

Flypad: Designing Trajectories in a Large-Scale Permanent Augmented Reality Installation

Martin Flintham¹, Stuart Reeves¹, Patrick Brundell¹, Tony Glover¹, Steve Benford¹, Duncan Rowland², Boriana Koleva¹, Chris Greenhalgh¹, Matt Adams³, Nick Tandavanitj³, Ju Row Farr³

¹University of Nottingham, UK; ²University of Lincoln, UK; ³Blast Theory, UK
mdf@cs.nott.ac.uk, stuart@tropic.org.uk, {prb,atg,sdb}@cs.nott.ac.uk, drowland@lincoln.ac.uk, {bnk,cmg}@cs.nott.ac.uk, {matt,nick,ju}@blasttheory.co.uk

Abstract. A long-term naturalistic study reveals how artists designed, visitors experienced, and curators and technicians maintained a public interactive artwork over a four year period. The work consisted of a collaborative augmented reality game that ran across eleven networked displays (screens and footpads) that were deployed along a winding ramp in a purpose-built gallery. Reflections on design meetings and documentation show how the artists responded to this architectural setting and addressed issues of personalisation, visitor flow, attracting spectators, linking real and virtual, and accessibility. Observations of visitors reveal that while their interactions broadly followed the artists' design, there was far more flexible engagement than originally anticipated, especially within visiting groups, while interviews with curators and technicians reveal how the work was subsequently maintained and ultimately reconfigured. Our findings extend discussions of 'interactional trajectories' within CSCW, affirming the relevance of this concept to describing collaboration in cultural settings, but also suggesting how it needs to be extended to better reflect group interactions at multiple levels of scale.

Introduction

Art galleries, museums and exploratoria have proved to be fertile ground for the development and study of CSCW technologies over recent years, due to both their willingness to experiment with new technologies that might engage visitors with cultural experiences, but also due to the inherently group-oriented nature of visiting. Thus, we have seen a variety of novel technologies deployed within these settings, from group-oriented mobile guides (Aoki et al., 2002; Not et al., 1997) and augmented reality technologies (Koleva et al., 2009) that enhance interpretation by overlaying digital material on physical artefacts; to tangible and tabletop interfaces that promise rapid engagement and learning as well as fluid interaction among groups (Mazalek, 2009); to sensor-based physical interfaces

that support full-body interaction and playful or even performative social experiences (Snibbe & Raffle, 2009). In turn, studies of visitor conduct with and around ‘interactives’ in museums and galleries (Brown et al., 2003; Costello et al., 2005; Heath & vom Lehn, 2002; Hindmarsh et al., 2005; vom Lehn, Heath & Knoblauch, 2001) have revealed new challenges and concepts for CSCW, including the idea of *interactional trajectories* in which one visitor’s public conduct shapes that of subsequent visitors (see Hindmarsh et al., 2005; Benford et al., 2009). Others have considered the diversity of these settings, highlighting their cultural (Bell, 2002), information (Nardi & O’Day, 1999) or display (Crabtree & Rodden, 2008; Terrenghi et al., 2009) ecologies.

This paper extends this body of work by reporting a study of an interactive installation called Flypad, an eleven-player augmented reality game that was commissioned for permanent exhibition in a major new public arts centre. Our study charts the development of Flypad over a four year period, from initial inception, to public deployment, to subsequent maintenance, drawing on the perspectives of the artists, visitors, curators and technical staff in order to articulate how a large and complex permanent public experience was designed to operate robustly within a high-throughput setting. As a result, we are able to shed new light on ongoing discussions of public interaction within CSCW.

A brief introduction to Flypad

We begin with a very brief overview of Flypad as an experience. Flypad was commissioned to be part of the permanent collection of The Public, an art gallery housed in a purpose-built building designed by architect Will Alsop (Figure 1, left). The internal form of the building is such that visitors were intended to take an elevator to the top (3rd) floor and then gradually wind their way down a sloping ramp, passing through a series of temporary and permanent exhibitions on the way. Flypad is the largest permanent exhibition, being distributed around a large 2nd floor balustrade overlooking the building’s central atrium (Figure 1, right & Figure 2). The work was developed by a team of artists, curators, researchers and technical subcontractors over a four-year period, and opened to the public in August 2009.

Flypad is a collaborative augmented reality game in which up to eleven players at a time engage in mid-air avatar wrestling. Eleven game terminals, one per player, are arranged in groups on three ‘blisters’ that protrude from three sides of a balustrade (four terminals on the 1st and 2nd blisters, three on the 3rd blister). Each terminal comprises a screen on which a player sees an image of their avatar that is overlaid on a video-view of the atrium beyond to create a see-through augmented reality effect (Figure 3, left). By jumping up and down on the centre of a ruggedised footpad that is placed in front of the screen (Figure 3, right), the player can keep their avatar floating in the air. By treading on the four corners of

the footpad, they can steer their avatar laterally in space in order to collide with the avatars of other players. These interactions also steer a motorised video camera that is mounted just below the blister (Figure 2, right) so that the camera follows the movements of the avatar in order to keep it in view (i.e., positioned in the centre of the video view that serves as the backdrop) as it moves. This creates the illusion that the avatar is floating in the atrium beyond the screen.



Figure 1. The Public's signature building (left). On the ramp looking across two blisters (right).



Figure 2. Flypad terminals and Tall Trees from below (left). Looking up at a blister (right).

When two or more avatars collide there is a chance that they will enter a wrestling hold in which case they grip onto one another and then mutate by exchanging body parts. The player awarded points for each hold and mutation that they manage to achieve.

