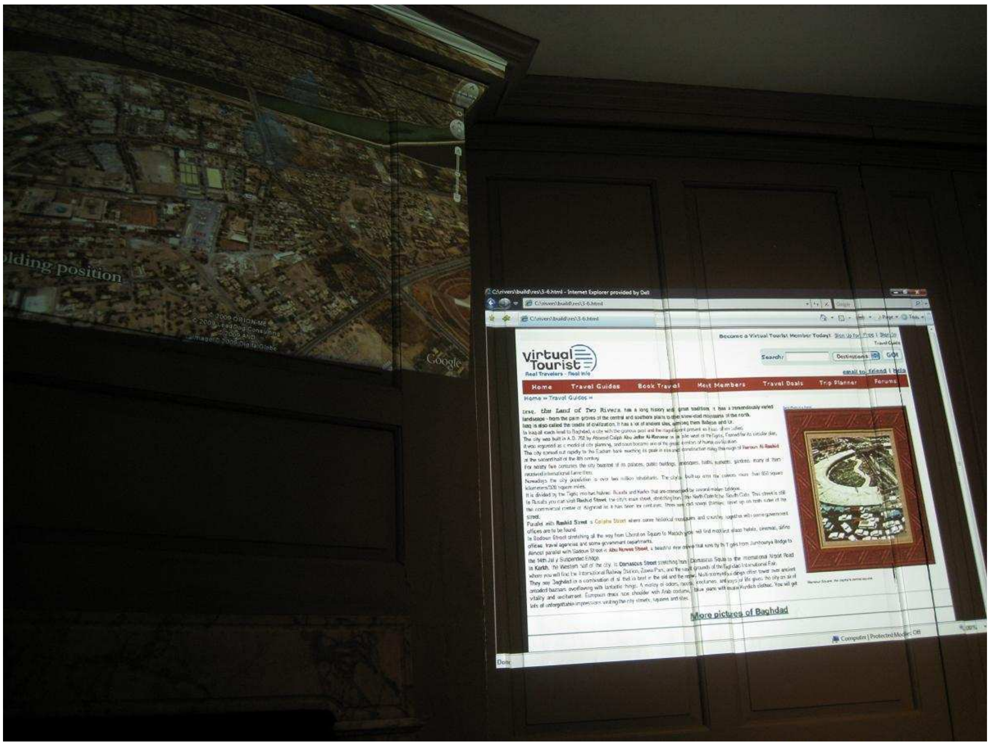

Figure 85 Two projected displays showing Baghdad on lefthand display and web-content on righthand display

[55] http://www.riversbaghdad.com (accessed 23/2/10)

Figure 86 User viewing a video discovered having 'clicked' on a water drop

Rivers Baghdad extended the *Google Earth* couple developed for the lab-based trials with the intention to encourage similar social interactions around the coupled interactions, i.e. discussions amongst the participant/bystanders (section 8.1.2ii). Projection equipment was arranged such that there was an open space in front of the projected displays for participants and bystanders to move freely. However seats were also placed along the walls of the room in which the couple was deployed – this addition caused a significant change to the social interactions that did occur at the couple. A clear distinction between the participant and the bystanders was observed emerging: whenever the couple was in use, bystanders would immediately seat themselves, leaving only the participant standing. This appeared to separate the participant and bystanders just as the participant's chair had done at the *Slideshow* couple in the user trials. A minority of participants relished this and began presenting to the bystanders (e.g. Figure 87 top right). A greater number of participants were clearly apprehensive of interacting with the couple in front of an audience, interacting only for a short period of time, while some bystanders avoided using the couple until other bystanders had left. Interestingly some bystanders would only take over control if they remained sitting with the other bystanders (Figure 87 bottom).

Figure 87 Staging coupled interactions: user standing in front of displays (top left); user discussing content with bystander (top right); user sitting with bystanders (bottom)

Observations of this deployment stress the need for a careful consideration of the physical arrangement of couples due to the ease with which social awkwardness can stifle useful social interactions and the engagement of users in the experience (section 8.3.2).

iii. Further dissemination

In order to maximise the benefits of the research conducted thus far dissemination of the work needs to continue; this dissemination also needs to occur via a variety of channels in order to reach the different potential beneficiaries. There has been relatively little dissemination of the material as a complete framework (beyond the early account in (Bedwell and

Koleva, 2007)) and this would be the key priority going forward in order to have an impact upon the *academic field*. A journal publication would be the target for an overview of the framework with sufficient material to discuss justifications and findings of the trials, while there are opportunities to discuss the infrastructure, couple designs, trials and briefer overview of the framework along with a discussion of the implications of the framework in conference or workshop publications.

Public deployments (while not a feature of the trials) have served well as a means of reaching and interacting with *members of the public* who might not have been recruited as participants for the trials. *Rivers Baghdad* attracted a number (the majority of the 44 participants) who are Iraqi residents of the UK, and also a wide range of ages (from less than 10 years old to greater than 60); *Future Garden* and *Anywhere-Somewhere-Everywhere* involved many participants who were very comfortable with being exhibitionists and with challenging the technology. Clearly, as the end-users of coupling environments will typically be neither academics, nor the designers of those environments, it is important not to forget the general public when considering dissemination of the research: further public deployments (of coupling environments, not just individual couples) will serve this. In collaboration with Theresa Caruana the work carried out for *Rivers Baghdad* continues, with a focus on how the nature of the couple in public affects social interactions at the couple, and how different couples relate to different types of content.

Dissemination must also continue with potential users of the framework, i.e. those who might develop coupling environments. The workshop carried out alongside trial 4 with exhibition professionals was a useful exercise in revealing the needs and viewpoints of the potential users of the framework, yet the participants on that day covered only a narrow section of the potential users. Additionally, trial 4 did not test the final configuration of the test environment that included many of the alterations suggested during the workshop. Further iterative trialling of the test-bed with the same and additional potential developers would be invaluable.

Finally, efforts will be made in all cases to advertise the availability of the software source of the test-bed created for the trials. This source is publicly available via GitHub[56] for reference or deployment.

[56] http://github.com/bzbhorizon/GlobalExplorer (accessed 16/3/10)

9.4 Future work

9.4.1 New technologies

Publicly-situated and mobile technologies are rapidly evolving. In the time it has taken to complete this thesis the smart-phone has become commonplace – Nokia released the first mainstream mobile with GPS (Nokia N95) while 802.11 is becoming ubiquitous in new mobiles. The application marketplace (popularised by Apple's iPhone appstore and Android marketplace) has emerged to provide a convenient answer to the challenge of deploying and updating software on mobiles. Technologies have crept further into public spaces: a comparison of a city centre now to five years ago would reveal a host of new situated digital displays at bus and tram-stops, digital shop-fronts (e.g. Urban Digital[57]) and community screens (e.g. BBC Big Screens[58]).

Figure 88 BBC Big Screen in Liverpool

What of the *next* five years? How do the advances that will take place affect the framework and design principles that have been presented here? A particularly interesting development

[57] http://www.urbandigitalmedia.co.uk/ (accessed 23/2/10)
[58] http://www.bbc.co.uk/bigscreens/ (accessed 23/2/10)

that has yet to reach the mainstream is the pico-projector; pico-projectors are small and efficient enough to be embedded within a mobile phone, as demonstrated by Samsung among others at CES 2009[59], a feature that will allow users to stage content from their mobile without resorting to situated technologies (Figure 89).

Figure 89 Mobile phones creating public displays

Given that the audio reproduction capabilities of mobile phones are also improving a near distant future can be foreseen where mobile users can create a situated visual and audio projection at will to share their content with others and indeed combine their devices to create collaborative content in public. The framework proposed in this thesis relies on the assumption that the locations of couples are known by the system and that there is *one* system that orchestrates experiences in the environment: if any user can recreate situated experiences in the location and at the time of their choosing how could those experiences be advertised and how could narratives be specified to combine sequences of these transient situated experiences?

9.4.2 Scale of coupling environments

At the start of part 3 of the thesis the external and ecological validity of the trials were re-flected upon. One of the questions raised was whether the framework might be applicable to coupling environments on a scale beyond that approximated in the trials. Consideration of the scale of real-world potential coupling environments leads to two significant questions: does the framework cater for environments that are much larger? Does its advice still apply when the volume of visitors is much greater? The intention of producing a framework is that

[59] http://www.cesweb.org/ (accessed 21/10/09)

the design principles have a degree of generality yet we can be sure that increases in scale will require consideration by the environment designer.

Environments that are much larger pose problems of complexity: environments such as shopping centres, or indeed large museums may have hundreds, if not thousands of situated points-of-interest that might be developed into couples. This amount of information would require a more complex process to determine which of these resources would be relevant to advertise to the mobile user: how much of this complexity must be hidden from the user? Narrative structures containing this many steps are also likely to be much more complex: how will a user understand more complex narratives?

The trials exposed users to relatively little passing traffic: one museum professional commented that the trial environment was like their museum “on the quietest day of the year”, yet social apprehension was still observed amongst the users over being staged: the thesis argued that measures had been determined to overcome this. Do these measures translate to much busier environments, or are they limited to being applicable only in the quietest of potential coupling environments?

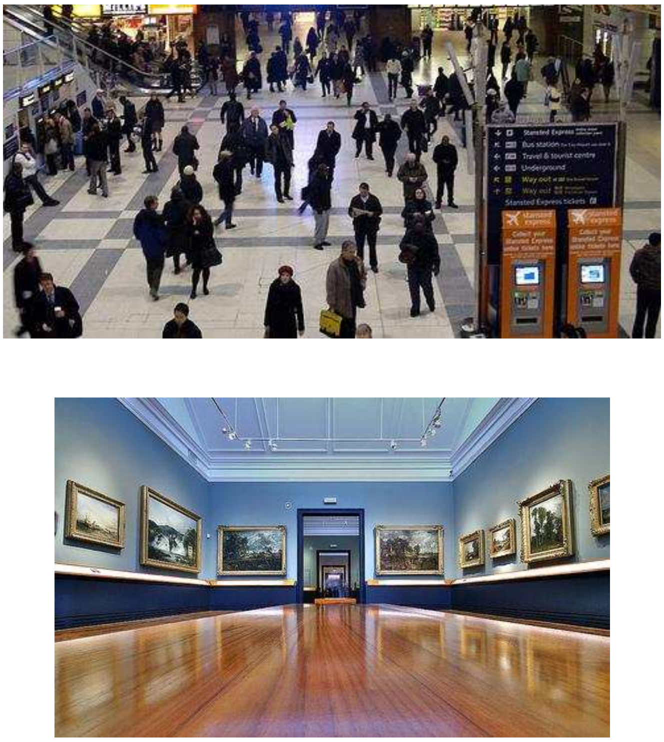

Figure 90 Different candidates for coupling environments: busy exposed commuter spaces (top); quiet low-throughput reflective spaces (bottom)

9.4.3 Overlapping environments

One final interesting issue that may be raised for the future is the issue of public space as multi-purpose space. Coupling environments have been deployed and trialled for this thesis with the assumption that the space in which they are situated is dedicated to the couples and to the experience of those couples. This may well be true of some real coupling environments, e.g. in a museum there may be one and only one narrative designed by the museum curator. The case may be very different however in truly public space, such as the streets of a city centre. In this environment there may be many situated devices that can serve a range of generic purposes and that may be combined in various different narratives designed for different purposes. As an example, the city council may create a narrative structure utilising the digital bus-stop signs so that a tourist can couple their mobile phone to trigger steps in a sequence of multimedia presentations at those locations telling the history of the city. A retail chain may create a narrative structure using the same bus-stop signs to guide customers from one shop to the next. In this example the same couples serve visitors following very different narratives: would contention for the couples between the two types of user be dealt with as couple capacity was dealt with in the trials? How would observation of shopping information at a couple affect the experience of a visitor waiting to use the couple for the tourist experience? The experiences during the *Anywhere-Somewhere-Everywhere* event highlighted the importance of viewing the point of overlap of different narratives as opportunities for interesting social interactions between users, yet this framework does not yet consider these opportunities.

Each of these questions represents an exciting opportunity for further development of the framework to increase its utility for those considering coupling environment design in the future. The framework in its current form offers an argument for the benefits of developing a space into a coupling environment alongside illustrative examples and design principles for the designer hoping to achieve those benefits. It is the hope of the author that this argument encourages the field to dedicate more resources to the exploration of coupling and that the framework presented here provides the basis for this exploration.

