Pirates!
Using the Physical World as a Game Board

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Abstract: We explore how computer games can be designed to maintain some of the social aspects of traditional game play, by moving computational game elements into the physical world. We have constructed a mobile multi-player game, *Pirates!*, to illustrate how wireless and proximity-sensing technology can be integrated in the design of new game experiences. We describe *Pirates!* and its implementation, and report insights gained during a demonstration at a scientific conference. Observations of test users indicate that *Pirates!* can be deployed in a social setting where co-located people play together in order to promote social interaction between players and non-players alike.

Keywords: computer games, ubiquitous computing, computer-augmented environments, wireless computing, entertainment applications, proximity-triggered interaction

1 Introduction

With computers and other interactive technologies, new forms of games have been made possible. Indeed, some of the very first computer applications were games, and computer games have permeated every computer and operating system, sometimes even pushing the development of new hardware and software techniques (Bushell 1996, Herz 1997).

While computer technologies have provided exciting directions for game design and game play, they have also tended to eliminate many of the social aspects of 'traditional' game play (cf. Zagal *et al.* 2000). With computer games, we no longer need to physically get together with friends and family to play games that involve other people than ourselves. In some sense, computers have turned game play into individual and isolated activities. In a typical computer game, the game and its mechanics are inside a stationary computer, and if we interact with fellow game players, we do so through a computer screen, rather than in a face-to-face, co-located situation.

One approach to merging the use of computers and the users' social interaction is found in the research field of *ubiquitous computing*. As defined by Weiser (1991), it is the vision of omnipresent computational resources made continuously available to people in their everyday lives. The notion of ubiquitous computing acknowledges, and supports, the fact that people interact socially, and emphasizes the importance of situating computers and computer applications in the context of their users, e.g. users' location, co-location, proximity to specific resources. Applications that make use of such *contextual* information to provide task-relevant functionality are generally referred to as *context-aware* (Schilit *et al.* 1994).

We are interested in how computer games can be designed to regain some of the social aspects of traditional game play. We have created a computer game that is situated and carried out in the physical world, and which recognizes the physical co-location of players and objects in the world as important elements of the game mechanics. We also wanted to create a computer game experience that takes place in a social setting, with multiple simultaneous participants playing together, while not impeding social, non-mediated interaction between the players. Therefore, the design of such a game would draw benefits from the research done in both ubiquitous and context-aware computing. As an added benefit, we believe that by explicitly looking at a game setting, we can expose a partly different set of research issues than would be the case if we had considered a work environment. (For a more thorough discussion of the importance of computer games applications in HCI research, see Starner *et al.* 2000a.)

In this paper we describe *Pirates!*, a joint research project between Nokia Research Center in Tampere, Finland and the PLAY research studio at the Interactive Institute in Sweden. We describe the game objectives, the implemented software and hardware architecture, and report preliminary findings from a demonstration of the game. We conclude with a discussion on how Pirates! uses the physical world as a game board, and how it affects social interaction.

2 Pirates!

Aiming to construct a context-aware computer game experience, and to explore how computer games can be designed for social settings, we created Pirates![1] The game is a multi-player game, implemented on handheld computers connected in a wireless local area network (WLAN), allowing the players to roam a physical environment, the *game arena*. An important reason to make Pirates! a mobile game, is to make real world properties, such as locations, objects, and states of co-location between multiple players, intrinsic elements of the game.

To determine the physical locations of the players, we connected proximity sensors to the handheld computers, as well as placed similar sensors at different locations in the arena. The players' movement between these locations triggers different game events.

2.1 The world of Pirates!

Pirates! takes place in a fantasy archipelago setting, where each player takes on the role as the captain of a ship. Game objectives include solving a number of missions, exploring the islands in search for trading goods, and fighting other players in sea battles.

The ships allow the captains to sail the ocean and transport commodities from the different islands in order to be sold at markets. All ships are equipped with cannons and can hold a number of crew members. Early in the game, captains are commissioned small and simple ships with low firepower. However, as captains successfully complete missions, they are rewarded larger and sturdier ships. If a ship sinks in battle, or if the crew is eaten by vicious cannibals or otherwise lost while exploring islands, the game is over for the player.

