Gaming on the Edge: Using Seams in Ubicomp Games

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ABSTRACT

Outdoor multi-player games are an increasingly popular application area for ubiquitous computing, supporting experimentation both with new technologies and new user experiences. This paper presents a set of experiments with an outdoor ubicomp game that exploits the gaps or seams that exist in complex computer systems. The Bill game is designed so that players move in and out of areas of wireless network coverage, taking advantage of the connectivity within a wireless 'hotspot' and also of the lack of connectivity outside it. We draw lessons for how ubicomp games can successfully encourage social interaction between players, discuss the interaction between the game and the local environment, and describe our approach to recording and 'replaying' such games. More broadly, this paper discusses how the notion of *seamful design* can be a source of design ideas for ubicomp games.

Categories and Subject Descriptors

D.3.3 [**Programming Languages**]: Language Contructs and Features – *abstract data types, polymorphism, control structures.*. The ACM Computing Classification Scheme: http://www.acm.org/class/1998/

General Terms

Experimentation, Human Factors.

Keywords

Ubiquitous computing, mobile games, seamful design.

1. INTRODUCTION

Games have long been one of the most popular applications of technology, both in terms of their impact on culture and their significant financial success [8]. Games have also been a key motivator in the development of many new technologies and techniques, particularly in the areas of computer graphics and artificial intelligence [3]. Yet games in their own right have only

recently attracted sustained academic attention [9]. One avenue of recent investigation has been *mobile* and *ubiquitous* games [1, 6, 10] through which a number of broader research themes (such as mixed reality) have been investigated. Games such as 'Can You See Me Now?' [6] explore the incorporation of urban environments and digital systems, forming games to support unusual yet enjoyable connections between online players and players on the street.

In this paper we describe our experiences with an outdoor mobile game that exploits seams. A seam is break, gap or 'loss in translation' in a number of tools or media, designed for use together as a uniformly and unproblematically experienced whole. Our designs draw upon the concept of 'seamful design' put forward by Mark Weiser [2, 11], but echoing established media theory, in which designers take advantage of the physical limits and characteristics that constitute a design medium rather than smoothing them out or ignoring them.

For example, many applications for mobile computers may be built as if they could be used along with the features of the environment one travels through, e.g. to display web pages about nearby buildings and people. Such applications often assume constant network connectivity, and yet this is not always the case when mobile systems really are mobile; as one walks away from an access point, such systems often crash or become unusable as the wireless network drops off and then disappears. Applications may be built to be uniform and 'seamless', but the seams of their infrastructure often show through in interaction.

Inspired by the seamful design idea, we designed a game, *Bill,* in which each player uses a handheld PDA equipped with GPS and 802.11. Players collect virtual 'coins' from outside the wireless network, and then runs back into network range to 'upload' the coins to gain points. Game strategy is based on observing, understanding and taking advantage of where coins and players are, hotspots of network coverage and the 'cold spots' out beyond them, and the urban setting of the game. We ran 14 observed trials of Bill, involving 46 players in all, and experimented with a number of different game features. Overall, we suggest that the 'seam' concept can be a productive resource for designing games and, potentially, for the design of ubicomp systems.

2. MOTIVATION AND RELATED WORK

While games offer considerable value and enjoyment for players, they also have the potential to be used by designers and researchers as experimental platforms for new technologies and design concepts [4]. Along with our desire to create a successful game, we were also interested in using a game to experiment with

Weiser's concept of seamful system design. In particular, we were interested in how the use of infrastructure such as 802.11 wireless networks can be very apparent in people's interaction with mobile computers. What may be 'infrastructure' to a system designer may be something that users have to understand, handle or react to—which perhaps then should be designed for in the interface and interaction design, rather than ignored or suppressed.