Credits

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- *Figure 5 Chameleon used with desktop computer (left) and to create 'active map' (right)*
    - http://www.dgp.toronto.edu/~gf/Research/Chameleon/ChameleonImages.htm accessed on 8/9/09
- *Figure 7 Disc-O-Share interaction with proximity regions highlighted*
    - http://www.deutsche-telekom-laboratories.de/~rohs/disc-o-share/ accessed on 10/9/09
- *Figure 9 Blinkenlights*
    - http://www.flickr.com/photos/viernullvier/3047866994/ accessed on 6/8/09
    - Credit to http://www.flickr.com/people/viernullvier/
- *Figure 10 Blinkenlights Stereoscope*
    - Adapted from http://www.flickr.com/photos/wvs/2909325436/ accessed on 6/8/09
    - Credit to Sam Javanrouh
- *Figure 88 BBC Big Screen in Liverpool*
    - http://www.flickr.com/photos/pixelsumo/3922605426/sizes/o/ accessed on 28/9/09
    - Credit to Chris O'Shea
- *Figure 89 Mobile phones creating public displays*
    - http://www.microvision.com/pico_projector_displays/application_gallery.html accessed on 29/10/09

Development & implementation

- *Eclipse IDE*
    - http://www.eclipse.org/
- *J2ME Polish*
    - http://www.j2mepolish.org/
- *Java SE/ME*
    - http://java.sun.com/
- *MySQL*

    - http://dev.mysql.com/
- *Google Earth*
    - http://earth.google.co.uk/
- *ARTECT*
- *Last.fm API*
    - http://www.last.fm/api/intro
- *GeoNames API*
    - http://www.geonames.org/export/web-services.html
- *Phidgets*
    - http://www.phidgets.com/

Documentation

- *Screenshot for Symbian OS*
    - http://mosh.nokia.com/content/47809CFFF4D1216AE040050A44300674
- *MySQL Workbench*
    - http://dev.mysql.com/workbench/
- *MySQL-to-Excel*
    - http://convert-in.com/sql2xls.htm

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References

ABOWD, G., ATKESON, C., HONG, J., LONG, S., KOOPER, R. & PINKERTON, M. (1997) Cyberguide: a mobile context-aware tour guide. *Wireless Networks,* 3 (5) pp. 421-433.

ACCOT, J. & ZHAI, S. (1997) Beyond Fitts' law: models for trajectory-based HCI tasks. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Atlanta, Georgia, United States. ACM. pp. 295-302

ANANNY, M., BIDDICK, K. & STROHECKER, C. (2003) Constructing Public Discourse with Ethnographic/SMS "Texts". In *Proceedings of MobileHCI conference on Human-Computer Interaction with Mobile Devices and Services* Udine, Italy. Springer Berlin/Heidelberg. pp. 368-373

APPLEYARD, D. A. (1969) Why buildings are known - A predictive tool for architects and planners. *Environment and Behaviour,* (1) pp. 131-156.

BALDAUF, M., DUSTDAR, S. & ROSENBERG, F. (2007) A survey on context-aware systems. *Ad Hoc and Ubiquitous Computing,* 2 (4) pp. 263-277.

BALLAGAS, R., BORCHERS, J., ROHS, M. & SHERIDAN, J. G. (2006) The smart phone: a ubiquitous input device. *Pervasive Computing,* 5 (1) pp. 70-77.

BEDWELL, B. & KOLEVA, B. (2007) Demonstrating Coherent Interactions between Personal Mobile Devices and Situated Installations. In BROLL, G., DE LUCA, A., RUKZIO, E., NODA, C., WISNER, P., CHEVERST, K. & SCHMIDT-BELZ, B. (Eds.) *Proceedings of joint workshop on Mobile Interaction with the Real World and HCI in Mobile Guides in conjunction with MobileHCI conference on Human Computer Interaction with Mobile Devices and Services,* Singapore. University of Munich. pp. 47-50

BEDWELL, B., SCHNÄDELBACH, H., BENFORD, S., RODDEN, T. & KOLEVA, B. (2009) In Support of City Exploration. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Boston, Massachusetts, USA. ACM. pp. 1171-1180

BEEHAREE, A. & STEED, A. (2006) A natural wayfinding exploiting photos in pedestrian navigation systems. In *Proceedings of MobileHCI conference on Human-Computer Interaction with Mobile Devices and Services,* Helsinki, Finland. ACM. pp. 81-88

BELLOTTI, V., BACK, M., EDWARDS, K., GRINTER, R., HENDERSON, A. & LOPES, C. (2002) Making sense of sensing systems: five questions for designers and researchers. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Minneapolis, Minnesota, USA. ACM. pp. 415-422

BELLOTTI, V., BEGOLE, B., CHI, E., DUCHENEAUT, N., FANG, J., ISAACS, E., KING, T., NEWMAN, M., PARTRIDGE, K., PRICE, B., RASMUSSEN, P., ROBERTS, M., SCHIANO, D. & WALENDOWSKI, A. (2008) Activity-based serendipitous recommendations with the Magitti mobile leisure guide. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Florence, Italy. ACM. pp. 1157-1166

BENFORD, S., CRABTREE, A., REEVES, S., SHERIDAN, J., DIX, A., FLINTHAM, M. & DROZD, A. (2006) The Frame of the Game: Blurring the Boundary between Fiction and Reality in Mobile Experiences. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Montreal, Quebec, Canada. ACM. pp. 427-436

BENFORD, S. & GIANNACHI, G. (2008) Temporal trajectories in shared interactive narratives. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Florence, Italy. ACM. pp. 73-82

BENFORD, S., GIANNACHI, G., KOLEVA, B. & RODDEN, T. (2009) From interaction to trajectories: designing coherent journeys through user experiences. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Boston, MA, USA. ACM. pp. 709-718

BENFORD, S., SCHNÄDELBACH, H., KOLEVA, B., ANASTASI, R., GREENHALGH, C., RODDEN, T., GREEN, J., GHALI, A., PRIDMORE, T., GAVER, B., BOUCHER, A., WALKER, B., PENNINGTON, S., SCHMIDT, A., GELLERSEN, H. & STEED, A. (2005) Expected, sensed, and desired: A framework for designing sensing-based interaction. *Transactions on Computer-Human Interaction,* 12 (1) pp. 3-30.

BREHAUT, J. & SIMONSSON, E. (2006) Dana Centre Audience Profile, November 2005 - July 2006. Dana Centre/Science Museum.

BRIGNULL, H. (2005) Design for the adoption of Community Displays in Communal Spaces. Unpublished DPhil Thesis, University of Sussex, Brighton, UK.

BRIGNULL, H. & ROGERS, Y. (2003) Enticing People to Interact with Large Public Displays in Public Spaces. In *Proceedings of INTERACT conference on Human-Computer Interaction,* Zurich, Switzerland. pp. 17-24

BROWN, B., CHALMERS, M., BELL, M., HALL, M., MACCOLL, I. & RUDMAN, P. (2005) Sharing the square: collaborative leisure in the city streets. In *Proceedings of ECSCW conference on Computer Supported Cooperative Work,* Paris, France. Springer-Verlag New York. pp. 427-447

BROWN, P. J. & JONES, G. J. F. (2001) Context-aware Retrieval: Exploring a New Environment for Information Retrieval and Information Filtering. *Personal Ubiquitous Computing,* 5 (4) pp. 253-263.

BURNETT, G. (2000) "Turn right at the traffic lights": the requirement for landmarks in vehicle navigation systems. *Navigation,* 53 (3) pp. 499-510.

BUXTON, W. (1983) Lexical and pragmatic considerations of input structures. *SIGGRAPH Computer Graphics,* 17 (1) pp. 31-37.

CAMARATA, K., DO, E., GROSS, M. & JOHNSON, B. (2002) Navigational blocks: tangible navigation of digital information. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems (extended abstracts),* Minneapolis, Minnesota, USA. ACM. pp. 752-753

CARD, S., MACKINLAY, J. & ROBERTSON, G. (1990) The design space of input devices. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Seattle, Washington, United States ACM. pp. 117-124

CARD, S., MACKINLAY, J. & ROBERTSON, G. (1991) A morphological analysis of the design space of input devices. *Transactions on Information Systems,* 9 (2) pp. 99-122.

CARTER, S., CHURCHILL, E., DENOUE, L., HELFMAN, J. & NELSON, L. (2004) Digital graffiti: public annotation of multimedia content. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems extended abstracts,* Vienna, Austria. ACM Press. pp. 1207-1210

CHALMERS, M. (2004) A Historical View of Context. *Computer Supported Cooperative Work,* 13 (3) pp. 223-247.

CHALMERS, M., RODDEN, K. & BRODBECK, D. (1998) The order of things: activity-centred information access. *Computer Networks and ISDN Systems,* 30 (1-7) pp. 359-367.

CHEN, H. (2004) An Intelligent Broker Architecture for Pervasive Context-Aware Systems. Unpublished PhD Thesis, University of Maryland, Baltimore.

CHEVERST, K., DAVIES, N., MITCHELL, K., FRIDAY, A. & EFSTRATIOU, C. (2000) Developing a context-aware electronic tourist guide: some issues and experiences. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* The Hague, The Netherlands. ACM. pp. 17-24

CHEVERST, K., DIX, A., FITTON, D., FRIDAY, A. & ROUNCEFIELD, M. (2003) Exploring the Utility of Remote Messaging and Situated Office Door Displays. *Human-Computer Interaction with Mobile Devices and Services.* pp. 336-341

CHEVERST, K., DIX, A., FITTON, D., KRAY, C., ROUNCEFIELD, M., SAS, C., SASLIS-LAGOUDAKIS, G. & SHERIDAN, J. (2005a) Exploring bluetooth based mobile phone interaction with the hermes photo display. In *Proceedings of MobileHCI conference on Human-Computer Interaction with Mobile Devices & Services,* Salzburg, Austria. ACM. pp. 47-54

CHEVERST, K., DIX, A., FITTON, D., KRAY, C., ROUNCEFIELD, M., SASLIS-LAGOUDAKIS, G. & SHERIDAN, J. (2005b) Exploring Mobile Phone Interaction with Situated Displays. In RUKZIO, E., HÄKKILÄ, J., SPASOJEVIC, M., MÄNTYJÄRVI, J. & RAVI, N. (Eds.) *Proceedings of PERMID workshop in conjunction with conference on Pervasive Computing,* Munich, Germany. pp. 43-47

CHEVERST, K., MITCHELL, K. & DAVIES, N. (2001) Investigating context-aware information push vs. information pull to tourists. In DUNLOP, M. D. & BREWSTER, S. A. (Eds.) *Proceedings of MobileHCI conference on Human-Computer Interaction with Mobile Devices and Services,* Lille, France. pp. 1-6

CHITTARO, L. & BURIGAT, S. (2005) Augmenting audio messages with visual directions in mobile guides: an evaluation of three approaches. In *Proceedings of MobileHCI conference on Human-Computer Interaction with Mobile Devices & Services,* Salzburg, Austria. ACM. pp. 107-114

CHURCHILL, E., NELSON, L., DENOUE, L., HELFMAN, J. & MURPHY, P. (2004) Sharing multimedia content with interactive public displays: a case study. In *Proceedings of DIS conference on Designing Interactive Systems,* Cambridge, MA, USA. ACM. pp. 7-16

CIAVARELLA, C. & PATERNÒ, F. (2004) The design of a handheld, location-aware guide for indoor environments. *Personal and Ubiquitous Computing,* 8 (2) pp. 82-91.

DIX, A. (2007) Designing for appropriation. In *Proceedings of BCS-HCI conference on Human-Computer Interaction,* University of Lancaster, United Kingdom. British Computer Society. pp. 27-30

DIX, A. & SAS, C. (2008) Public displays and private devices: A design space analysis. *Workshop on Designing and Evaluating Mobile Phone-based Interaction with Public Displays in conjunction with SIGCHI conference on Human-Computer Interaction.* Florence, Italy.

DOURISH, P. (2003) The Appropriation of Interactive Technologies: Some Lessons from Placeless Documents. *Computer Supported Cooperative Work,* 12 (4) pp. 465-490.

DREYFUS, H. (1990) *Being-in-the-World: A Commentary on Heidegger's Being and Time, Division I*, The MIT Press.