The islands in the archipelago can be explored in search for treasures and commodities. They are all different, not only in terrain and what types of merchandise and valuables can be found, but also in what kind of dangers can be encountered. Whereas some islands have iron ore in abundance, others are fertile growing grounds for bananas and coffee. Islands also differ in their inhabitants; one is haunted by Captain Blackbeard and his skeleton crew, while another is the home of the mysterious Phoenix birds.

At the free harbor, new crew members can be recruited and ships can be repaired at the shipyard. Goods can be traded for money, which is required to pay crew members and repair ships. Also located in the free harbor is the Viceroy's office. The Viceroy sends the captains on missions of various nature (e.g. searching for treasures or killing evil monsters). When captains successfully complete missions, the Viceroy awards them with higher rank, and bigger and sturdier ships.

3 Playing Pirates!

Before the game can begin, each player creates a game character. This alter ego is given a name and a password used when logging into the game on a handheld device. A picture of the player is also taken to depict the captain on a highscore board.

The first time a player joins the game, he or she is a *newbie*, that is, a beginner. In order to advance from newbie to full-fledged captain, the player must solve the *newbie mission*, which is assigned by the Viceroy. In the current implementation of the game, the newbie mission is the same for all players: collect a number of boxes of bananas. Newbies are safe from dangerous encounters, such as attacks from more experienced players. When the newbie mission objectives are fulfilled, the newbie returns to the Viceroy's office in the free harbor with the goods.

For those players that have acquired captain status, the game objectives include gaining gold, experience, and rank, by trading merchandise and solving additional missions. There is one mission to be solved at each island in the archipelago, some more difficult than others. Just like after solving the newbie mission, the captain must return to the Viceroy once solved in order to be acknowledged for it. It is however not necessary to solve missions in order to play the game. A player may freely "browse" the game environment, and visit islands, trade goods, and engage in player-to-player combat regardless of the games mission structure.

As islands are encountered, the captain is given the choice to make landfall and explore the island. Figure 1 shows the graphical image of the archipelago as it appears on the handheld computer from a player's point of view. Initially, all islands appear as undiscovered, indicated by a question mark. As they are discovered and explored, they are revealed on the map. If a player comes in close proximity to an island it appears bright and colorful, otherwise it appears dimmed. Figure 1 shows that two islands have been discovered, and that the player is in the proximity of one of them.

1. Not to be confused with the Commodore 64 game Pirates!, © 1987 by Microprose.

Figure 1: Screen shot when sailing the open sea in Pirates!

Figure 2: The initial view when exploring an island.

Figure 3: A two-player combat scene.

Figure 2 shows a screen shot from Pirates! after a landfall at one of the islands. Similarly to how question marks are used to indicate unexplored islands when sailing, question marks are used to indicate locations that can be explored on each island. As can be seen in the figure, five locations can be explored on the Skull island, each of which will reveal dangerous encounters or lucky finds.

A secondary objective in the game is to challenge other captains in battle. When two players are in proximity of each other, they have the opportunity to attack. To indicate what ships are currently attackable, pictures of identified nearby captains appears on the screen (see Figure 1). This helps the players recognize each other as opponents. Figure 3 shows a player-to-player combat situation.

A large highscore board projected on a wall displays information about the top six players currently in the game. They are ranked according to number of experience points, which are displayed together with their picture, name, number of kills, and a location icon. The highscore board provides players with important information about game activities, and also allows non-players to follow the game (see Figure 4).

3.1 Exploring the game world

In Pirates! the players' location in the game arena dictates some of the game events. To solve the issue of traveling, i.e. sailing the ship, we coupled the players' movement in physical space with the ships' movement in the virtual archipelago. In other words, sailing the ship between different islands becomes equivalent to walking between different places in the game arena.

Although most game-related events are mediated by the system, the user must initiate them by physically moving between different locations. Thus, various physical locations correspond to specific virtual locations in the game, which encourages the players to explore the entire game arena. In addition, by referring to physical locations as landmarks, players can share their knowledge about the virtual game world.

In a player-to-player combat situation, the interaction is naturally mediated by the game. If a player wishes to battle with another player, he or she must approach that player in the same manner an island is approached. Correspondingly, if a player wants to avoid being attacked, he or she must avoid the proximity of other players in the game arena.

4 Game Architecture

Early on in the design process it was clear that a robust client-server architecture was needed to handle multiple mobile devices in real time. To this end, we developed custom software and hardware. The game architecture was designed to be as general as possible in order to ensure re-usability in future applications. The result was a modular system, flexible enough to allow graphics and game rules to be modified in real time during game play.