Wireless networks have distinct physical characteristics such as a tendency to be absorbed by metal, water and other conductive materials, and a pattern of coverage that makes for a limited area of usable network connectivity. Usable network coverage, therefore, rarely covers all the areas one moves through and spends time in during a day of work or leisure. Furthermore, when one takes a mobile computer into network coverage, one can receive and transmit information to other machines and other players but one might also be tracked, recorded or spied upon electronically. Out of network coverage one can, then, be more private or 'safe' from these negative aspects of network use, and do parts on one's work or leisure that do not rely on network access—deferring or avoiding parts of one's work or leisure that do rely on network access, of course. Depending on one's context, one might wish to be in a network hotspot—but at other times one might prefer to be outside the network.

This tension between the good and bad aspects of being either in or out of a network appears, to us, to be a seam in the sense that Weiser discussed. Where there is and is not coverage, and the context–specific choice about whether to be in network coverage or out of it, are aspects of network use that are common in use but under–represented in the design of ubicomp systems and user experiences. Instead, most such systems are built on the assumption that all use of the system happens within network coverage.

Bill's design used this seam in particular as a starting point. The setting of a mobile multiplayer game let us experiment without requiring long–term commitment from users (i.e. players), or demanding that they have any conceptual understanding of the notions of seams and seamful design. Instead, players would be using game limitations or constraints in a way that is commonplace in games, in the form of limits, boundaries and rules [9].

There are several research projects that have used outdoor gaming as a means of exploring new research ideas, and a number of games that work with similar design features and techniques. 'Can You See Me Now?' (CYSMN) [6] linked on-line and street players in a chase game. Street players (*runners)* moved around the game area covered by a game–specific wireless network, and had their positions tracked by GPS. On-line players used arrow keys to move themselves around a 3D view of the same streets, with icons showing the locations of runners. Similarly, online players' positions were shown on the mobile computers carried by runners. Runners chased on-line players through the city, making their GPS positions match the on–line players' positions i.e. 'catching' them. In playing CYSMN, the variable accuracy of GPS caused problems for street players when trying to catch players in areas of bad GPS coverage. However, as the game progressed, street players became more skilled at using their knowledge of good and bad GPS areas, luring online players into areas of good GPS where catching them was easier. In this way the players took advantage a limitation—a seam—of the game's construction to their advantage, but the game was not designed to make explicit use of this.

Another game that was influential in the design of Bill was NodeRunner (www.noderunner.com), which made use of the wireless network infrastructure existing in a city. Each team had a PDA equipped with 802.11 and a camera. Teams of players raced against time, logging as many wireless access points as they could and uploading photographic proof of each find to a central server. While NodeRunner made original use of the existing invisible wireless infrastructure, it made no use of the signal beyond the existence of access points.
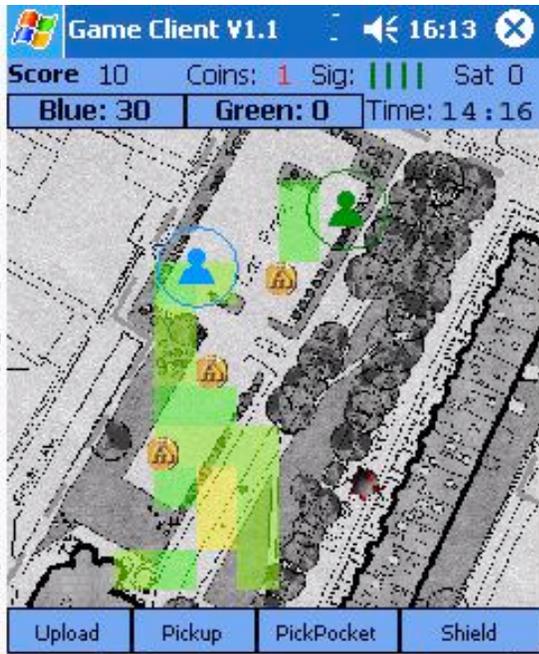
The 'Pirates!' game [1, 5] used RF technology to determine the proximity of players to one another and specific resources. The game mapped an ocean environment on to the real world and players took the role of a ships commander travelling from island to island trading and fighting in order to gain wealth. The underlying RF infrastructure was mapped to specific game events so that when a player came close to a RF beacon representing an island, a game event was triggered. In particular, face–to–face interaction was a key part of the game, encouraging some of the social aspects of gaming that can be lost in some computer game designs.