DUCATEL, K., BOGDANOWICZ, M., SCAPOLO, F., LEIJTEN, J. & BURGELMAN, J. C. (2001) Scenarios for Ambient Intelligence in 2010. IST Advisory Group.

DUH, H., TAN, G. & CHEN, V. (2006) Usability evaluation for mobile device: a comparison of laboratory and field tests. In *Proceedings of MobileHCI conference on Human-Computer Interaction with Mobile Devices and Services,* Helsinki, Finland. ACM. pp. 181-186

EDWARDS, K., BELLOTTI, V., DEY, A. & NEWMAN, M. (2003) The challenges of user-centered design and evaluation for infrastructure. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Ft. Lauderdale, Florida, USA. ACM. pp. 297-304

EGENHOFER, M. (1999) Spatial Information Appliances: A Next Generation of Geographic Information Systems. *GEOINFO workshop on Geoinformatics.* São Paulo, Brazil.

FINKE, M., TANG, A., LEUNG, R. & BLACKSTOCK, M. (2008) Lessons learned: game design for large public displays. In *Proceedings of DIMEA conference on Digital Interactive Media in Entertainment and Arts,* Athens, Greece. ACM. pp. 26-33

FISHKIN, K. (2004) A taxonomy for and analysis of tangible interfaces. *Personal and Ubiquitous Computing,* 8 (5) pp. 347-358.

FITZMAURICE, G. (1993) Situated information spaces and spatially aware palmtop computers. *Communications of the ACM,* 36 (7) pp. 39-49.

FITZMAURICE, G. & BUXTON, W. (1994) The Chameleon: spatially aware palmtop computers. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Boston, Massachusetts, United States. ACM. pp. 451-452

FITZPATRICK, G., MANSFIELD, T. & KAPLAN, S. (1996) Locales Framework: Exploring Foundations for Collaboration Support. In *Proceedings of OZCHI conference on Computer-Human Interaction,* Hamilton, New Zealand. IEEE. pp. 34

FOLEY, J., WALLACE, V. & CHAN, P. (1984) The human factors of computer graphics interaction techniques. *Computer Graphics and Applications,* 4 (11) pp. 13-48.

FRANZ, G., MALLOT, H. & WIENER, J. (2005) Graph-based models of space in architecture and cognitive science - a comparative analysis. In *Proceedings of INTERSYMP conference on Systems Research, Informatics and Cybernetics,* Baden-Baden, Germany. pp. 30–38

FRÖHLICH, P., SIMON, R., BAILLIE, L. & ANEGG, H. (2006) Comparing conceptual designs for mobile access to geo-spatial information. In *Proceedings of MobileHCI conference on Human-Computer Interaction with Mobile Devices and Services,* Helsinki, Finland. ACM. pp. 109-112

FRUHLING, A. & WILSON, V. (2007) Minitrack: HCI Issues in Healthcare IT. In *Proceedings of HICSS conference on System Sciences,* Big Island, Hawaii. IEEE. pp. 137

GARZOTTO, F. & PAOLINI, P. (2008) A Conceptual Framework for Content-Intensive Phone-based Interaction with Public Displays. *Workshop on Designing and Evaluating Mobile-phone-based Interaction with Public Displays in conjunction with SIGCHI conference on Human Factors in Computing Systems.* Florence, Italy.

GHIANI, G., PATERNÒ, F., SANTORO, C. & SPANO, L. (2008) Enhancing Mobile Museum Guides with Public Displays. *Workshop on Designing and Evaluating Mobile-phone-based Interaction with Public Displays in conjunction with SIGCHI conference on Human Factors in Computing Systems.* Florence, Italy.

GIBSON, J. (1979) *The Ecological Approach to Visual Perception*, Houghton Mifflin.

GILLNER, S. & MALLOT, H. (1998) Navigation and Acquisition of Spatial Knowledge in a Virtual Maze. *Cognitive Neuroscience,* 10 (4) pp. 445-463.

GOFFMAN, E. (1956) On Face-Work: An Analysis of Ritual Elements in Social Interaction. *Psychiatry,* 18 pp. 213-231.

GOFFMAN, E. (1959) *The Presentation of Self in Everyday Life*, Anchor.

GOODMAN, J., BREWSTER, S. A. & GRAY, P. (2005) How Can We Best Use Landmarks to Support Older People in Navigation. *Behaviour and Information Technology,* 24 pp. 3-20.

GROSS, M. & DO, E. (2004) Toward Design Principles for Invisible Interfaces. *Workshop on Invisible and Transparent Interfaces in conjunction with AVI conference on Advanced Visual Interfaces.* Gallipoli, Italy.

HANSMANN, U., NICKLOUS, M. & STOBER, T. (2001) *Pervasive computing handbook*, Springer-Verlag New York.

HARDY, R. & RUKZIO, E. (2008) Touch & interact: touch-based interaction of mobile phones with displays. In *Proceedings of MobileHCI conference on Human-Computer Interaction with Mobile Devices and Services,* Amsterdam, The Netherlands. ACM. pp. 245-254

HITZEMAN, J., MELLISH, C. & OBERLANDER, J. (1997) Dynamic Generation of Museum Web Pages: The Intelligent Labelling Explorer. *Archives and Museum Informatics,* pp. 107-115.

HOLMQUIST, L., REDSTRÖM, J. & LJUNGSTRAND, P. (1999) Token-Based Access to Digital Information. IN GELLERSEN, H.-W. (Ed.) *Handheld and Ubiquitous Computing.* Springer-Verlag. pp. 234-245

HOLMQUIST, L., SANNEBLAD, J. & GAYE, L. (2003) Total recall: in-place viewing of captured whiteboard annotations. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems (extended abstracts),* Ft. Lauderdale, Florida, USA. ACM. pp. 980-981

HOPE, T., NAKAMURA, Y., TAKAHASHI, T., NOBAYASHI, A., FUKUOKA, S., HAMASAKI, M. & NISHIMURA, T. (2009) Familial collaborations in a museum. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Boston, MA, USA. ACM. pp. 1963-1972

HORNECKER, E., MARSHALL, P. & ROGERS, Y. (2007) From entry to access: how shareability comes about. In *Proceedings of DPPI conference on Designing Pleasurable Products and Interfaces,* Helsinki, Finland. ACM. pp. 328-342

HP, L. P. & PERICH, F. (2002) A service for aggregating and interpreting contextual information. Hewlett Packard.

HUANG, C. & CHARMAN, T. (2005) Gradations of emulation learning in infants' imitation of actions on objects. *Experimental Child Psychology,* 92 (3) pp. 276-302.

INDULSKA, J. & SUTTON, P. (2003) Location management in pervasive systems. In *Proceedings of ACSW conference on Australasian Information Security Workshop Frontiers,* Adelaide, Australia. Australian Computer Society. pp. 143-151

ISHII, H. & ULLMER, B. (1997) Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Atlanta, Georgia, United States. ACM. pp. 234-241

IZADI, S., BRIGNULL, H., RODDEN, T., ROGERS, Y. & UNDERWOOD, M. (2003) Dynamo: a public interactive surface supporting the cooperative sharing and exchange of media. In *Proceedings of UIST conference on User Interface Software and Technology,* Vancouver, Canada. ACM. pp. 159-168

IZADI, S., FITZPATRICK, G., RODDEN, T., BRIGNULL, H., ROGERS, Y. & LINDLEY, S. (2005) The iterative design and study of a large display for shared and sociable spaces. In *Proceedings of DUX conference on Designing for User eXperience,* San Francisco, California. American Institute of Graphic Arts. pp. 2-19

IZADI, S., FRASER, M., BENFORD, S., FLINTHAM, M., GREENHALGH, C., RODDEN, T. & SCHNÄDELBACH, H. (2002) Citywide: Supporting Interactive Digital Experiences Across Physical Space. *Personal and Ubiquitous Computing,* 6 (4) pp. 290-298.

JAIMES, A. (2010) Data Mining for User Modeling and Personalization in Ubiquitous Spaces. IN NAKASHIMA, H., AGHAJAN, H. & AUGUSTO, J. (Eds.) *Handbook of Ambient Intelligence and Smart Environments.* Springer US. pp. 1015-1038

JIN, C., TAKAHASHI, S. & TANAKA, J. (2006) Interaction Between Small Size Device and Large Screen in Public Space. *Knowledge-Based Intelligent Information and Engineering Systems.* Springer Berlin/Heidelberg. pp. 197-204

KAPLAN, S. (1976) Adaptation, structure and knowledge. IN MOORE, G. & GOLLEDGE, R. (Eds.) *Environmental knowing: Theories, research and methods.* Stroudsburg, PA, Dowden, Hutchinson and Ross. pp. 32-45

KARAM, M., PAYNE, T. & DAVID, E. (2007) Evaluating BluScreen: Usability for Intelligent Pervasive Displays. In *Proceedings of ICPCA conference on Pervasive Computing and Applications,* Birmingham, UK. pp. 18-23

KIRSH, D. (2001) The Context of Work. *Human-Computer Interaction,* 16 (2) pp. 305-322.

KJELDSKOV, J. & GRAHAM, C. (2003) A Review of Mobile HCI Research Methods. *Human-Computer Interaction with Mobile Devices and Services.* Springer Berlin/Heidelberg. pp. 317-335

KOZUCH, M. & SATYANARAYANAN, M. (2002) Internet suspend/resume. *Workshop on Mobile Computing Systems and Applications.* Callicoon, NY, USA, IEEE.

KRAY, C., KORTUEM, G. & KRÜGER, A. (2005) Adaptive navigation support with public displays. *IUI conference on Intelligent User Interfaces.* San Diego, California, USA, ACM.

KRAY, C. & ROHS, M. (2007) Swiss Army Knife meets Camera Phone: Tool Selection and Interaction using Visual Markers. IN BROLL, G., DE LUCA, A., RUKZIO, E., NODA, C., WISNER, P., CHEVERST, K. & SCHMIDT-BELZ, B. (Eds.) *Joint Workshop on Mobile Interaction with the Real World and HCI in Mobile Guides in conjunction with MobileHCI conference on Human Computer Interaction with Mobile Devices and Services.* Singapore.

KRAY, C., ROHS, M., HOOK, J. & KRATZ, S. (2008) Group coordination and negotiation through spatial proximity regions around mobile devices on augmented tabletops. In *Proceedings of TABLETOP workshop on Horizontal Interactive Human Computer Systems,* Amsterdam, The Netherlands. IEEE. pp. 1-8

LAGOUDAKIS, G., CHEVERST, K., DIX, A., FITTON, D. & ROUNCEFIELD, M. (2006) Hermes@Home: supporting awareness and intimacy between distant family members. In *Proceedings of OZCHI conference on Computer-Human Interaction,* Sydney, Australia. ACM. pp. 23-30

LEONG, T., HOWARD, S. & VETERE, F. (2008) Choice: abidcating or exercising? In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Florence, Italy. ACM. pp. 715-724

LEONG, T., VETERE, F. & HOWARD, S. (2005) The serendipity shuffle. In *Proceedings of OZCHI conference on Computer-Human Interaction,* Canberra, Australia. Computer-Human Interaction Special Interest Group of Australia. pp. 1-4

LIDWELL, W., HOLDEN, K. & BUTLER, J. (2003) *Universal Principles of Design*, Rockport Publishers.

LIJDING, M. E. M., MERATNIA, N., BENZ, H. P. & MATYSIAK (2007) Smart Signs Show You the Way. *I/O Vivat,* 22 (4) pp. 35-38.

LINDGAARD, G. (2006) Notions of thoroughness, efficiency, and validity: Are they valid in HCI practice? *Industrial Ergonomics,* 36 (12) pp. 1069-1074.

LYNCH, K. (1960) *The Image of the City*, The MIT Press.

MAUNDER, A., MARSDEN, G. & HARPER, R. (2007) Creating and sharing multi-media packages using large situated public displays and mobile phones. In *Proceedings of MobileHCI conference on Human-Computer Interaction with Mobile Devices and Services,* Singapore. ACM. pp. 222-225

MAUNDER, A., MARSDEN, G. & HARPER, R. (2008) SnapAndGrab: accessing and sharing contextual multi-media content using bluetooth enabled camera phones and large situated displays. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems (extended abstracts),* Florence, Italy. ACM. pp. 2319-2324

MIYAOKU, K., HIGASHINO, S. & TONOMURA, Y. (2004) C-blink: a hue-difference-based light signal marker for large screen interaction via any mobile terminal. In *Proceedings of UIST conference on User Interface Software and Technology,* Santa Fe, NM, USA. ACM. pp. 147-156

MORI (2005) Renaissance in the Regions, Museum Visitor Survey 2004 - West Midlands Region. Museums, Libraries and Archives Council.