Each player's avatar is generated from a library of pre-defined parts to have a quirky and distinct different visual form (inspired by the traditional costumes and masks of Mexican wrestlers) and physical behaviours in terms of how it floats and moves. As time passes in a player's game, so their avatar appears to become heavier requiring them to work harder by jumping on the footpad in order to keep it airborne. Eventually, no matter how hard they work, their avatar sinks to the floor and their game is over. Flypad is a rolling experience in the sense that new players can join the game at any time (i.e., there is no synchronised start and end time for all players).

Finally, highlights from live or recent (recorded) games are displayed on the 'Tall Trees' a series of large screens mounted on the tops of tall stands that are located in the central atrium (separate from the players' terminals) in order to engage the attention of passing visitors and so attract them to the experience.



Figure 3. Player's screen showing an avatar with instructions overlaid in-game (left). A handpad (top right) and a footpad (bottom right).

Studying Flypad

Our study of Flypad employed ethnography to produce a rich description of the experience of an interactive artwork 'in the wild', that is within the actual setting of a public gallery. In so doing, we build on a tradition of ethnographic studies of interactives in galleries, museums, exploratoria and similar settings as noted previously. Our study is distinct, however, in charting the evolution of Flypad over a four year period from its initial inception as a proposal through to reflections on its sustainability one year after opening to the public. Both the installation and study were delivered by an interdisciplinary team comprising artists, developers and social scientists (the artists had collaborated with members of the team on previous projects). One developer on the project, who had also been trained in ethnography, documented the initial design process as a participant-observer, while a second, who had not been involved in the wider project, was introduced during the study phase to observe visitors and also interview staff at the Public.

Our study provides three complementary perspectives on Flypad, each drawing on a distinct set of materials:

First, we cover the *artists' perspectives on developing Flypad*, drawing on interviews with artist in our team as well as artists and designers involved in the wider project, design documents and field notes from design meetings and testing sessions (all over a three year period) to articulate the rationale behind its design as it evolved from the initial proposal to the public opening.

Second, we explore the *visitors' perspectives on experiencing Flypad*, drawing on observations and field notes (including four hours of video recordings captured at The Public) to show how groups of visitors actually interacted with and around the installation.

Third, we consider the *curators' perspectives on sustaining Flypad*, drawing on interviews with two key staff at The Public—its Artistic Director and a member of the technical support team—as they describe various aspects of day-

to-day maintenance, but also reflect on the longer term reconfiguration of the work based on their own observations of use.

We now consider each of these three perspectives in turn before drawing them together in a subsequent discussion.

Developing Flypad

The artists derived inspiration for Flypad in part from sourced such as Char Davies's work (e.g., *Osmose*), and the arcade experiences of *Dance Dance Revolution*. Their rationale for Flypad was set out in detail in their initial proposal to a competitive bidding process which included an animated fly-through of the experience as originally envisaged. The stills from this animation shown in Figure 4 reveal how the overall physical arrangement of Flypad was already in place at this very early stage, showing the footpads and screens arranged in groups at the blisters, steerable cameras mounted on the balustrade, and the Tall Trees in the centre. Flypad's overall design evolved in its detail over subsequent years as the artists addressed several key issues in cooperation with the exhibition's curators.

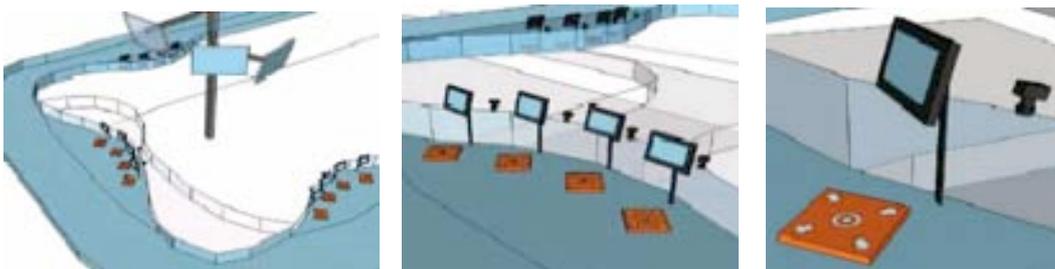


Figure 4: stills from the original proposal animation showing the core design

Responding to the architectural setting

The relatively detailed, and ultimately quite stable, form of this early design arose, at least in part, from being able to respond to the specific architectural setting of the building. As one of the artists stated at interview “the whole work itself springs from the architectural location”. Perhaps the most distinctive feature of this setting is the idea that visitors will ascend a lift to the top floor and descend through the exhibit down the spiralling ramp and past the three blisters. Quoting from The Public's own design brief for the overall exhibition, the ramp structure was conceived of as a “dramatic line”, starting high-up and moving down to become increasingly focussed, guiding visitor flow through exhibits. The physical design was influenced by this concept, such as the continuous metal handrail that runs along the ramp, which “mutates” into each exhibit's framework. Flypad is situated on the “Hill Top” section of the ramp, which is an area designed “to encourage visitors to form into 3 groups in each of the blisters regardless of [whether] the visitors know one another”. The ramp, being physically quite narrow (accommodating a couple of visitors abreast), was seen as

significant, particularly due to the “funnelling” and “clumping” of visitors (as the building designers called it).

Personalisation

The original vision for The Public was that each visitor would receive a highly personalised experience. The initial idea was that visitors would first register some personal details and in return, receive an RFID tag that they could use to identify themselves to each new exhibit they encountered and that would also help record their progress around the exhibition. The artist’s response to this opportunity was for Flypad to take this evolving ‘data body’ and somehow use it to create a uniquely personal avatar for each player. However, the networked RFID backbone was eventually dropped by The Public due to cost and time constraints, so that the artists had to instead try and generate avatars from a database of pre-designed parts as noted above. However, the decision to drop the RFID system was to have other ramifications as we explore below.