3. OVERVIEW OF THE *BILL* GAME

The main aim of a Bill player is to collect 'coins' placed in areas of poor network coverage, and then bring these coins back into an area of good network coverage to gain points. By moving in and out of areas of network coverage, players also inadvertently survey the wireless network they are playing in, building up a changing map of network coverage that they all share.

At the beginning of the game, each player is given a PDA with GPS and 802.11 wireless capabilities. The PDA interface (Figure 1) consists of a map that supports panning and zooming, on which the player's location, the location of coins, and the location of other players are displayed. To pick up a coin, a player must walk or run to the location of the coin as indicated on the map, so that his or her GPS–tracked location is close to the coin's location, and then press the *Pickup* button. For the player to gain points for this coin he or she must then walk or run to an area of sufficiently high network signal strength and click *Upload* so as to send the coins they have collected to the game server. The chances of a successful coin upload increase the deeper a player is inside wireless network coverage. To be successful in the game, players must therefore learn which areas are covered by wireless network and which are not. In other words, they have to learn and use the 'seams' of the infrastructure over which the game is played.

A key competitive game feature is 'pickpocketing'. When players are close to each other they can use the *Pickpocket* button to steal coins that are being carried by other players.

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In a... ndom loca... PDA vibrates and is disabled for sixty seconds. This causes the player to drop all coins he or she was carrying and prevents the player from playing or observing what is going on in the game via the game interface. A player who has walked on a mine can still see other players, and can get into a good position to wait for their PDA to become active again.

In our development of the game we have trialed two distinct versions. The first version was a two–player game in which one player competed 'head to head' against another player. Feedback from this early pilot led us to increase the team size from one to two, and to add more features for social interaction between players. We maintained the essential competition between players in different teams, but we also added a feature involving collaboration between players in the same team: *collaborative uploads.* If teammates upload their coins to the same access point within two seconds of each other, they gain double the normal number of points.

In the first version of the game, players' PDAs collected data on the distribution of wi–fi signal strength as they moved around. At the end of the game, the server made a map from the data collected from all the players, which could be shown to players after their game. Forcing each player to discover network coverage individually, and to build up their own mental model of coverage without system assistance, was frustrating to players. In the second version of the game we made this data available during game play. A wireless coverage map was constructed dynamically by the server, and was regularly broadcast as part of the game state for display as a semi–transparent map layer on users' PDAs. Green squares show areas of high sampled signal strength, and yellow squares show areas of weak coverage. These maps provide players with additional awareness of the network strength in the game environment, and also reveal where players have been. These collaboratively constructed maps can be used to decide places to upload coins and areas where pickpocketing should work.

4. ARCHITECTURE & DEPLOYMENT

Our game was initially designed for play over our own wireless network set up at the University of Glasgow's campus. The Bill network consisted of five VPN-connected fixed wireless access points, arranged to create three distinct areas of network coverage. The map in Figure 1 shows part of this area. We also trialled the team version of Bill in the course of demonstrations at the MobileHCI 2004 and Ubicomp 2004 conferences, and the user trial findings reported in the next section of this paper stem from these trials.

At Mobile HCI we set up our own temporary wireless network that spanned much of a park–like area outside the conference venue. At Ubicomp we made use of the network set up by the conference organisers, one of whom kindly set up an access point in a window of the conference centre. The game was played in an area of grass and trees just outside this window. Each player in the game was provided with an HP 5550 iPAQ with built–in 802.11b wireless and a compact flash GPS unit. The game client itself was written in C# and makes use of the .Net Compact Framework.

Designing a system that would work reliably across the 'seams' of the wireless network proved challenging. We needed an appropriate networking system that could handle disconnection and reconnection, and would also work in areas of patchy signal strength. To this end, we developed both a custom wireless driver and messaging system.

The standard iPAQ PocketPC wireless driver automatically connects to the strongest network signal if it is not currently connected to a network. Unfortunately, this meant that the iPAQ would connect to non-game wireless networks when outside the range of the game network. Our replacement wireless driver allowed us to lock the iPAQ onto one network, disconnecting and reconnecting to that one network as needed without user intervention.