MÜLLER, J. O., JENTSCH, M., KRAY, C. & KRÜGER, A. (2008) Exploring factors that influence the combined use of mobile devices and public displays for pedestrian navigation. In *Proceedings of NordiCHI conference on Human-Computer Interaction,* Lund, Sweden. ACM. pp. 308-317

MYERS, B. (2001) Using handhelds and PCs together. *Communications of the ACM,* 44 (11) pp. 34-41.

MYERS, B., STIEL, H. & GARGIULO, R. (1998) Collaboration using multiple PDAs connected to a PC. In *Proceedings of CSCW conference on Computer Supported Cooperative Work,* Seattle, Washington, United States. ACM. pp. 285-294

NARAYANASWAMI, C., COFFMAN, D., LEE, M. C., MOON, Y. S., HAN, J. H., JANG, H. K., MCFADDIN, S., PAIK, Y. S., KIM, J. H., LEE, PARK, J. W. & SOROKER, D. (2008) Pervasive symbiotic advertising. In *Proceedings of HotMobile workshop on Mobile Computing Systems and Applications,* Napa Valley, California. ACM. pp. 80-85

NIELSEN, C., OVERGAARD, M., PEDERSEN, M., STAGE, J. & STENILD, S. (2006) It's worth the hassle!: the added value of evaluating the usability of mobile systems in the field. In *Proceedings of NordiCHI conference on Human-Computer Interaction,* Oslo, Norway. ACM. pp. 272-280

NORMAN, D. (1990) *The Design of Everyday Things*, Doubleday Business.

NORMAN, D. (1991) Cognitive artifacts. IN CARROLL, J. M. (Ed.) *Designing interaction: psychology at the human-computer interface.* Cambridge University Press. pp. 17-38

NORMAN, D. (1999) Affordance, conventions, and design. *Interactions,* 6 (3) pp. 38-43.

O'GRADY, M. J., O'HARE, G. M. P. & DONAGHEY, C. (2007) Delivering adaptivity through context-awareness. *Network and Computer Applications,* 30 (3) pp. 1007-1033.

O'HARA, K., HARPER, R., UNGER, A., WILKES, J. & JANSEN, M. (2004) TxtBoard: from text-to-person to text-to-place. *Workshop on Ubiquitous Display Environments in conjunction with Ubicomp 2004.* Nottingham, UK.

OBERLANDER, J., MELLISH, C., O'DONNELL, M. & KNOTT, A. (1997) Exploring a gallery with intelligent labels. *MIM conference on Cultural Heritage Systems Design and Interfaces.* Le Louvre, Paris, France, Archives & Museum Informatics.

OFFICE FOR NATIONAL STATISTICS (2005) The National Statistics Socio-economic Classification User Manual. Palgrave Macmillan.

OJALA, T., KORHONEN, J., AITTOLA, M., OLLILA, M., KOIVUMÄKI, T., TÄHTINEN, J. & KARJALUOTO, H. (2003) SmartRotuaari – Context-aware Mobile Multimedia Services. In *Proceedings of MUM conference on Mobile and Ubiquitous Multimedia,* Norrköping, Sweden. pp. 9-18

OPPERMANN, R. & SPECHT, M. (1999) A Nomadic Information System for Adaptive Exhibition Guidance. *Archives and Museum Informatics,* 13 (2) pp. 127-138.

PHAM, T., SCHNEIDER, G. & GOOSE, S. (2000) A situated computing framework for mobile and ubiquitous multimedia access using small screen and composite devices. In *Proceedings of MULTIMEDIA conference on Multimedia,* Marina del Rey, California, United States. ACM. pp. 323-331

POSLAD, S., LAAMANEN, H., MALAKA, R., NICK, A., BUCKLE, P. & ZIPL, A. (2001) CRUMPET: creation of user-friendly mobile services personalised for tourism. In *Proceedings of conference on 3G Mobile Communication Technologies,* London, UK. IEEE. pp. 28-32

RAGHUNATH, M., NARAYANASWAMI, C. & PINHANEZ, C. (2003) Fostering a Symbiotic Handheld Environment. *Computer,* 36 (9) pp. 56-65.

RAJ, H., GOSSWEILER, R. & MILOJICIC, D. (2004) ContentCascade incremental content exchange between public displays and personal devices. In *Proceedings of MOBIQUITOUS conference on Mobile and Ubiquitous Systems: Networking and Services,* Boston, Massachusetts, USA. pp. 374-381

REEVES, S., BENFORD, S., O'MALLEY, C. & FRASER, M. (2005) Designing the spectator experience. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Portland, Oregon, USA. ACM. pp. 741-750

REKIMOTO, J. (1997) Pick-and-drop: a direct manipulation technique for multiple computer environments. In *Proceedings of UIST conference on User Interface Software and Technology,* Banff, Alberta, Canada. ACM. pp. 31-39

RUKZIO, E., SCHMIDT, A. & KRÜGER, A. (2005) The rotating compass: a novel interaction technique for mobile navigation. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems (extended abstracts),* Portland, OR, USA. ACM. pp. 1761-1764

SADALLA, E. K., BURROUGHS, W. J. & STAPLIN, L. J. (1980) Reference points in spatial cognition. *Experimental Psychology: Human Learning and Memory,* 6 (5) pp. 516-528.

SCHILIT, B., ADAMS, N. & WANT, R. (1994) Context-aware computing applications. In *Proceedings of WMCSA workshop on Mobile Computing Systems and Applications,* Santa Cruz, CA, US. pp. 89–101

SCHILIT, B. & THEIMER, M. (1994) Disseminating active map information to mobile hosts. *IEEE Network,* 8 pp. 22-32.

SCHMIDT-BELZ, B., LAUKKANEN, M., LAAMANEN, H., VERÍSSIMO, M., ZIPF, A., ARAS, H. & POSLAD, S. (2003) CRUMPET, Creation of User Friendly Mobile Services Personalised for Tourism.

SCHNÄDELBACH, H., HALE, J., DORNER, W., BEDWELL, B., BENFORD, S. & MARDELL, J. (2006) Future Garden. *Technologies for Interactive Digital Storytelling and Entertainment.* pp. 346-351

SCHOLKOPF, B. & MALLOT, H. (1995) View-Based Cognitive Mapping and Path Planning. *Adaptive Behavior,* 3 (3) pp. 311-348.

SCHOLTZ, J. & CONSOLVO, S. (2004) Towards a discipline for evaluating ubiquitous computing applications. *Pervasive Computing Magazine,* 3 (2) pp. 82-88.

SHARIFI, M., PAYNE, T. & DAVID, E. (2006) Public Display Advertising Based on Bluetooth Device Presence. *MIRW workshop on Mobile Interaction with the Real World in conjunction with MobileHCI conference on Human Computer Interaction with Mobile Devices and Services.* Helsinki, Finland.

SIMCOCK, T., HILLENBRAND, S. & THOMAS, B. (2003) Developing a location based tourist guide application. In *Proceedings of ACSW conference on Australasian Information Security Workshop Frontiers,* Adelaide, Australia. Australian Computer Society. pp. 177-183

TWIDALE, M. (2005) Over the Shoulder Learning: Supporting Brief Informal Learning. *Computer Supported Cooperative Work,* 14 (6) pp. 505-547.

ULLMER, B. (2002) Tangible interfaces for manipulating aggregates of digital information. Unpublished PhD Thesis, Massachusetts Institute of Technology.

ULLMER, B. & ISHII, H. (2000) Emerging frameworks for tangible user interfaces. *IBM Systems,* 39 (3-4) pp. 915-931.

ULLMER, B., ISHII, H. & JACOB, R. (2005) Token+constraint systems for tangible interaction with digital information. *Transactions on Computer-Human Interaction,* 12 (1) pp. 81-118.

UNDERKOFFLER, J. & ISHII, H. (1999) Urp: a luminous-tangible workbench for urban planning and design. In *Proceedings of SIGCHI conference on Human Factors in Computing Systems,* Pittsburgh, Pennsylvania, United States. ACM. pp. 386-393

WANG, Y., AROYO, L., STASH, N., RUTLEDGE, L., CONATI, C., MCCOY, K. & PALIOURAS, G. (2009) Interactive User Modeling for Personalized Access to Museum Collections: The Rijksmuseum Case Study. *User Modeling 2007.* Springer Berlin/Heidelberg. pp. 385-389

WANT, R., BORRIELLO, G., PERING, T. & FARKAS, K. (2002a) Disappearing Hardware. *Pervasive Computing,* 1 (1) pp. 36-47.

WANT, R., PERING, T., DANNEELS, G., KUMAR, M., SUNDAR, M. & LIGHT, J. (2002b) The Personal Server: Changing the Way We Think about Ubiquitous Computing. In *Proceedings of UbiComp conference on Ubiquitous Computing,* Goteborg, Sweden. Springer-Verlag. pp. 194-209

WEISER, M. (1991) The computer for the 21st century. *Scientific American,* 265 (3) pp. 94-104.

ZANCANARO, M., KUFLIK, T., BOGER, Z., GOREN-BAR, D., GOLDWASSER, D., CONATI, C., MCCOY, K. & PALIOURAS, G. (2009) Analyzing Museum Visitors' Behavior Patterns. *User Modeling 2007.* Springer Berlin/Heidelberg. pp. 238-246

ZHANG, J. & NORMAN, D. (1994) Representations in distributed cognitive tasks. *Cognitive Science,* 18 (1) pp. 87-122.

10. Appendix

10.1 Software infrastructure architecture

The relationships and cardinalities of relationships between actors in the coupling environment are summarised conceptually in Figure 91. Figure 92 and Figure 93 isolate the relationships comprising exploration and situated interaction respectively from Figure 91.

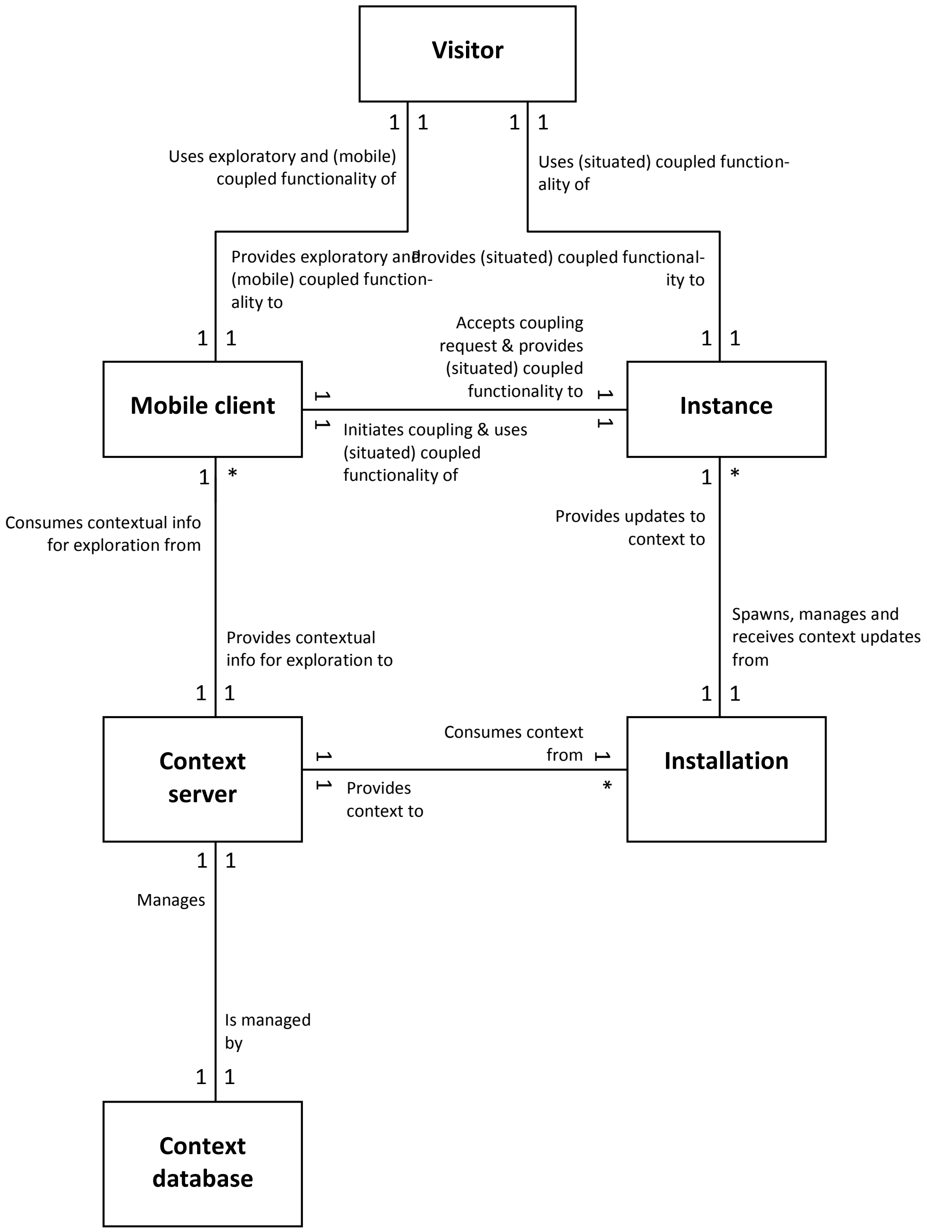


Figure 91 Coupling environment system infrastructure's major conceptual relationships