Managing visitor flow

Based upon projected visitor throughput, The Public provided a strict brief as to target ‘dwell times’ at each exhibit, requiring a game of Flypad to last for a maximum period of five minutes. The artists responded with a game design that, though the use of increasing gravity, would naturally bring each player’s game to an end within this period, no matter how well they played. To complement this, the start of the game involved a quick animated instruction and training sequence designed to rapidly bring the player up to speed. The “rolling” nature of Flypad also encouraged high throughput by not having to wait for multiple players to be in place before starting a game. This concern for throughput extended to the physical design of the footpad, whose low profile and lack of a surrounding guard rail was intended to ensure rapid physical engagement and disengagement and a quick handover between players.

The artists envisaged that the spatially bulging nature of the blisters would accommodate both players and spectators, along with a flow of visitors walking past. In sympathy with this, the physical design of Flypad carefully positioned the footpads and screens so as to accommodate an adequate flow past the terminals, but at the same time offer the potential for spectators to cluster around players. However, at interview, the artists expressed some concern about the “linear” structure of the ramp causing a “clump at the first blister”, rather than a reasonably even distribution across all terminals that might best exploit the sense of space and “encourage people to think about the space between [them]”. Their proposed solution lay in the use of the envisaged RFID tracking system which might control which terminals could be used next or even direct incoming players to a given terminal, so as to ensure a more even distribution of players around the

balustrade. Dropping the RFID system resulted in the final version of Flypad making no attempt to balance the loading of players across terminals.

Attracting spectators

Another key concern that was evident from the outset was supporting spectating. In designing the footpads and gameplay the artists attempted to walk a line between encouraging physical movement that would attract spectators in a way similar to “dance pad machines [with] people stand[ing] behind them practicing the moves”, but without being “something where you had to move around so much that you made a spectacle of yourself”. This visibility also extended to the motorised cameras; the artists wanted visitors on the atrium floor to be “very conscious of these cameras, and if they are all rotating in space”. However, it should be noted that to physically protect them and ease power and cabling issues, the cameras were eventually mounted some distance below the game terminals rather than on top of the rail near the screen as originally envisaged (see Figures 2, right and 4, right for the contrast between the final and proposed positions).

The Tall Trees were more explicitly targeted at spectators, not only for visitors already on the ramp, but also for visitors at the start of the experience, in the words of the artists: “leading their eyes up to the gallery”, creating a connection between the ground floor and the other ramp floors. However, the artists commented that there was only “limited [...] awareness that we can play with” before visitors could engage with Flypad, “because [visitors are] not just physically remote, they’re temporally quite remote from the experience”.

Linking real and the virtual

As the artists described it, Flypad was intended to provide a “seamlessly interlinked” experience of the real and the virtual but at the same time retain “the frisson of difference” between the two, a design concept that also impacted on the physical design of the terminals. The artists’ ideal was to have “a screen that’s as big as possible, with as small a surround to the screen as possible, on as light an arm or mount as possible, on a glass balustrade”. The footpads were employed in order to support this experience, as they represent “interactive devices that don’t actually get physically in-between you and the experience”. Practically this also meant positioning the footpad and screen so a player’s “eye moves from the screen to the atrium around them [...] as easily [...] as possible” thus merging of the augmented view and the real view.

Other issues became more apparent during testing. One of these was the nature of interaction via the game’s software; that is how the footpads should connect to the movement of avatars and cameras. After various early experiments, the artists and developers homed in on a distinctive approach where the avatars operated relatively autonomously (driven by an underlying rigid-body real-time physics engine), floating, entering holds, and exchanging body parts, with the players

‘nudging’ them around the space rather than controlling their movements in a fine grained way. By using the footpad, players apply simulated forces to avatars, giving the players a sense of ‘pushing’ or ‘prodding’ their avatar in a general direction rather than steering it precisely. Use of the physics engine in this way also means that the flexibly jointed avatars may also ‘collide’ with one another, or bounce off the (invisible) bounding box of the atrium in a deliberately ‘buoyant’ way. Avatar limbs attract one another when sufficiently close so that the avatars can easily enter pre-programmed wrestling holds without the players having to control the fine details of positioning, grasping and releasing. Consequently, the connection between movements on the footpads and the movements of the avatars became relatively indirect or ‘fuzzy’ in feel.

Enabling accessibility

Accessibility is a key concern for public institutions and was raised as a requirement shortly after the initial proposal had been accepted. The primary consequence of this was the design and introduction of the three ‘handpads, one per blister, to support access by visitors with limited physical mobility.

Experiencing Flypad

Our discussion thus far has been of the artists’ (and also curators’ and even architects’) views of how a visitor’s experience should ideally unfold. In order to see how it actually unfolds, one needs to observe visitors in situ. Our recordings (and subsequent interviews with the curators) suggest that for the most part, visitors were generally able to engage with Flypad and play the game following the artists’ overall design. However, we observed in the detail of interaction a greater sense of fluidity, less linearity of experience, and often longer overall dwell times than originally anticipated. We saw frequent dis- and re-engagements and exchanges of footpads between players, especially within groups. The following vignette from our video corpus follows a single group—a family—captured by our ethnographers through an extended engagement with Flypad and is broadly representative of many experiences that we observed¹.

Phase 1—Approaching, engaging and disengaging

A family consisting of an adult man (M), adult woman (W) and two children, a boy (B) and a girl (G), walk down the ramp, approaching the first terminals of Flypad. On the family’s approach, B steps straight onto the rightmost terminal, shouts “dad” and

¹ Due to space and scope constraints we have chosen to detail intra-group interactions rather than attempting to treat inter-group interactions as well. Nevertheless, we found inter-group interactions to be less ‘intimate’ (e.g., no direct intervention on occupied footpads by another group) yet remain highly fluid and characteristically ‘rolling’. As such our vignette does illuminate to *some* extent more general collaborative interactions.

beckons with his hand. G joins him, and steps directly onto his footpad alongside him so that the two are sharing. M then steps onto the adjacent footpad while W stands watching between the two footpads. Another visitor momentarily steps onto the next footpad along from the family group but then walks away from the group. B pushes G off the footpad at the same time as uttering “get off” (Figure 5, left); in response W points to the now-free game terminal to their left, stating “there’s another one there”.