On top of this we implemented a simple UDP based messaging system. Since connections to the network are constantly being made and broken, TCP would have added considerable setup overhead. UDP allows us to use a 'one shot' messaging system without a guaranteed transaction mechanism. A central server periodically broadcasts notifications of all new game events (new coins and mines, scores, player positions), to all clients who are within range. Player's PDAs in turn send information over UDP to the server about their position and player events, such as coin pickups and uploads. While this introduced a time overhead in that events were only periodically updated, and only scales to a moderate number of PDAs, it removed the need for guaranteed messages.

Due to the limits in wireless networks, UDP packets are often or even usually not received by all devices. The game was designed to work with these technical problems and drop outs, and display them as features of the game. So, for example, if one is outside network range then a user will not be given updates on other player's positions. This could be seen as a disadvantage to our system; but instead we have designed this as a game feature. For example, one can ambush other players by 'hiding' out of network range and then running into the network and pickpocketing other players .

Our first set of trials used our specifically installed network, set up around the university campus, and the first version of the game, with individual players rather than multiplayer teams. Ten

computer science students were recruited as pairs of friends who competed against each other. Eight of the players were male, and two were female. After an introduction to the game and the PDA interface, players were taken outside and played the game against each other for 25 minutes. Players were then given a 10 minute debriefing interview, and a small gift was awarded to the highest scoring player.

In the first set of trials, while the trials participants reported an enjoyable game, from our analysis and observations we could see that there was very limited social interaction between players. Indeed, in the post–game interviews a number of players commented that Bill could have been played as a single player game: there was hardly any interaction between players. At times players almost bumped into each other as they concentrated on playing the game and their iPAQs.

As mentioned earlier, we used the results from this trial to redesign the game, in particular to encourage more social interaction between players. This second version of the system was run with six trials at the Ubicomp 2004 conference in Nottingham, and three trials at the MobileHCI 2004 conference in Glasgow. Each of these games took place outdoors in small parks outside the conference venues. Participants were recruited from the conference attendees, with games lasting a shorter fifteen minutes. Each of these games had four players in each game, involving 24 males and 8 females altogether. In total across the Glasgow and Nottingham games we ran 14 trial games involving 46 players overall.

The overall impression of the game was that it was broadly successful. Players reported that they found the experience of playing the game enjoyable and engaging, to the point of returning from playing the game physically exhausted. As one trial participant commented: "That was fun […] least I don't need to go to the gym now".

The main forum for social interaction in this version of the game was competition: the game was designed so that players would compete for a higher score. While there was evidence that players did put effort into competing for a higher score, this generated little social interaction during the game. The only specific game feature that required physical proximity between players was the Pickpocket, which allowed a player to steal coins from another. While players attempted to pickpocket a considerable number of times—in the first trial six times per player per trial, on average—there was only *one* successful pickpocket in the whole complete first trial. It appeared that there was insufficient support for awareness of the network coverage.

To address this, in the second version of the game we introduced the collaborative production and sharing of a network coverage map. We also changed the game to involve two teams of two players each, with a joint team score, and we added collaborative uploading of coins between members of the same team to achieve higher points.

The second set of trials certainly shows more evidence of collaborative events, such as pickpockets than trial one. Successful pickpockets jumped from negligible to an average of 1.6 per player per game, and there was considerably more interaction between players recorded in our videos and observations. Collaborative uploading—only available in the second set of trials—proved to be a focus for interaction, in that players would call each other over to both attempt to upload in the same spot, and verbally synchronise and confirm the success of the upload (e.g. Figure 3). Indeed, nearly half of all successful uploads were such collaborative uploads.

More broadly, these experiences show some of the value in supporting collaboration in outdoor games as well as competition. Our move to team games, and implementation of new features such as collaborative uploading, produced a second version of the game with more social interaction. While game designs often emphasise the importance of competition between players, our experience suggests the value of also supporting collaboration between players. Indeed, our game even supported a limited form of collaboration between competing players, through the way in which the shared map of wireless network coverage was built up during play.