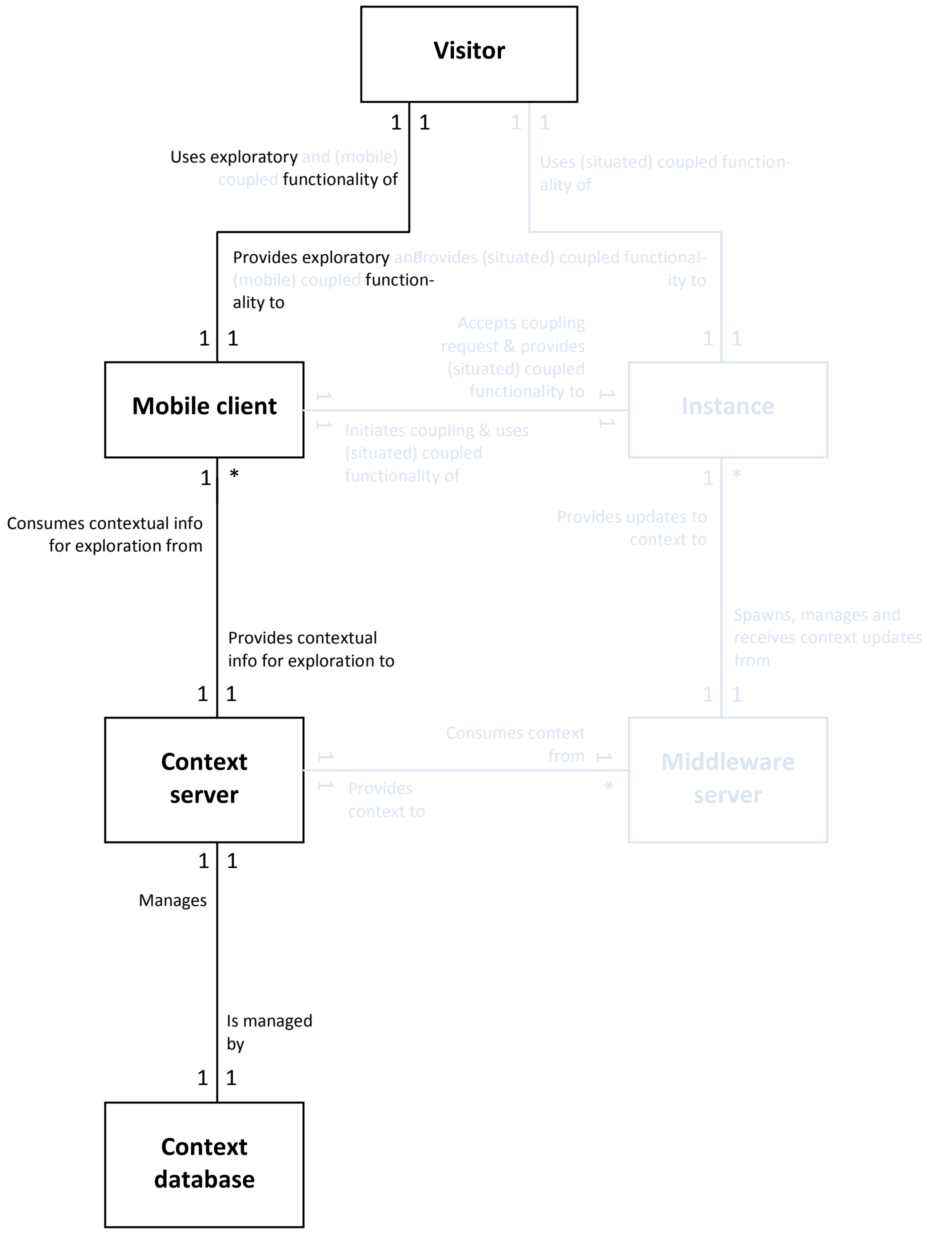


Figure 92 Conceptual relationships relating to exploration

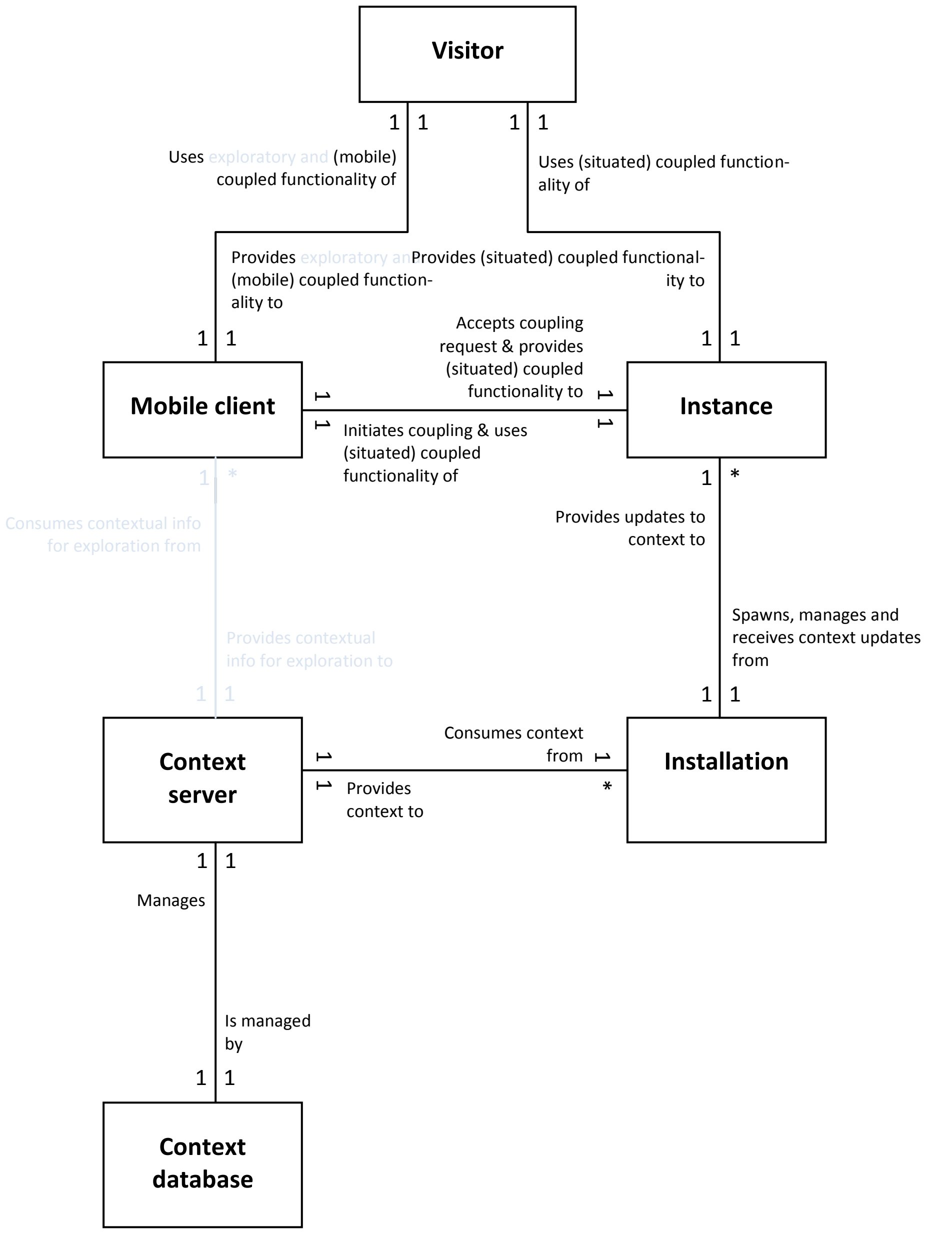


Figure 93 Conceptual relationships supporting situated interaction

10.1.1 Communication

The components of the test-bed are distributed across multiple distinct devices (see Figure 94). Underpinning the central relationships is the infrastructure's message passing system. There are three external bridges (E_1, E_2, E_3) where communication occurs via the network between devices and two internal (I_1 and I_2) where components from different infrastructure tiers deployed on the same device communicate.

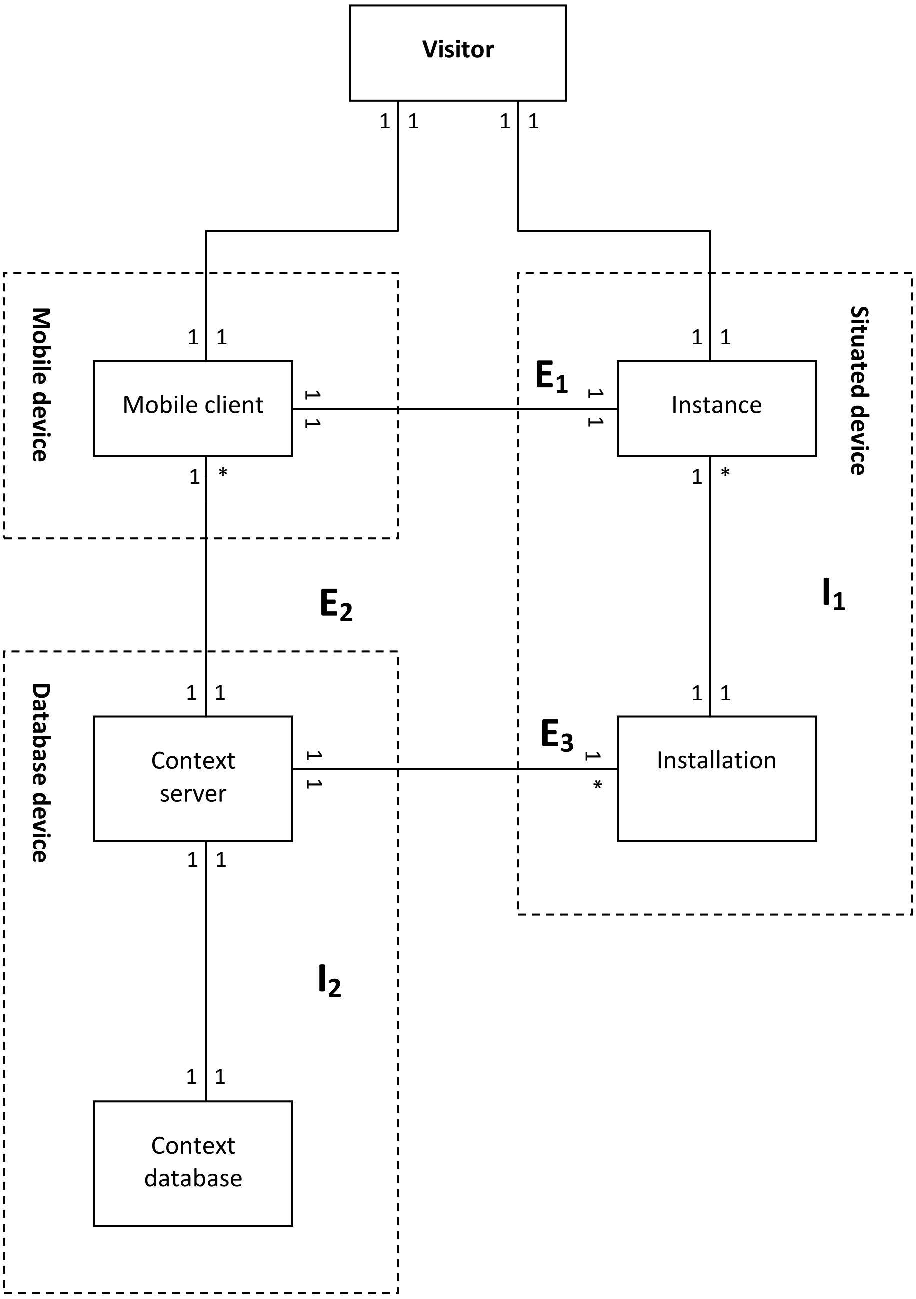


Figure 94 Device deployment and communication between infrastructure components

For simplicity of development situated devices and database device (all PCs) are connected using wired Ethernet, and 802.11 to connect wifi-enabled mobile phones to the same LAN. The same communication structure could be achieved using Bluetooth to connect mobile phones to the LAN, yet IP networking, particularly UDP communication has lower implementation overheads. The 802.11 capabilities becoming a mainstay of middle-upper-end mobile phones (particularly Nokia's E and N series, Apple iPhones, Blackberry phones, Sony Ericsson's W and C series and Samsung's I series) promise higher data throughput and range in comparison to Bluetooth (typically an order of magnitude greater in both cases). Even so, it should be stressed that (at this moment in time) there is no reason to advocate the use of 802.11 networking exclusively: in this case the choice was made simply as a means of allowing the test-bed to be rapidly deployed.