W accompanies G to the footpad and begins reading out the on-screen instructions (“step on the booster to...”) as G steps on to play. During their play, G and B repeatedly glance across at adjacent screens. Family members then remain on their footpads for around 40s (with W still spectating between M and G). During this time, B exclaims “I can see you” (although it is unclear who this utterance is directed towards). G steps off her pad, and W quickly hits the footpad with one foot (Figure 5, middle) while G gets back on the pad. G then steps off the pad again, and says “look, look” (she appears to be watching her avatar slowly sink to the ground). W intervenes, uttering “boost” and stepping onto the footpad, but is subsequently pushed off by G (Figure 5b). B now says “yes I got someone’s leg” and G walks over to stand by him, watching. Just as she does this, W, watching the screen of the 3rd terminal, steps onto the now vacant footpad herself and begins another game (Figure 5, right). G returns and stands by W, who steps aside as G remounts her original footpad.



Figure 5. “get off” (left); intervention (middle); the family of players (right).

This complex series of movements and interactions is revealing in several regards. First, the design of the footpads and their relationship to the screens, appears to encourage approach and immediate, experimental engagement as we see here with B as he steps on the rightmost footpad. We observed similar approaches by other visitors, who often walk or run up to the footpads and jump on them, and only after this seem to begin interaction with the game in earnest. The nature of the physical engagement also reflects this, for instance W uses just one foot to play experimentally with the footpad (Figure 5, middle). Indeed the whole sequence here is notable for the ease with which the family repeatedly engages and disengage with the footpads, including trying to share footpads as we see when W steps onto the semi-occupied footpad before G wards them off.

We also note that this rapid handover of footpads enables participants to sustain one another's engagement with the game, as we saw at the end of this phase when W begins a new game on G's recently-vacated footpad, which G then returns to. However, rapid (re)engagements also enable players to take over from each other mid-game. Sometimes this appears to be opportunistic, taking over a game when someone has moved on (as we will see next in phase 2, B takes over G's game seconds after her departure). The 'fuzzy' nature of interactions with avatars due to the physics engine may also contribute to the ease of handing over an ongoing game as it becomes relatively easy to disengage for a few seconds without losing the game, and for others to take over without having to precisely orient to the current state of play. Taking over other's games is also supported by 'sideways spectating' that is, by being able to glance over at an adjacent terminal while playing the game yourself.

It is interesting to speculate here that the original proposal to use RFID to direct visitors to specific blisters or terminals and provide them with personalised avatars might have inhibited this kind of rapid engagement and handover which relies on being able to quickly step onto a footpad and pick up on someone else's game. We saw how some members of a group, W in this phase, take on the role of assigning players to footpads within their group ("there's another one there").

Phase 2—Overlapping game sequences and the footpad

As we rejoin the action, B's game has now finished and he comes over to G and W, looking over the balustrade into the atrium as G plays. M's game also finishes, and he and W stand back, watching G as she jumps up and down the footpad. W and G walk away from the blister, W says "anybody need the toilet?". At this moment (Figure 6, left), B jumps onto the footpad G has just vacated, mid-game, and begins playing while M turns slightly and watches B. M goes over to the handpad next to B and begins playing; B jumps off the footpad mid-game and joins M. After approximately a minute of play, M steps aside and B uses the handpad as M stands behind B (Figure 6, right).

Overlapping games are common, in which a player's game ends while others' are ongoing, leading the player to begin a new one rather than wait around. Thus, although each game may last only a few minutes, overall player engagement can be quite long due to overlapping sequences of games, particularly where a group is concerned, such as this family. Here we see how B does not wait till G's avatar has hit the floor (precipitated by her departure), but rather, seamlessly takes over the vacated spot (Figure 6, left). B later does the same with M's game on the handpad (which M relinquishes for B—Figure 6, right). We suggest that handing over ongoing games may naturally accommodate different roles for adults and children within a party. Thus, we see how B took over M's handpad as M stood aside, and how in phase 1, W, who often watches, stepped up to fill in gaps in play for G on two occasions (Figure 5).



Figure 6. G playing (leftmost image), then leaving with W, after which B takes over mid-game; B playing on the handpad with M behind (rightmost image).

This overlapping play may be further encouraged by the presence of adjacent footpads at each blister, and also by the presence of the handpad at the end of each blister which offers a player a novel and alternative way of experiencing the game again just before they leave a blister. We found that the design of Flypad, both physically and in terms of game structure, to our surprise, often resulted in the kind of repeated, sequential engagements *within* a single blister (as players moved from terminal to terminal) that we see here in this vignette.

Phase 3—Making sense of the augmentation, and local, not global, spectating

B plays on the hand terminal for a further minute. He then points towards the Tall Trees, saying “there’s me”. M directs his gaze momentarily along the direction of B’s arm, but begins answering a call on his mobile phone. W and G return; W stands to the left of B, and M remains standing some distance behind B on his mobile phone. G watches B playing briefly before jumping back onto the middle footpad. A short time later during play, B utters “you’re on the screen... you see”. G laughs and, continuing to jump on the pad, says “you’ve got my leg ... I can actually see you”. G’s game ends as her avatar hits the floor, she gets off the pad and walks over to W, saying “mum can one of us go over there [points towards the atrium floor] so we can see each other?” as B continues to play on the handpad.