To send information between different modules in the system, we used the MEX (MEssage eXchanger) communications interface (Lehikoinen *et al.* 1999), which fundamentally is a TCP/IP wrapper that transforms low-level socket layer network communications into a higher-level abstraction. In the following sections we will provide a description of the game architecture, as depicted in Figure 5.

4.1 Game server

A centralized game server runs the game code and maintains the overall game logic. This server keeps track of the activities of all on-line players and auto-

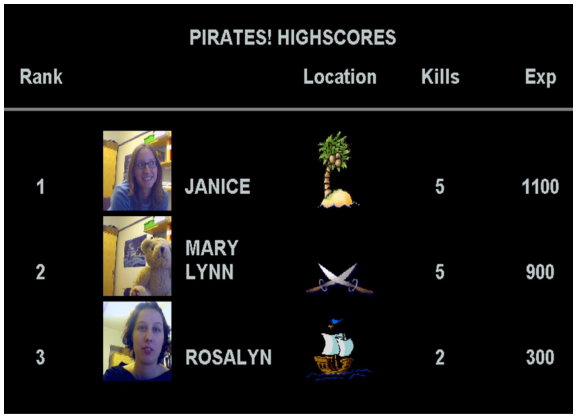

Figure 4: The *Pirates!* highscore board is projected in a public space.

matically and periodically makes backups of player data. The game server runs on a Windows PC, using a wired network connection to the login server (see section 4.4), and a WLAN to connect the game clients (see section below). The game server is implemented as a Prolog terminal with a low-level DLL interface to MEX. The use of Prolog allowed a high-level specification of the game rules, which could also be updated at runtime. The same PC also hosts a simple *file server* with all graphics and sounds, available to the game clients upon request.

4.2 Game clients

The current implementation of the game clients uses HP Jornada 690 handheld computers running Windows CE, fitted with IEEE 802.11 WLAN cards and proximity sensors. The client is essentially a dumb graphics terminal, fully controlled by the server, somewhat similar to how X-Windows functions. The graphics, fonts, and sound files reside on the clients, and updates to the client are conveniently done through MEX, by downloading new files from the file server. However, with minimal changes to support different screen properties, the game client could be ported to other handheld devices.

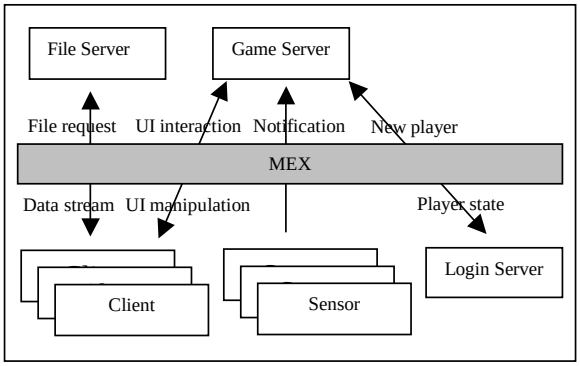

Figure 5: Schematic overview of the system architecture.

The HP Jornada 690 is a pen-based handheld computer with a 640x240-pixel, 65536-color screen. The game interface is designed to make use of the stylus, and all interactions with the game, such as deciding to make landfall on a particular island, or making the choice to sell some commodity, are made by tapping on the screen with the stylus. Because the game is mobile, and because players are required to walk around with the device in their hands, it would not have been suitable to make use of the Jornada's keyboard for user input.

On the handheld devices, the game is represented by a graphical interface accompanied by sound effects to highlight the transitions between game events. For example, as a player approaches an island, the corresponding image of that island is highlighted on the screen. To further highlight this event, a sound effect is played, *"Land Ahoy!"*

4.3 Proximity sensors

To determine the physical whereabouts of players in the game, proximity sensors were built to tag physical locations and the handheld devices. All the proximity sensors, which are radio frequency (RF) based, act as beacons, regularly transmitting a unique ID code in the free, unregulated ISM band. The range of the RF transmissions is deliberately very short, thus limiting the range of signal detection. Because indoor radio wave propagation is prone to interference and disturbance, we designed the RF beacons with a manual knob for calibrating the transmitted RF power at each specific location. In addition to regularly transmitting ID codes, all the proximity sensors also "listen" for RF activity in their immediate surroundings. When a sensor mounted on a handheld device detects a signal from another device, a notification is sent to the game engine via the WLAN. The proximity sensors are based on the TR1001 RF transceiver from RF Monolithics, with low-level control using an Atmel AT89C4051 microcontroller and an RS-232 voltage level converter for interfacing with the serial port of a handheld device.