i. Messages

All four types of component involved in cross-device communication (mobile clients, installations and instances, and context server) each extend and instantiate a generic message handler object which listens for incoming UDP datagram packets. Datagram packets are interpreted as **Messages**[60] where a delimited array of bytes (the "payload") corresponds to a specific **message code** (specifying the type of the message) and optional additional message parts.

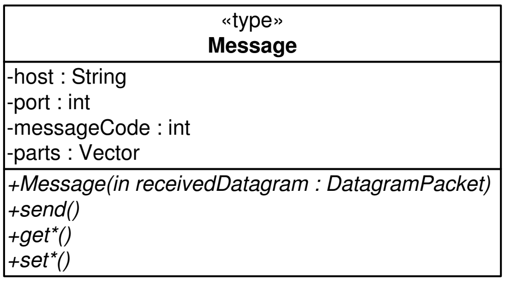


Figure 95 Message class

Messages received by the mobile client are checked first against a range of generic types of message[61]; message codes 400 and 401 indicate a message type sent by the context server only[62].

[60] See bzb.me.messaging.Message and bzb.se.messaging.Message
[61] See bzb.me.meta.MessageCodes
[62] See bzb.me.meta.MessageCodes.From.Instance.VisitorMonitor

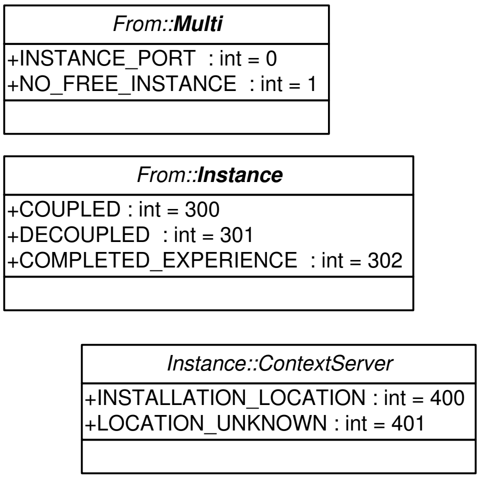


Figure 96 Generic message codes for messages received by mobile client

If a received message matches none of these types then the message may be passed to a further message handler instantiated during coupled interaction which handles messages expected only during interaction at particular couples. Figure 97[63] visualises the message codes of additional messages expected by the mobile client during coupled interaction at the *Slideshow* couple only.

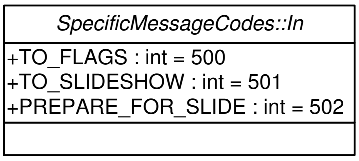


Figure 97 Specific message codes for messages received by mobile client during coupled interaction at *Slideshow* couple

If a message remains unhandled by both the generic message handler and any specific coupled interaction message handler currently instantiated then the message is assumed to have been received in error.

[63] Also see bzb.me.microenvironments.Slideshow.SpecificMessageCodes.In

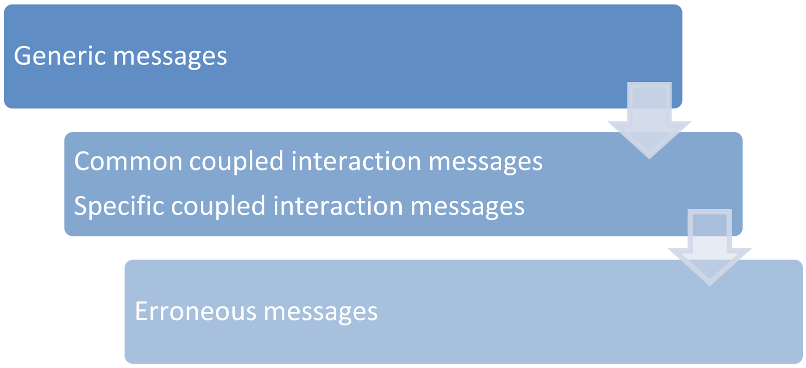


Figure 98 Waterfall mechanism for message handling by mobile client

Installations and the context server also maintain generic and specific message handlers utilising a similar waterfall mechanism[64]. In this case visitors may have coupled their mobile to a specific situated device thus owning their own instance; as such messages sent from a mobile to a situated device may either be intended for the installation at the device, or for the visitor's personal instance: messages received by a situated device are handled initially by the installation at the device, then (if unhandled) by any instances currently assigned to the sender. Figure 99 visualises specific message codes for *Registration* instances, **In** containing message codes for messages received by these instances and **Out** containing codes for messages sent by these instances.

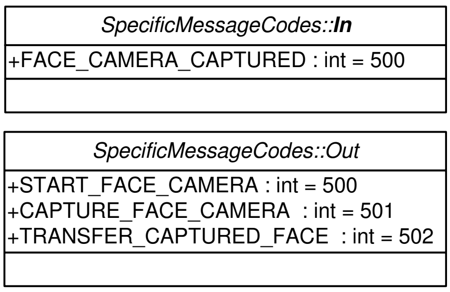


Figure 99 Specific message codes for messages received (In) and sent (Out) by instances of *Registration*

Each of the communicating components (mobile clients, installations/instances, and the context server) is also capable of generating and sending messages, where necessary utilising message codes relevant to the ongoing interaction.

Naturally both sides of any communication (i.e. sender and receiver of messages) must have knowledge of the message codes of messages sent during the communication. As such the

[64] See bzb.se.installations.Multi.MessageRouter

mobile client and context server both contain identical listings of the message codes for communication regarding exploration, while the mobile client and instance for couple *x* both contain identical listings of the message codes for communication during coupled interaction at couple *x*, and so on.

Messages are typically used to trigger or progress an interaction, leading to conversations between devices. These conversations may involve transfers of much larger bodies of data, e.g. during coupled interaction at the *Photo Wall* couple the mobile device indicates to its assigned instance that it wishes to push photographs currently contained on the mobile to the situated display by sending a message with a PUSH_THOUGHTS message code[65]. The instance reacts by opening a socket to which the mobile client then delivers the bytes comprising the photographs. Sockets are used by the components in such situations as this when it is necessary to guarantee a continuous quality-of-service over a period of time, while messages are used for the majority of communication.

ii. Addressing

Each mobile device in the coupling environment is assigned a unique IP address for the duration of its visit (i.e. the length of time connected to the environment wifi AP); in the case of situated devices and database device an IP is assigned for as long as the device is operational. IP acts as the identity of the device in the environment and as a means of routing communication. The database device is assigned a static IP address which is disseminated as part of each installation and mobile client such that these applications can communicate with the context server without need for a discovery process. As messages are sent and sockets created based upon IP addresses, and the IP addresses of devices other than the database device (i.e. situated devices and mobile devices) are dynamic there must be a mechanism to allow these devices to discover IP addresses.

10.1.2 Populating the context database

To afford this process of discovery the context database is populated with entity ID in the form of the devices' IP addresses. Relevant IP addresses are then passed by the context server to other devices as required in order to facilitate communication. Population of the database with IP addresses takes place constantly over time:

[65] bzb.me.microenvironments.Photowall.SpecificMessageCodes.Out.PUSH_THOUGHTS

Mobile devices register themselves with the context server upon instantiation of the mobile client, delivering a message to the context server triggering the mobile's IP to be added by the context server to the context database as a new visitor entity. In a similar manner, when installations are instantiated they are also registered in the context database (including IP address of their host device) as installation entities. Entities communicating via message require an end-point port (in addition to host) in order to send their messages, thus each new entity registered with the context server registers both a port and host address (by default 50000 for mobile clients, and 49990 to 49999 for instances, installations and context server depending upon how many instances are active at a situated device). Socket communication utilises an alternative port. Mobile devices become aware of the IP address of situated devices once the situated device has been chosen as the next destination of the visitor (i.e. when the visitor has chosen that particular coupling opportunity). Installations become aware of the visitor's IP at the same time and provide an instance for the visitor that will handle only messages from its visitor's IP, thus avoiding unnecessary overheads. Each mobile client is thus always aware of the IP of the database device and of the situated device to which it is currently coupled/intending to be coupled. An installation is also aware of the IP of the database device, and each instance generated by an installation is aware of the IP of the mobile device that they are currently serving (i.e. the mobile device currently coupled or intending to be coupled).

See appendix 10.2 for an entity-relationship diagram of the entire context database.

i. Static attributes

As previously stated, both mobile devices and situated devices register themselves with the context server upon instantiation in the coupling environment. Beyond that which has so far been mentioned as being added to the database (IP host and port) upon registration there are additional static attributes of these entities that are also registered.

Referring back to *Orchestration* (section 4.2.1), mobile devices must contribute a profile of technological capabilities[66]. Mobile devices, through Java ME, are capable of inspecting themselves for various capabilities, notably the ability to capture data from multimedia sources (microphone and cameras), display resolution, and the presence of sensors such as accelerometers. Upon registration a mobile device determines these aspects of its technological profile and passes them to the context server for population of the database.

[66] See visitors.* in appendix 10.2

A number of attributes of context required by the system are specified alongside the definitions of the coupled functionality at the installations, and are registered in the context database when the installations are instantiated[67]. These attributes include total coupling capacity, technological requirements, narrative dependencies and a textual name and description[68]. Technological capabilities are expressed as being either not required, a "soft" requirement (i.e. not necessary, but providing more interaction possibilities at the couple), or a "hard" requirement (a necessity for any coupled interaction)[69]. Narrative dependencies are simply a list of the other couples that must have been visited and "completed" before the coupled functionality becomes relevant; completion in this context is a fairly general concept that could refer to viewing a particular piece of content, pressing a particular button, and so on. See appendix 10.4 for a visualisation of the narrative dependencies of the final trial environment.

In addition the static topography of the coupling environment[70] is written to the context database when the context server is initialised. This topography consists of the locations and the *connectivity* of the situated devices. By this connectivity is referred to in the sense of wayfinding, i.e. whether or not a visitor can walk from one device to another and what paths through the environment the visitor can take to do so. In the context database connectivity is represented in the form of graph edges by pairs of locations[71] dictating that a visitor can walk between those pairs of locations. There is also scope within the infrastructure for the context server to interpret additional points-of-interest beyond situated devices, e.g. additional nodes in the environment topology, that allow for finer-grained paths between couples. As such representations of the coupling environment, such as that shown in appendix 10.3, contain a number of *pois* (points-of-interest)[72] which may simply be nodes on paths travelled by visitors, or may have a specific type: a poi with a type indicates that interaction occurs at that poi, e.g. a coupling opportunity.