Throughout our analysis so far we have seen how, through the careful spacing and placing of the footpads, Flypad supports what might be termed ‘local spectating’ including multiple transitions from spectating to playing and back again. The closeness of the footpads also allows observation of other players’ screens while continuing to play (e.g., see phase 1). This support for spectatorship also helps players make sense of the augment reality by relating avatars to one another. As this sequence shows, B and G appear to make sense of the relationship between their avatars (referring to their avatar’s limbs and “seeing” one another in the virtual space). Having identified B’s avatar, G verbally highlights the action they have performed collaboratively (“you’ve got my leg”). G also shows understanding to some extent of the nature of the augmentation, in linking the physical space (the atrium floor) with the augmentation on-screen. Interestingly, the immediacy of the footpads permits the visitors to rapidly engage with the game, without requiring that they fully understand the collaborative or augmented reality aspects of it. Instead this understanding is developed gradually.

Finally, in this phase of the vignette, we see how another spectator-oriented aspect of the design, the Tall Trees, which might be termed ‘global spectating’, comes into play. While the Tall Trees screens are clearly noticeable as B verbally and physically highlights here, both for the display of his own play, and pointing out that of G’s (“you’re on the screen”), we note that in this sequence his activity had been displayed on the Tall Trees for some time (74 seconds) before he remarked on it. Further to this, the family group has by this time been present at the first blister for over six minutes. In general, we noted that visitors rarely attended to or referenced the Tall Trees. Thus, while the arrangement of the terminals, coupled with the size of the terminal screens and the space behind and to the side of them seems to support spectating upon the local action, the Tall Trees appear have been far less impactful as a global spectator interface.

Maintaining and reconfiguring Flypad

To get a third perspective on Flypad we interviewed the Artistic Director (AD) responsible for the overall curation of The Public, as well as a member of the technical support team (TS) who had been working directly on the day-to-day maintenance of Flypad. In addition to their distinctive professional perspectives, both had spent considerable time observing Flypad in use and were able to extend our own observations; or in the words of TS “I’m an IT guy but I’ve been watching what people do!”

Maintaining Flypad

While Flypad was reported as generally stable and could mostly operate with mostly only minimal routine maintenance, it became clear that busy times could be more problematic. For instance, as AD reported to us, “last week or the week before we had about 4000 people in a week so [Flypad] got a pasting and perhaps like anything has been difficult this week”. In these situations Flypad “needs constant maintenance”. Problems mostly involved physical wear and tear such as broken speakers, video cable problems, and faulty USB connections. These tended to be focused around the game terminals nearer the top of the ramp; as TS related “they do take a lot of hammering, those 4 [terminals in the first blister]”. Some variation was mentioned at this first blister: “ironically 2 [terminal number 2 within the first blister] gets the most hammering because they’re the first ones [visitors] come down to, and they walk past the first screen and jump on to the second screen”. Compounding this are challenges with the physical maintenance of Flypad. Resolving problems may require “total downtime” for the whole exhibit for safety reasons, due to the danger of objects falling to floors below while the terminals are dismantled—especially difficult at busy periods [TS].

Reconfiguring Flypad

Beyond routine maintenance, this team was also involved in the longer-term reconfiguration of Flypad in response to their own observations of use and other changes to the exhibitions housed in the space. They identified two main changes to the exhibit itself and the ecology surrounding the exhibit. Firstly, like ourselves, AD had come to the conclusion that the Tall Trees were not especially effective as a spectator interface for Flypad: “nobody ever used them, nobody looked at them or didn’t even realise that they were their [player] representations” [AD]; [TS] made similar comments. In response, the Tall Trees had become screens to display other exhibition work: “we’ve got two Josh Nimoy’s [...] now running on it [the Tall Trees]” [TS].

However, this reconfiguration extended beyond the Tall Trees to address the entire trajectory through the experience, arguably the most fundamental feature of its design. As AD reflected, “the thought of going up to the top and coming down is an alien one to people visiting a place like this so going the other way makes much more sense”. AD was now encouraging reception to steer some visitors up the ramp so that people would approach Flypad from either end. As well as having an overall aesthetic impetus, AD related that this change had practical dimensions. For instance, in order to avoid confusion, visitors had to be “pushed towards the lift [for the 3rd floor]”; AD notes that in spite of this, the curators “lose so many people when they come out of the lift at the third floor [...] visitors] don’t really know where to go”. A secondary but no less important impetus for AD was the need to alleviate visitor flow when crowded and spread wear and tear across terminals. We note that such reconfiguration would be different were the RFID system implemented, as it would have required reprogramming the Flypad software. On the one hand, this might afford curators greater control over the flow through the exhibit, but would also require dedicated software tools.

Finally, there is an issue for more complete reconfiguration of the exhibition space, and the need to “refresh many of the pieces on the ramp”, however Flypad is only reconfigurable to a small degree and so is “a difficult piece to think about because I [AD] can’t just put different data in and get a different output in that piece”. AD observed that the highly distinctive physical form of Flypad compared to some of the other permanent exhibits would make it far more difficult to change in the long term, meaning that “Blast Theory’s piece will be on until frankly it doesn’t work anymore [...] or] get Blast Theory to come in and think of another way they could use the facilities to engage in a different way” [AD].

Discussion—summary of key findings

We begin our discussion by drawing together our findings from a diverse range of sources to identify key issues and challenges for Flypad as a public installation,

before then widening our perspective to consider how our study sheds light on recent discussions of interactional trajectories within HCI at large.

As a public experience, Flypad was successfully delivered, installed and has been in use (and re-use) by many thousands of visitors for over a year in a prominent public arts centre. Observations and interviews with curators suggest that, in broad terms, Flypad appears to be playable by a variety of users, including both children and adults, in the sense that they are able to engage with the work and complete a game; and seems to be generally well appreciated by visitors and support staff. However, our study also reveals that, in the detail, the characteristics of use are somewhat different from those anticipated in the original design. While visitors do often undertake an overall journey along (usually down) the ramp, into engagement with Flypad and through the game as envisaged in the initial design, there is also much greater flexibility surrounding how they engage at any given moment, which manifests itself in two main ways as exhibited by the vignette. First, players may rapidly and repeatedly disengage from and reengage with Flypad, including competing for footpads and also taking over each other's footpads and ongoing games. Second, players may repeatedly engage and experience multiple games as they progress along the ramp, perhaps while waiting for colleagues to finish or maybe when new opportunities present themselves such as the novelty of trying out a handpad.