4.4 Login & highscore board server

Before entering the Pirates! game, all players create an account by choosing a name and password and have their picture taken. This functionality was provided by a web-based system, using an Apache web server and a video camera running on a Linux PC. As new users create accounts, the game server is notified. The login server also maintains the highscore board (see Figure 4), and continuously receives updates regarding the status of each player from the game server.

5 Preliminary User Feedback

To learn out about the Pirates! potential, we felt that it was important to let people play the game in a "realistic" setting. We therefore organized game session at the *Handheld and Ubiquitous Computing (HUC)* conference in August 2000, in Bristol, U.K. We invited all conference participants (~200) to play the game and to provide us with feedback about the experience. We allowed up to seven simultaneous players since we were limited by the number of handheld devices available. During an approximately 4 hour long session, 31 test users played Pirates! with an average number of simultaneous players of 4.

13 players agreed to an interview and to fill out a questionnaire after they had played the game. The majority of the interviewed users were male in their thirties. Interestingly, playing computer games was not a popular activity among the interviewed users, who very rarely played computer games at all.

5.1 Demonstration setup

The demonstration and play session took place at the reception during the first evening of the conference. The reception was held at Hewlett-Packard Laboratories, and we were given permission to use the full space of their atrium to set up the game environment.

At one end of the atrium we set up the free harbor, which also served as a central base from where we could control and manage the demonstration. We placed one proximity sensor at this site. We placed 7 additional sensors throughout the atrium, 6 that functioned as designated islands in the game, and 1 that served as a second free harbor at the opposite end of the atrium, to function as a trading post. The range of each sensor was adjusted to suit the location where it was placed, to ensure that the "islands" were neither too small to be found, nor too large to overlap.

During the demonstration, 8 researchers ambulated the game arena to support the players with game-related questions and problems, but also to observe the progress of the game. In addition, one researcher video recorded the players' actions and reactions during the session.

5.2 Objective measures

During the play session a system log was created with time-stamped data of each user's log-ins, log-outs, islands explored, and what encounters took place. During the play session, 45 users created accounts, and 31 users played the game[1].

Further, the game logs show that 50% of the players visited islands more than 3 times, and that they spent an average 1 minute and 29 seconds on each island. Few of the players engaged in player-to-player battle, but 20% were in 2 or more combat situations. Most of the player characters that died in the game did so in player-to-player combat; only three died on islands when fighting computer-controlled opponents.

5.3 Subjective measures

Most players described Pirates! to be an interesting and fun computer game idea. While some encountered problems with the hardware and the rules of Pirates!, the majority had a positive experience playing the game. They also appreciated the theme. However, the option to engage in player-to-player combat did not appeal to the majority of players, who preferred to concentrate on solving missions. In the current implementation of Pirates!, only one captain can survive a battle while it is *Game Over* for the defeated captain. This was described as discouraging player-to-player combat because players generally did not want to risk Game Over. Some users expressed that islands were hard to locate in the arena, suggesting the addition of cues or props that hint to the location of islands.

An important flaw of the game, which relates to the noise level at the reception, is that the sound effects in the game were difficult to hear. The sound capacity of the Jornada speakers was not sufficient for the social setting we designed the game for, and since the sounds were designed to inform the players about events in the game, this was a little unfortunate. Another shortcoming in the current implementation is that there are not many possibilities for player-to-player interaction besides the combat functionality. A few users expressed that they would have wanted to interact more with others, e.g. by swapping goods, or team up against dangerous monsters, etc.

6 Emerging Game Genres

Previous efforts to combine aspects of computer game play with the real world have been made, but interestingly, this research has primarily focused on investigating possibilities for new technology, rather than in future directions of computer game play. The actual games, or applications, have been demonstrators for the technology, such as wearable computers or augmented reality systems. Our focus with Pirates! has primarily been on the game experience, and on using technology to develop a new game architecture.