[67] See bzb.se.installations.Multi.Multi()
[68] See installations.* in appendix 10.2
[69] See bzb.se.meta.Requirements
[70] See appendix 10.3 for the XML definition of the final trial coupling environment topography used by the context server to populate the context database and routes.* and environmentmap.* in appendix 10.2 for the resulting context database entities
[71] See routes.* in appendix 10.2
[72] See environmentmap.* in appendix 10.2

ii. Dynamic attributes

The capacity of situated devices represented in the context database[73] is the total capacity of the device (i.e. the total number of instances generated by the device's installation) while the remaining free capacity of the couple, i.e. the number of instances currently unassigned to visitors, is also stored[74]. The installations update their own free capacity whenever an instance is assigned to a new visitor as they couple their mobile device to the situated device, or unassigned when a visitor decouples their mobile.

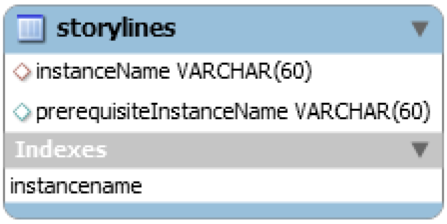
The locations of mobile devices, in contrast to situated devices, are dynamic and thus need to be updated in the context database continuously. The practical issues associated with accurate sensing of location have previously been discussed; the test-bed instead makes use of knowledge of the visitors actions in the coupling environment to determine location: both installations and context server may update the context database with a mobile device's location[75] and do so when visitors couple (where their location is at a particular situated device) and when the visitor progresses along a photographic trail (where their location is at the last viewed point on the photographic trail) respectively. As such the visitor's mobile does not sense its own location and the visitor does not report their own location – all is determined by the situated devices.

The visitor's historical interaction is fairly simply logged in the context database, in this case by the visitor's instances/installations. When a visitor "completes" coupled interaction, the visitor's instance informs its installation which in turn passes this information on towards the context database[76].

[73] See installations.capacity in appendix 10.2
[74] See installations.freeCapacity in appendix 10.2
[75] See visitors.lastKnownPosition in appendix 10.2
[76] See completeexperiences.* in appendix 10.2

10.2 Context database structure

10.2.1 Table structure



10.2.2 Entity relations

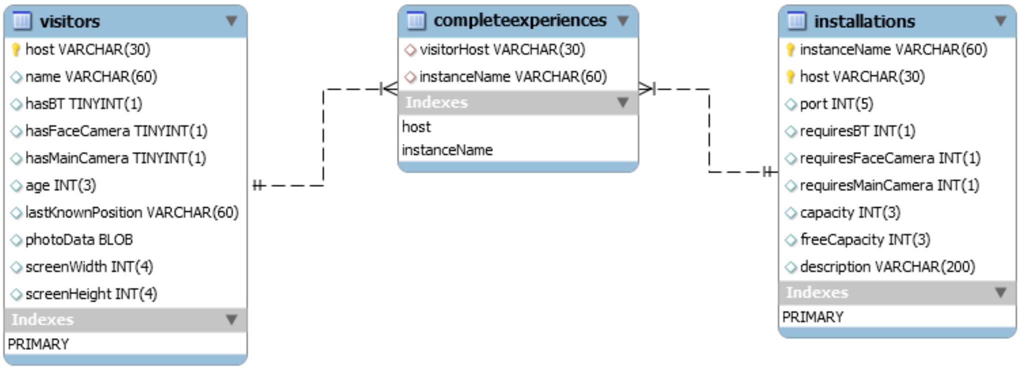


Figure 100 A visitor may have completed many experiences at an equal number of couples (installations)

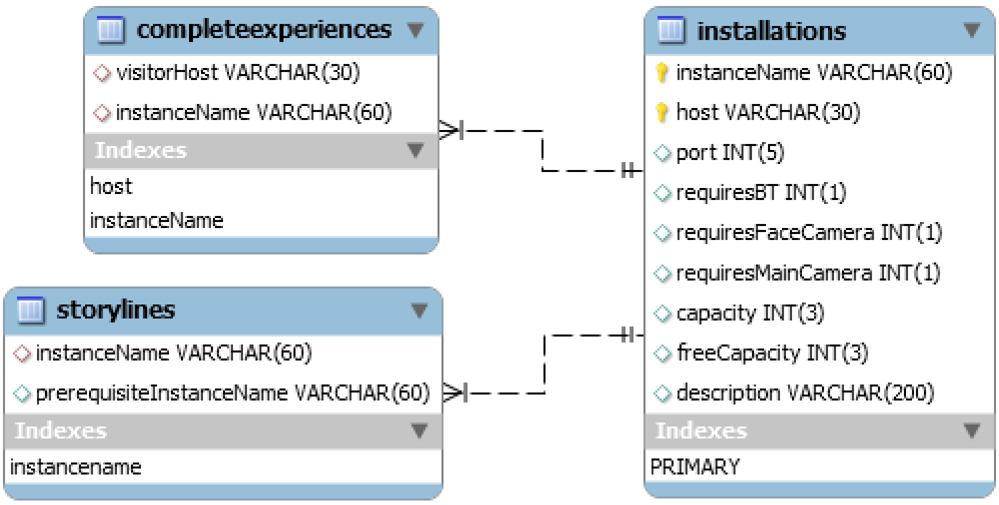


Figure 101 At one situated device (installation) many experiences may have been completed; one situated device may have many narrative (storyline) prerequisites

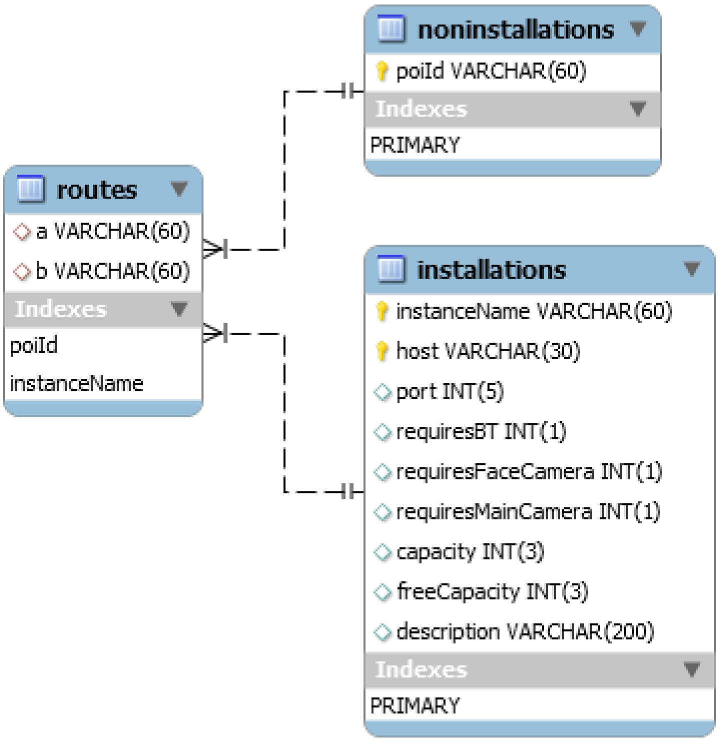


Figure 102 A *route* consists of two nodes, i.e. couples (*installations*) and/or non-coupling points-of-interest (*noninstalltions*); each coupling opportunity/non-coupling opportunity may be a node in many routes

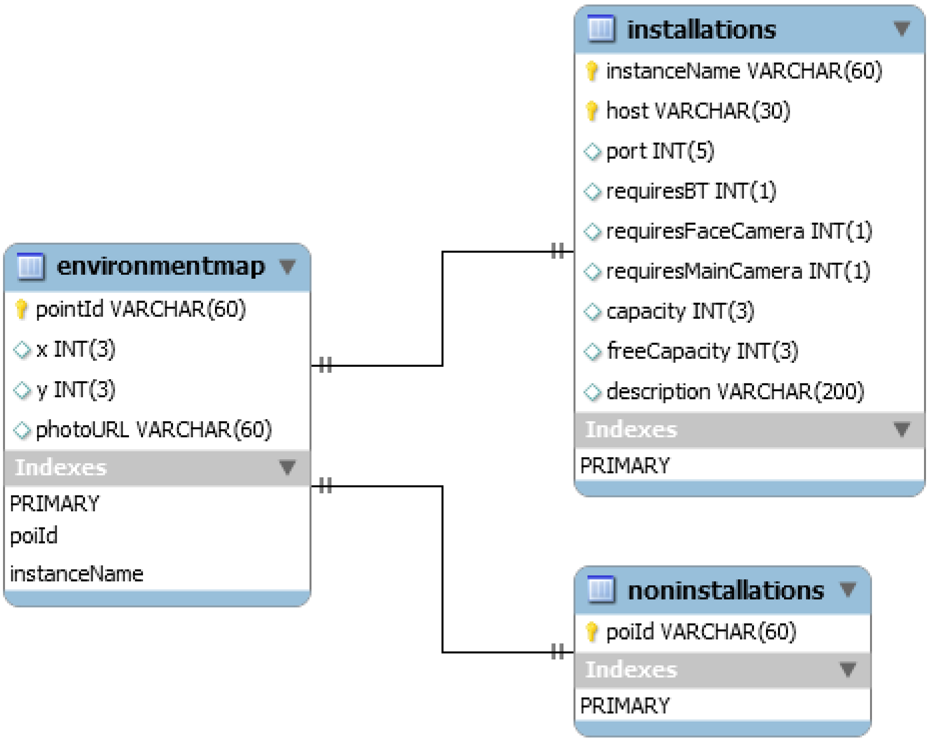


Figure 103 Each coupling opportunity/non-coupling opportunity is represented once as an entity in environmentmap

10.2.3 Sample context database contents

N.B. Database contents extracted during final trials as representative of state of coupling environment during visit by two visitors concurrently.

*i. visitors.**

host	name	has BT	hasFace Camera	hasMain Camera	age	lastKnown Position	photoData	screen Width	screen Height
128.243.22.200	Debs	1	1	1	19	Art	<Binary Field>	240	320
128.243.22.202	David!	1	1	1	21	Slideshow	<Binary Field>	240	320

*ii. storylines.**

instanceName	prerequisiteInstance Name
Slideshow	WorldMap
WorldMap	Registration
Art	WorldMap
GoogleEarth	WorldMap
Photowall	Registration

iii. routes.*

a	b
RestStop	BC3
BC3	RestStop
RestStop	CoffeeMachine
CoffeeMachine	RestStop
BC3	BC2
BC2	BC3
BC2	BC1
BC1	BC2
BC1	Art
Art	BC1
BC1	Storychart
Storychart	BC1
BC3	WorldMap
WorldMap	BC3
Decoupled	WorldMap
WorldMap	Decoupled
Registration	WorldMap
WorldMap	Registration
Decoupled	Registration
Registration	Decoupled
BC3	Decoupled
Registration	BC3
GoogleEarth	Registration
Slideshow	BC3
PhotoWall	Slideshow
RestStop	GoogleEarth
PhotoWall	RestStop
CoffeeMachine	PhotoWall
Storychart	CoffeeMachine
Art	PhotoWall
SketchPad	Art
CoffeeMachine	Storychart
SketchPad	CoffeeMachine
RestStop	SketchPad
SketchPad	PhotoWall
PhotoWall	SketchPad

iv. noninstallations.*

poild
Storychart
CoffeeMachine
SketchPad

v. installations.*

instanceName	host	port	requiresBT	requiresFaceCamera	requiresMainCamera	capacity	freeCapacity	description
Slideshow	128.243.19.180	49990	0	0	0	1	0	view photos and information about the keys you discovered
PhotoWall	128.243.19.183	49990	0	0	0	1	1	add your photos to the public display
WorldMap	128.243.19.183	49991	0	0	2	8	8	uncover hidden locations
Art	128.243.19.179	49990	0	0	0	3	3	handle objects from the keys you discovered
VisitorMonitor	128.243.19.182	49990	0	0	0	8	8	null
GoogleEarth	128.243.19.181	49990	0	0	0	1	1	explore the Earth from space
Registration	128.243.19.178	49990	0	1	0	1	1	introduce yourself

vi. environmentmap.*

pointId	x	y	photoURL
Slideshow	38	4	slideshow.jpg
PhotoWall	8	8	photowall.jpg
RestStop	10	6	coffee.jpg
WorldMap	14	12	worldmap.jpg
Art	26	3	art.jpg
GoogleEarth	32	3	googleearth.jpg
Decoupled	10	11	entrance.jpg
BC3	12	8	bc3.jpg
BC2	18	10	bc2.jpg
BC1	24	7	bc1.jpg
Registration	6	10	registration.jpg
Storychart	30	7	storychart.jpg
CoffeeMachine	8	3	coffeemachin.jpg
SketchPad	8	4	sketch.jpg

vii. completeexperiences.*

visitorHost	instanceName
128.243.22.200	Art
128.243.22.200	GoogleEarth
128.243.22.200	Registration
128.243.22.200	SketchPad
128.243.22.202	WorldMap
128.243.22.202	Registration
128.243.22.200	WorldMap