Underlying these observations, and of clear interest to CSCW, is the group nature of the visiting experience. Visiting cultural institutions such as galleries and museums is very often a group experience leading to a tendency for groups of visitors to stick together as they progress through the exhibition. This natural gravity between individuals in a group, for example, as parents stand by and observe children, or members of a party wait for someone to finish before moving on, underpins the pattern of multiple and rapid engagement that we have documented. In the same way that Flypad is a rolling game, so the experience of a visiting group is also rolling as they appear to gradually tumble along the ramp, engaging and disengaging with Flypad terminals in an interleaved way as they go. We speculate that this rolling engagement might be similar to a group of visitors moving along a traditional gallery of paintings or sculptures, but with the notable difference that they are also collaborating *through* the terminals (i.e., within the game) as well as *around* them. Indeed, we suggest that the detailed design of Flypad encourages this kind of rolling engagement, and now revisit some of early design decisions that we documented previously to consider how this might be so.

- **Responding to the architectural setting**—the linear and elongated nature of Flypad as it is stretched along a winding ramp and affords multiple points of engagement through eleven discrete terminals distributed around three distinct blisters affords a kind of 'stickiness' to the experience. However, this linear structure also led to some unforeseen maintenance problems as terminals on the first blister suffered greater wear and tear than others.

- **Personalisation**—the original plan to have personalised avatars might have inhibited taking over others' games, while the associated decision to drop the RFID system may have enabled a far more fluid engagement as players could easily engage with any vacant, and sometimes even occupied, terminal.
- **Managing visitor flow**—we suggest that the rolling nature of the experience provides a powerful way of managing variations in visitor flow. While each individual game of Flypad lasts for no more than five minutes, repeated reengagement allows for a much longer overall experience during quiet times. Put another way, having an experience with short but repeated engagements may allow people to socially negotiate or self-regulate flow and throughput through the experience.
- **Attracting spectators**—the physical form and placement of the terminals and footpads appears to have been successful at supporting 'local spectating' while also accommodating a flow of visitors along the ramp. Local spectating also extended to sideways monitoring of adjacent players. In contrast, the explicit use of the Tall Trees as a separate spectator interface appears to have been far less successful at supporting 'global spectating', perhaps due to a fragmentation of views in which there were no obvious connections between the clips they were displaying and specific terminals.
- **Linking real and virtual**—not only did the indirect linking of real and virtual through the use of a physics engine make the game more playable, but it also supported the ability to hand over an ongoing game from one player to another.
- **Enabling accessibility**—finally, the provision of the handpad as an alternative way of interacting further encourages reengagement by the wider population as well as supporting accessibility for those with limited mobility.

Interactional Trajectories

Our final contribution in this paper is to relate our findings to the growing literature on interaction in public settings, and especially to recent work on interactional trajectories. As noted in the introduction, previous studies of museum exhibits (Heath & vom Lehn, 2002), artistic installations (Costello et al., 2005) and more general tangible interfaces (Hornecker & Buur, 2006) have raised the idea that there are 'interactional trajectories' through museum and gallery installations in which one visitor's interactions with an exhibit establish a trajectory for subsequent visitors who, having observed them, subsequently approach the interface and engage with it. This idea is closely related to the notion of 'spectatorship' in which a user's interactions with an interface may be made more or less visible to and legible for others. For example, Reeves et al. (2005) introduce a taxonomy that classifies interfaces according to the extent to which they hide, reveal or even amplify a user's *manipulations* of the interface to

observers, compared to the extent to which they hide, reveal or amplify the *effects* of these manipulations. Their classification of various interfaces reveals four broad design strategies that they call: *secretive* (manipulations and subsequent effects both hidden); *expressive* (manipulations and effects both amplified); *magical* (effects revealed but the manipulations that caused them hidden) and *suspenseful* or *intriguing* (manipulations revealed but effects—the payoff from these—remain hidden). These strategies suggest various different ways in which interfaces in public settings might attract, engage or inform observers as part of establishing an interactional trajectory.

Other researchers have pointed out that a consideration of interaction within public (or indeed other collaborative) settings needs to extend beyond an individual interface to instead address an entire ecology of interfaces: Nardi has argued for ‘information ecologies’ that combine people, practices values and technologies within a local environment (Nardi, 1999); Huang et al introduced ‘display ecologies’ to explain the evolution of use of a series of large displays in the NASA Mars Exploration Rover (MER) control room; while Crabtree and Rodden analysed the operation of a mixed reality game that combined online players with those on the streets of a city in terms of ‘hybrid ecologies’ (Crabtree & Rodden, 2008). Specifically within museums, Bell (Bell, 2002) introduced the idea of ‘cultural ecologies’ that combine liminality (meaning an experience set apart from everyday life), sociality, and engagement. Finally, in a practical demonstration of how such ecologies might be assembled, Fraser et al. describe a museum visiting experience in which groups a visitors explored the grounds of an ancient castle, gathering information such as drawings and rubbings on pieces of paper that were electronically tagged (using RFID) so that they could be used to interact with various public displays inside the museum in order to reveal further information (Fraser et al., 2003).