The *MIND-WARPING* game/game system (Starner *et al.* 2000b) uses computer game applica-

1. One possible explanation to why some users never played the game, although they created accounts, is that at times the queue to play became very long, which caused some people to give up their turn.

tions to explore aspects of wearable computing and augmented reality. As an example, they constructed a game where two players compete against each other but are given radically different gaming experiences. One player uses voice and gesture commands to fight monsters in a first-person augmented reality. The second player has an overhead view and by moving token representations, directs monsters to attack his opponent. However, as the system puts players in different experiences, it limits social interaction without mediation through the computer system.

With a primary focus on the underlying technology, Mixed Reality Systems Laboratory developed two games, *AR2 Hockey* and *RV-Border Guards*. Using high-precision body tracking and see-through head-worn displays, virtual game elements are superimposed onto the player's worldview (Tamura 2000). In RV-Border Guards, the players can see each other through their displays, with virtual helmets and guns rendered on top of their real-world appearance. Though this game setup allows the players to see each other, the real world and virtual game objects, it actually hinders face-to-face interaction. There is little attention paid to the actual physical environment or the players' movements in space as important elements of the gaming experience.

PingPongPlus (Ishii *et al.* 1999) explores the concept of Computer-Supported Cooperative Play, in which traditional games and sports are transformed and augmented. Using a sound-based tracking system and a ceiling-mounted projector to show graphics on a Ping Pong table, several applications have been designed that support both cooperation and competition. In this sense it is similar to Pirates!, however game play in PingPongPlus is restricted to the location of the table and it cannot be played alone. Moreover, the overall experience is that of Ping Pong, rather than a radically new experience.

Recently, there has been an increasing interest in games utilizing cellular networks and in particular mobile phones, which often come bundled with a few simple games. More advanced examples include *Nokiagame*[1] in Europe and many games using *i-Mode* in Japan. Both market analysts (Datamonitor, 2000) and the Mobile Applications Initiative[2] are considering wireless games to be one of the major application areas of future cellular networks such as GPRS and 3G, often including some degree of location dependence. However, the games proposed so far have utilized location information with much higher granularity than Pirates!, such as a city or neighborhood, and also mainly considered single-user settings at each end. Pirates!, on the other hand, explicitly draws on co-located people, interacting together in real time within a relatively limited area.

1. http://www.nokiagame.com

2. http://www.mobileapplicationsinitiative.com

7 The world as a game board

In many non-electronic games, features of the physical environment are used to facilitate the execution of the game. In a sense, the physical world in which the game takes place, functions as a "game board", where game related objects and locations are spread throughout the physical space. Using the world as a game board has been explored, perhaps most notably, in live action role-playing (LARP) games. These games constitute a genre where players share a fictional world, in which they improvise, and act out an agreed-upon theme. Physical locations and objects in the world are given meaning in the context of the theme, and a story emerges (cf. Murray 1997). This is also true for just about any children's game - it is carried out in distinct physical spaces, where the children share an understanding of inscribed, 'virtual' properties of objects in the game (e.g. stones, dolls, or toy guns), and corresponding game rules.

In Pirates!, we added a computational layer to certain locations in a physical environment, and thereby integrated the locations as features of the game. We designed Pirates! to explore how a player's proximity to those locations, and to other players, can trigger different events in the game. Thus, Pirates! turns the physical world into a game board, a stage where players and the game can meet.

7.1 Proximity-triggered interaction

In Pirates! a player's location in the game arena partly dictates the game events, such as the possibility to explore an island or engage in combat with another player. To determine the players physical whereabouts, we made use of short-range radio frequency (RF) proximity sensors. We placed sensors at a number of fixed locations in the game arena, marking virtual islands in the game world. We also fitted each handheld computer with a similar proximity sensor, used to detect when the players are in proximity of islands (*player-to-place proximity*), or other players (*player-to-player proximity*). This setup enables some of the game mechanics to be taken "out of the box" and forces the players to physically navigate the game arena in order to explore the virtual game environment (Falk, *et al.* 2001). Some variations to this scheme can be made. For example, *thing-to-thing* proximity can be used to acknowledge spatial relations between moveable objects, and *thing-to-place* can provide mechanisms for moveable objects to trigger different game events in different places. In summary, the formalization of proximity to places, people, or things (cf. Redström *et al.* 1999) allows the encoding of semantic information to cue interaction in the game.