5. CONCLUSION

Bill was a successful attempt to apply the concept of seamful systems to an urban ubicomp game. Infrastructure becomes a central feature of the game, rather than the peripheral technical context. The deliberate exposing of selected aspects of the infrastructure suggests something of how users could develop their own ways to take advantage of the limits, gaps and seams in technology.

The trials of Bill show it to be both an enjoyable and provoking game for players. In particular, our redesign of the game had some success in encouraging more social interaction—competition and collaboration—between players. Although there was concern about the interaction between the game and the urban environment, in particular about whether players would be too distracted from cars, roads, walls and so forth, we found this not to be the case. We suggest that this may be due to the way that the game already involves continual comparison and relating between features of the game interface on the PDA and features of the wider environment. This quality of such interrelation may in fact be one of the defining features of ubicomp games, since the design area of ubicomp centres on ways to richly interweave digital media with the other older media that make up our everyday environment.

Lastly, we found the evaluation of Bill to be a challenge, initially. We were aided by tools such as Replayer, which combines logs from players' PDAs, the game server, evaluators' PDAs and video cameras. Replayer's facilities for playback and analysis have been invaluable in our redesign of the game system and in our evaluation of its use. We also point out the potential value of using such replays as part of the user experience, i.e. of the game itself, in order to support players in understanding their own and others' play, and developing new ways of playing.

Making seamful systems can be a challenge. Indeed, much of our implementation work involved dealing with the ways in which systems are generally designed to fail on encountering seams, rather than to continue and to communicate those seams to users. Most systems (e.g. TCP) either succeed or fail when used on the boundary. However, as Bill shows, these boundaries can have value as positive system features, rather than simply as points of failure. Again, we emphasise that we do not see seamlessness as always bad and seamfulness as always good. Seams shown in an interface have to be chosen and designed well, and our experience of Bill has been that it opens up an area of design that so far has not been intensively explored. While design techniques and lessons from such research may be applicable to areas beyond games, we intend to continue using mobile games both as a design

area to work in, understand and contribute to, and as a vehicle for developing new technologies, tools for analysis and design concepts.

6. ACKNOWLEDGEMENTS

7. REFERENCES

[1] Björk, S., Falk, J., *et al.* Pirates! - Using the Physical World as a Game Board. in *Proceedings of Interact 2001*, Tokyo, Japan, 2001, 9-13.

[2] Chalmers, M. and Galani, A. Seamful Interweaving: Heterogeneity in the Theory and Design of Interactive Systems. *Proc. ACM DIS*, 2004.

[3] Cliff, D. and Grand, S. The Creatures Global Digital Ecosystem. *Artificial Life*, *5*. 77-94.

[4] Dyck, J., Pinelle, D., *et al.* Learning from Games: HCI Design Innovations in Entertainment Software. *Proc. Graphics Interface*, 2003.

[5] Falk, J., Ljungstrand, P., *et al.*, Pirates: Proximity-Triggered Interaction in a Multi-Player Game. *Proc. ACM CHI*, 2001.

[6] Flintham, M., Anastasi, R., *et al.* Where On-Line Meets On-the-Streets: Experiences with Mobile Mixed Reality Games. *Proc. ACM CHI*, 2003, 569-576.

[7] Lundgren, S. Joining Bits and Pieces - How to Make Entirely New Board Games Using Embedded Computer Technology, *Computing Science*, IT University of Goteborg, Goteborg, 2002.

[8] Rutter, J. and Bryce, J. Editorial Comment. *Information, Communication and Society*, *6* (4). 5-11.

[9] Salen, K. and Zimmerman, E. *Rules of Play: Game Design Fundamentals*. MIT Press, 2004.

[10] Schneider, J. and Kortuem, G., How to Host a Pervasive Game: Supporting Face–to–Face Interactions in Live-Action Roleplaying. *UbiComp workshop on Designing Ubiquitous Computing Games, 2*001, 6.

[11] Weiser, M. Building Invisible Interfaces. Keynote talk, *Proc. ACM UIST*, 1994.