These notions of interactional trajectories and ecologies have recently been combined into a broader conceptual framework for describing cultural experiences that extend over hybrid ecologies of space, time, roles and interfaces (Benford et al., 2009). This framework proposes that such extended experiences can best be described in terms of journeys whose structures are expressed by the relationships between three fundamental types of trajectory. *Canonical trajectories* are defined by artists and represent intended journeys through the experience. *Participant trajectories* are inscribed by individuals undertaking the experience and diverge from canonical trajectories due to interactivity, but then reconverge due to orchestration. *Historic trajectories* synthesise different accounts of what happened in the past, selecting, filtering and recombining different recorded participant trajectories in order to support reflection after the event. The ways in which participant trajectories interweave with one another, approaching, crossing and diverging express varying possibilities for social encounters and isolation. Moreover, these trajectories must be designed to

negotiate key *transitions*, moments when coherence may be at risk, including beginnings, endings, role and interface transitions, traversals between real and virtual worlds, disengaging and reengaging as part of episodic interaction, and negotiating disconnections of other technical limitations.

Interactional trajectories in Flypad

How does our study of Flypad relate to this body of literature? We propose that our findings affirm many of these existing concepts, but also suggest ways in which further research might extend them in the future. First, we have shown how the artists, through the fine details of the design and placement of the terminals, support local spectating and so establish a trajectory of interaction into engagement with individual terminals and hence the game. This engagement of local spectators in Flypad mirrors earlier studies of popular dance games such as Dance Dance Revolution (DDR) and ParaParaParadise, which also use footpads, and support organised and impromptu public performance (Smith, 2006). We have described how the artists deliberately designed the terminals to support ‘expressive’ interactions in Reeve’s terminology. However, we have also revealed the impact of aligning several footpads side-by-side on a blister, leaving sufficient space to accommodate spectators and passersby, mirroring Brignull and Roger’s (2003) discussion of the ‘Honey Pot’ effect in which people socialise around public displays and move from being onlookers to participants and back again.

Flypad supports an especially fluid relationship between spectating and participating. We have described how players watch each other’s games whilst playing their own, comparing views, interjecting and even swapping over. Thus, we also see the importance of a kind of ‘sideways’ spectating between players, reflecting Alan Dix’s discussion of feedthrough, feedback and awareness in collaborative interfaces (Dix, 1997).

In its larger structure, Flypad affirms the idea of systematically designing an entire ecology of interfaces. Flypad’s ecology includes multiple interfaces (8 footpads, 3 handpads, 11 screens, 11 cameras, and the Tall Trees), each of which consists of further components, and which are distributed around the ramp and carefully integrated into the wider ecology of the surrounding building. Our study highlights the problems that can occur when an ecology of displays is not sufficiently integrated; in the case of Flypad, the Tall Trees are not well integrated with the other displays leading to a ‘fragmentation of views across multiple displays’ (Gaver et al., 1993). While we would not necessarily argue against large public displays as external spectator interfaces, the experience of Flypad suggests that they require careful integration with the overall display ecology.

Finally, there is a clear sense of there being a larger trajectory through the entire hybrid ecology of Flypad of the kind proposed by Benford and colleagues. The most obvious manifestation of this is the way in which the entire experience is largely defined by the presence of the sloping ramp which shapes a clear and

constrained path into and through the experience. We have seen how the artists carefully created an overarching ‘canonical trajectory’ to follow this path from the very first design iteration, but also how ‘participant trajectories’ do indeed locally diverge from and reconverge to and from this. We have also described examples of designing key transitional moments, especially stepping onto a footpad and subsequent engagement with the game software.

However, while our study affirms this general approach of thinking in terms of extended trajectories, it also challenges it in several important respects, suggesting productive avenues for further study or technical development.

Group trajectories: perhaps the most notable implication of our study is the significance of groups of visitor and the way in which a rolling group trajectory, emerges from several individual overlapping and interleaved participant trajectories. Our descriptions suggests a sense in which each group as a whole may have its own collective trajectory through the exhibit which emerges from or somehow constrains and shapes the ways in which individual participant trajectories overlap and tend to ‘stick’ together. In our vignette, for example, we saw that, the group, family trajectory through the exhibit as a whole interacted with each individual trajectory (such as B taking over G’s game, or W’s repeated requests for the group to move onwards). Current notions of trajectories within the literature do not explicitly express the idea of group trajectories, raising an important question for further research.

Multi-scale trajectories: Our study also reveals the presence of nested and interlocking trajectories at a variety of scales. Trajectories defined in *The Public* range from building scale (the sequence and ordering of exhibits, the ramp), down to individual interfaces (encounters with Flypad), and then into gameplay. Trajectories at these different scales are designed to be interconnected so as to create a coherent overall experience; however we found in our study occasional divergence between the intended, canonical trajectories and the trajectories participants actually engaged in. For instance, we observed visitors revisiting exhibits and travelling in reverse to the designed trajectory. Further, in the vignette, we saw visitors conduct multiple sequential engagements with different terminals, meaning that several individual game trajectories came to be nested within the overall trajectory of interaction with Flypad as a whole. We therefore propose that further research is needed to articulate how the application of trajectories to the study and design of cultural experiences can take into account the ways in which multiple trajectories at multiple-scales can be interlocked.

Evolving trajectories: Finally, we have seen how trajectories may evolve with use. Our study uncovered how curators at *The Public* have begun to reconfigure the overall trajectory through Flypad, most notably by encouraging the reversal of the flow of visitors from down to up the sloping ramp. A key role of curators may be to continually shape trajectories through multiple exhibits, especially when exhibits change, to reflect patterns of changing use of their space. Our study has

also revealed how trajectories may have varying levels of reconfigurability—for instance, certain aspects of the canonical trajectory may be adapted, such as ramp direction, whereas other parts of the trajectory are more fixed, such as the physical arrangement of elements found in Flypad (e.g., screens, cameras, footpads). The broad question of how trajectories evolve and adapt over time, especially as experiences come and go within a given setting, has not been widely discussed in the literature and so offers a further avenue for future research.