The sensors let us determine players' *relative position* to one another and to locations, i.e. the game does not keep track of any absolute location of a player or an island. A noteworthy implication for social interaction, particularly when using a relative positioning technique, occurs when proximity is measured without regards to the physical layout of a place (Redström *et al.* 1999). Consider a scenario where two users are physically close to one another, but separated by a wall. The users are indeed close, but the wall will clearly affect their social interaction. The *Hummingbird* (Holmquist *et al.* 1999) also used a relative position scheme to support location awareness between mobile people that are in each other's vicinity, without relying on any pre-installed infrastructure. Similarly, Neaves and Bedford-Roberts (1998) used a near-field RF link to allow connections between wearable computers in close proximity, though their emphasis was on technology and not on possible applications.

Pirates! could have used an *absolute positioning* technique to calculate the players' positions, based on for instance the WLAN field strength and a triangulation algorithm. There are a number of positioning systems that rely on similar techniques, perhaps GPS is the most well known, but positioning based on mobile telephony networks is gaining interest. There are also several systems for indoor use, where often a higher granularity is needed, e.g. the Active Badges system and its successors (Ward *et al.* 1997), or the Locust Swarm (Starner *et al.* 1997). Common to these systems is that they rely on some fixed infrastructure, in addition to the mobile nodes, to be functional. However, in order to obtain a high resolution spatial information, an equally fine-grained model of the relevant space, a coordinate system, is required. We chose not to use this model in Pirates, because whenever we may want to set up the game in a new arena, we would have to remodel the coordinate system, which would be both time consuming and unnecessary. Using relative positioning simply meant a more flexible system architecture, and simplified deployment.

In Pirates!, two events were proximity-driven: reaching islands and meeting other players at the open sea. Even though these events were initialized by the system, the player had the choice to initiate an action (make landfall or attack another player) or to continue with some other activity. Thus, the player controlled all actions in the game where the proximity sensors acted as filters for what actions was possible.

In the initial prototype of the game, the disengagement from an activity was also initiated by commands to the handheld device. While this could easily be maintained by the game system, we chose to not do so as the range of the proximity sensors could vary depending on external factors such as location in the building and various obstacles between the players. However, the addition of proximity-based disengagement would nicely fit with coupling of physical and virtual worlds: to flee from an island or an enemy ship the player would have to run away in the physical world!

7.2 Social impact

Zagal *et al.* (2000) identify a dichotomy between-*spontaneous* or *stimulated* social interaction in multi-player games. Spontaneous social interaction occurs naturally between players, whereas stimulated social interaction is interaction mandated by the game. Although Pirates! is intrinsically a multi-player game, it is possible for a single player to play Pirates! Hence, it is not mandated to interact socially with other players to succeed in the game, but since the game takes place in a social setting, it encourages social interaction to occur naturally during game play. Whereas social interaction in Pirates! is primarily spontaneously induced, the game explores some stimulated social interaction. This occurs when the game detects that two players are in close proximity of each other at the open sea, which triggers the option for the players to initiate a battle.

As mentioned earlier, augmented reality systems have shown how computers can mediate new forms of games. However, most of these use wearable computers and head-worn displays, to superimpose game elements onto the player's field of view. While this allows for many interesting possibilities, a head-worn display might be in the way when two or more players are interacting socially. Partly for this reason, we chose to use a handheld rather than a head-worn device.

Pirates! could have supported additional forms of social interaction, e.g. providing more cooperative actions, such as trading, allying in battle, or exploring islands together. Further, the game could provide functionality for team play (the players could for examples belong to different countries), letting players compete and have quests that must be solved together. Many of these actions were originally intended to be part of the current system, but time limitations forced them to be omitted. To promote further social interaction, the game could introduce clues and rumors that have to be spread by players, providing a system for leaving notes and maps at islands.

8 Conclusions

We have presented Pirates!, a multi-player computer game that is supported by proximity-sensing handheld devices in a wireless network, and provides a social game play experience in a physical environ-

ment. By mapping places in the game world to physical locations, the players' movement in the environment and their position relative to one another determine the game events that take place.

The demonstration of the game at the HUC2k conference showed that players enjoyed the game and did interact with one another both through game mechanics and by talking about the game. Furthermore, the game could be played in an environment were other activities were taking place without disturbing either activity. We have showed how location-aware technology can enhance multi-player games that are carried out in the physical world.

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