10.3 Coupling environment topography


```
<?xml version="1.0" encoding="UTF-8"?>
<environment>
	<pathways>
		<poi type="entrance">
			<id>Decoupled</id>
			<position>
				<x>10</x>
				<y>11</y>
			</position>
			<photo>entrance.jpg</photo>
		</poi>
		<poi type="installation">
			<id>Art</id>
			<position>
				<x>26</x>
				<y>3</y>
			</position>
			<photo>art.jpg</photo>
		</poi>
		<poi type="installation">
			<id>Slideshow</id>
			<position>
				<x>38</x>
				<y>4</y>
			</position>
			<photo>slideshow.jpg</photo>
		</poi>
		<poi type="installation">
			<id>GoogleEarth</id>
			<position>
				<x>32</x>
				<y>3</y>
			</position>
			<photo>googleearth.jpg</photo>
		</poi>
		<poi type="installation">
			<id>Registration</id>
			<position>
				<x>6</x>
				<y>10</y>
			</position>
			<photo>registration.jpg</photo>
		</poi>
		<poi type="installation">
			<id>WorldMap</id>
			<position>
				<x>14</x>
				<y>12</y>
			</position>
			<photo>worldmap.jpg</photo>
		</poi>
```

```xml
<poi type="installation">
	<id>PhotoWall</id>
	<position>
		<x>8</x>
		<y>8</y>
	</position>
	<photo>photowall.jpg</photo>
</poi>
<poi type="nonInstallation">
	<id>Storychart</id>
	<position>
		<x>30</x>
		<y>7</y>
	</position>
	<photo>storychart.jpg</photo>
</poi>
<poi>
	<id>RestStop</id>
	<position>
		<x>10</x>
		<y>6</y>
	</position>
	<photo>coffee.jpg</photo>
</poi>
<poi type="nonInstallation">
	<id>CoffeeMachine</id>
	<position>
		<x>8</x>
		<y>3</y>
	</position>
	<photo>coffeemachin.jpg</photo>
</poi>
<poi type="nonInstallation">
	<id>SketchPad</id>
	<position>
		<x>8</x>
		<y>4</y>
	</position>
	<photo>sketch.jpg</photo>
</poi>
<poi>
	<id>BC1</id>
	<position>
		<x>24</x>
		<y>7</y>
	</position>
	<photo>bc1.jpg</photo>
</poi>
<poi>
	<id>BC2</id>
	<position>
		<x>18</x>
		<y>10</y>
```

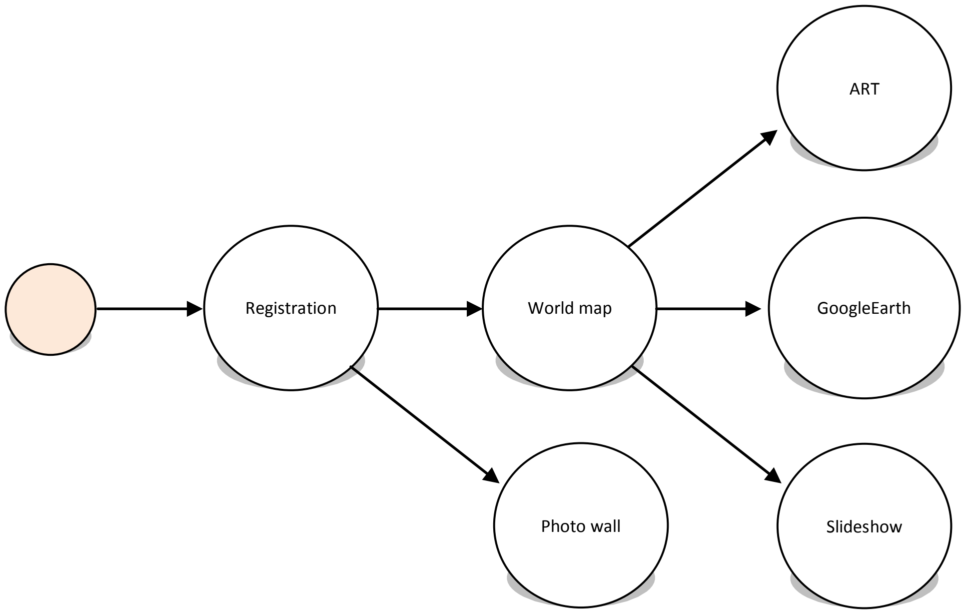
```
		</position>
		<photo>bc2.jpg</photo>
	</poi>
	<poi>
		<id>BC3</id>
		<position>
			<x>12</x>
			<y>8</y>
		</position>
		<photo>bc3.jpg</photo>
	</poi>

	<route bi="true">
		<a>BC3</a>
		<b>RestStop</b>
	</route>
	<route bi="true">
		<a>CoffeeMachine</a>
		<b>RestStop</b>
	</route>
	<route bi="true">
		<a>GoogleEarth</a>
		<b>Storychart</b>
	</route>

	<route bi="true">
		<a>BC2</a>
		<b>BC3</b>
	</route>
	<route bi="true">
		<a>BC1</a>
		<b>BC2</b>
	</route>
	<route bi="true">
		<a>Art</a>
		<b>BC1</b>
	</route>
	<route bi="true">
		<a>Storychart</a>
		<b>BC1</b>
	</route>
	<route bi="true">
		<a>WorldMap</a>
		<b>BC3</b>
	</route>
	<route bi="true">
		<a>WorldMap</a>
		<b>Decoupled</b>
	</route>
	<route bi="true">
		<a>WorldMap</a>
		<b>Registration</b>
	</route>
```

```
                <route bi="true">
                        <a>Registration</a>
                        <b>Decoupled</b>
                </route>
                <route bi="true">
                        <a>Decoupled</a>
                        <b>BC3</b>
                </route>
                <route bi="true">
                        <a>Registration</a>
                        <b>BC3</b>
                </route>
                <route bi="true">
                        <a>Slideshow</a>
                        <b>GoogleEarth</b>
                </route>
                <route bi="true">
                        <a>RestStop</a>
                        <b>PhotoWall</b>
                </route>
                <route bi="true">
                        <a>CoffeeMachine</a>
                        <b>PhotoWall</b>
                </route>
                <route bi="true">
                        <a>Art</a>
                        <b>Storychart</b>
                </route>
                <route bi="true">
                        <a>CoffeeMachine</a>
                        <b>SketchPad</b>
                </route>
                <route bi="true">
                        <a>RestStop</a>
                        <b>SketchPad</b>
                </route>
                <route bi="true">
                        <a>PhotoWall</a>
                        <b>SketchPad</b>
                </route>
        </pathways>
</environment>
```

10.4 Narrative dependencies



10.5 Post-experience questionnaire

This HTML form was accessible by a trial visitor via a desktop computer terminal following a trial experience. The same form was used during all trials. The form was hosted locally with responses logged automatically for easy processing.

---

i. Demographic profile

Age: ◯ Less than 18 ◯ 18-21 ◯ 22-25 ◯ 26-30 ◯ 31-40 ◯ 41-50 ◯ 51-60

◯ 61 or over

Sex: ◯ Female ◯ Male

Occupation (if applicable): [ ]

ii. Technological profile

How do you perceive your adoption of new technologies?

◯ I adopt new technologies before most other people

◯ I follow the latest trends

◯ I adopt new technologies when they have been proven to work

◯ I adopt new technologies only when absolutely necessary

Do you own a mobile phone?

◯ (1) No and I don't use one

◯ (2) No, but I do use other people's

◯ (3) Yes, one

◯ (4) Yes, more than one

If you answered 2, 3 or 4 to the previous question, do you use mobile phones in conjunction with other devices? If yes, please state briefly how, why and where

How/why?

Where (tick as many as are applicable)? ☐ At home ☐ At work ☐ In public

In addition, how else do you use a mobile phone (tick as many as are applicable)?

- ☐ For phone calls
- ☐ To send/receive texts (SMS)
- ☐ To send/receive multimedia messages (MMS)
- ☐ To share media via Bluetooth
- ☐ To play mobile games
- ☐ To view websites
- ☐ To capture photographs/video
- ☐ To use web-based messaging applications (MSN, etc.)/VOIP (Skype, etc.)
- ☐ To send/receive e-mail
- ☐ To manage time
- ☐ To manage contacts
- ☐ To record sounds
- ☐ To play music
- ☐ To play video

Other (please explain)

Do you own a mobile computer (laptop, notebook, PDA or netbook)?

(1) No and I don't use one

(2) No, but I do use other people's

(3) Yes, one

(4) Yes, more than one

If you answered 2, 3 or 4 to the previous question, how, why and where do you use mobile computers?

How/why?

Where (tick as many as are applicable)? At home At work In public

Do you own a desktop computer?

(1) No and I don't use one

(2) No, but I do use other people's

(3) Yes, one

(4) Yes, more than one

If you answered 2, 3 or 4 to the previous question, how, why and where do you use desktop computers?

How/why?

Where (tick as many as are applicable)? At home At work In public

iii. Visiting profile

Which of the following have you visited in the last year?

A museum: ○ Not in the last year ○ Once or twice ○ Regularly

An art gallery: ○ Not in the last year ○ Once or twice ○ Regularly

A cinema: ○ Not in the last year ○ Once or twice ○ Regularly

A shopping centre: ○ Not in the last year ○ Once or twice ○ Regularly

A conference: ○ Not in the last year ○ Once or twice ○ Regularly

A trade fair: ○ Not in the last year ○ Once or twice ○ Regularly

Typically, how would you visit/have you visited the following (tick as many as applicable)?

A museum: ☐ By myself ☐ With a partner ☐ With friends ☐ With family

An art gallery: ☐ By myself ☐ With a partner ☐ With friends ☐ With family

A cinema: ☐ By myself ☐ With a partner ☐ With friends ☐ With family

A shopping centre: ☐ By myself ☐ With a partner ☐ With friends ☐ With family

Have you ever been encouraged or discouraged to use your mobile phones or mobile computers in any of the environments listed above? Please briefly explain your experiences either way

iv. Experience

How would you describe, in general, the pace of the experience today?

○ Too rapid ○ Comfortable ○ Too slow

If you described the pace as either too rapid or too slow, can you give memorable examples of such aspects of the experience and/or state which features of the experience are responsible?

How much control did you feel that you had over your path through the exhibition, i.e. the order in which you experienced the exhibits?

- I had no control
- I could control the experience when I wanted
- I was forced to take control at times
- I had too much control

Were you aware of any differences between your experience and those of the other visitors in the environment at the same time as you? If so, explain what they were and how you learnt of the differences

What was different?

How did you notice the differences?

If you visited as part of a group, how did your other group members affect your experience?

Beyond yourself or your group, how did other visitors within the environment affect you or your experience?

Were you familiar with the environment before the experience?

◯ Yes ◯ No

If no, how effective did you find the photographic trail mechanism for navigation between the exhibits?

◯ I had no problems finding my way and felt the mechanism was suitable

◯ I had no problems finding my way but felt the mechanism was unsuitable

◯ I had problems but felt the mechanism was suitable

◯ I had problems and felt the mechanism was unsuitable

If you stated that the navigation mechanism was unsuitable, please explain why

Were you aware that your actions at certain exhibits affected what actions were possible for you at other exhibits?

◯ Yes ◯ No

If yes, can you give an example?

Were you aware that you could save content found at exhibits to your mobile phone and view it later?

○ Yes ○ No

If yes, can you give an example?

Were you aware that you could take photographs during the experience?

○ Yes ○ No

If yes, can you give an example of how/why you used this capability?

Did you have any problems using your mobile phone at the exhibits?

○ Yes ○ No

If yes, can you state where and which aspects were problematic?

Which exhibits were most memorable and/or enjoyable? Why?

How would you briefly describe the roles the mobile phone played during the experience?

v. End

Submit responses

Thank-you!