Conclusion

By studying the design, experience, maintenance and reconfiguration of Flypad over a four-year period we have been able to shed new light on the design of large-scale interactive experiences for galleries, museums and other settings. We revealed how the artists responded to the architectural setting of the building and paid particular attention to issues of visitor flow, personalisation, spectating, the integration of real and virtual, and accessibility. Beyond documenting a unique example of designing and maintaining a major artwork, our observations of use show that, in the large, these design strategies were broadly successful. However, engagement was often more fluid than anticipated, with many rapid dis- and re-engagements and the sharing of footpads and ongoing games. Finally, we also revealed the challenges of integrating external spectator interfaces—the Tall Trees—into the overall ecology of the experience. From a more theoretical point of view, our study has affirmed several concepts from the CSCW literature including interactional trajectories, spectatorship and notions of ecology. At the same time we have also argued for further extending these ideas, in particular, for extending current notions of trajectories to better accommodate multiple-scales, evolution over time—and significantly for CSCW—the impact of group visiting.

Acknowledgments

We gratefully acknowledge support of the EPSRC grant ‘The Challenge of Widespread Ubiquitous Computing’ (EP/F03038X/1) and RCUK for the Horizon project (EP/G065802/1). We also acknowledge the useful comments of reviewers.

References

- Aoki, P., Grinter, R., Hurst, A., Szymanski, M., Thornton, J. & Woodruff, A (2002); ‘Sotto voce: exploring the interplay of conversation and mobile audio spaces’, *Proc. CHI*, pp. 431-438, ACM.
- Bell, G. (2002): *Making Sense of Museums*, Intel Labs.

- Benford, S., Giannachi, G., Koleva, B. & Rodden, T. (2009): 'From Interaction to Trajectories: Designing Coherent Journeys Through User Experiences', *Proc. CHI*, pp. 709-718, ACM.
- Brignull, H. & Rogers, Y. (2003): 'Enticing people to Interact with Large Public Displays in Public Spaces', *Proc. Interact*, pp. 17-24, IOS Press, IFIP.
- Brown, B., MacColl, I., Chalmers, M., Galani, A., Randell, C. & Steed, A., (2003): 'Lessons From the Lighthouse: Collaboration in a Shared Mixed Reality System', *Proc. CHI*, pp. 577-584, ACM.
- Costello, B., Muller, L., Amitani, S. & Edmonds, E. (2005): 'Understanding the Experience of Interactive Art: Iamascope in Beta_space', *Proc. 2nd Australasian Conference on Interactive entertainment*, Sydney.
- Crabtree, A & Rodden, T. (2008): 'Hybrid Ecologies: Understanding Cooperative Interaction in Emerging Physical Digital Environments', *Personal & Ubiquitous Computing*, 12:481-493, Springer.
- Dix, A., (1997): 'Challenges for cooperative work on the web: An analytical approach', *Computer Supported Cooperative Work*, 6(2-3):135-156.
- Fraser, M., Stanton, D, Ng, K., Benford, S., O'Malley, C., Bowers, J., Taxen, G., Ferris, K., Hindmarsh, J., (2003): 'Assembling history: achieving coherent experiences with diverse technologies', *Proc ECSCW*, Kluwer.
- Gaver, W., Sellen, A., Heath, C., & Luff, P., (1993): 'One is not enough: multiple views in a media space', *Proc. CHI*, pp. 335-341, ACM.
- Heath, C. & vom Lehn, D. (2002): 'Misconstruing interactivity', *Proc. Interactive Learning in Museums of Art and Design*, Victoria and Albert Museum, 2002.
- Hindmarsh, J., Heath, C., vom Lehn, D., & Cleverly, J., (2005): 'Creating assemblies in public environments', *Journal of CSCW*, 14(1):1-41, Kluwer.
- Hornecker, E. & Buur, J. (2006): 'Getting a grip on tangible interaction', *Proc. CHI*, pp. 437-446, ACM.
- Koleva, B., Egglestone, S., Schnädelbach, H., Glover, K., Greenhalgh, C. & Rodden, T. (2009): 'Supporting the creation of hybrid museum experiences', *Proc. CHI*, pp. 1973-1982, ACM.
- Mazalek, A., Winegarden, C., Al-Haddad, T., Robinson, S., & We, C., (2009): 'Architales: physical/digital co-design of an interactive story table', *Proc. TEI*, pp. 241-248, ACM.
- Nardi, B. & O'Day, V. (1999): '*Information Ecologies: Using Technology with Heart*', pp. 49-58, MIT Press.
- Not, E., Peterelli D., Stock O., Strapparava C., & Zancanaro M., (1997): 'Person-oriented guided visits in a physical museum.', *Proc. ICHIM'97*, Archives and Museum Informatics.
- Reeves, S., Benford, S., O'Malley, C. & Fraser, M., (2005): 'Designing the spectator interface', *Proc. CHI*, pp. 741-750, ACM.
- Smith, J., (2006): 'Digital Dance Hall: The Fan Culture of Dance Simulation Arcade Games.', *Consuming Music Together*, pp. 193-210, Springer.
- Snibbe, S. & Raffle, H., (2009): 'Social Immersive Media Pursuing Best Practices for Multi-user Interactive Camera/projector Exhibits', *Proc. CHI*, pp. 1447-1456, ACM.
- Terrenghi, L., Quigley, A. & Dix, A. (2009): 'A Taxonomy for and Analysis of Multi-Person-Display Ecosystems', *Personal & Ubiquitous Computing*, 13:853-598, Springer.
- vom Lehn, D., Heath, C. & Knoblauch, H., (2001): 'Configuring exhibits', *Verbal Art Across Cultures*, pp. 281-297, Gunter Narr Verlag Tübingen.
- vom Lehn, D., Hindmarsh, J., Luff, P. & Heath, C. (2007): 'Engaging constable: revealing art with new technology', *Proc. CHI*, pp. 1485-1494, ACM.