"Why is everyone inside me?!" Using Shared Displays in Mobile Computer Games

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Abstract. We have investigated the use of shared mobile displays to create a new type of computer games for mobile devices – Collaborative Games, which require players to physically coordinate their activities to succeed. Collaborative Games are played on mobile devices connected in wireless networks where users can start, join and leave games ad hoc. In a user study, one of these mobile games was made available in a café frequented by high school students for a period of two weeks. During the test period we noted several new forms of interaction emerging, such as players running away with their displays to avoid other players from accessing them. We also found interesting verbal exchanges, such as the use of "me" to refer to both the user's handheld display and her on-screen representation. We believe that these new ways of interaction is a result of using the shared display in a new domain.

1 Introduction

The use of handheld computers has increased rapidly over the past few years. Initially sold as replacements to pocket calendars, handheld computers are now being used for activities commonly seen on stationary computers, such as playing visually advanced computer games and surfing the web. With the invention of low-power and single-chip Bluetooth and Wireless LAN, wireless interconnectivity is becoming something of a de-facto standard on mobile devices. In fact, most current handheld devices has the ability to wirelessly connect to several other devices within the close proximity, a feature that has been explored in several recent research projects (e.g. proximity-based music sharing systems such as SoundPryer [2] and TunA [3]).

We believe that there are still areas related to the use of handheld computers in wireless ad hoc networks that are relatively unexplored. One such area is the sharing and combination of displays. In contrast to stationary computers, the displays of handheld computers can be moved, paired together, and re-arranged to form larger display areas of various sizes and forms. While some approaches for handheld computers have been made where people are required to *look* at each other's handheld displays to perform an activity (such as Geney [5]), most of them do not explore the possibility of synchronously *controlling* elements on another user's display using the wireless peer-to-peer network. Even though the use of mobile shared displays may

Fig. 1. An example of novel interaction triggered by shared display games: one player is running away with a display on which another user's game character resides

seem similar to shared displays in stationary environments (e.g. multiple monitor use [8], or face-to-face consultations [15]), the difference is that handheld computers can be used in any environment, and that users are not restricted by stationary technologies and can move about freely.

In a university course we recently supervised, students were given the assignment to create games for handheld computers that require players to share their displays with each other to advance in the game. The play area in the games was distributed across several screens, and players had to move their in-game character to the other displays to succeed. We call these games *Collaborative Games* since players are required to collaborate with each other to manage the sharing of the displays. We report from a user study where the Collaborative Games were handed out to high school students at a local café. Since our collaborative games use a wireless ad hoc peer-to-peer network with no requirements on infrastructure, we were able to evaluate the system in an environment already familiar with the students. Based on our study, we believe that the use of shared displays in mobile computer games has the potential to introduce new interaction models, which have not been previously explored in literature.

2 Shared Displays

The use of multiple and interconnected displays has previously been explored extensively in literature. While many studies have focused on developing new interaction techniques or designing new models for data sharing, it is only recently that usability studies of *mobile* shared displays has emerged. We believe that our approach with shared displays for Collaborative Games is a novel contribution.

2.1 Shared Displays in Pervasive Environments

One of the first systems for interacting across multiple displays was the *Pick-and-Drop* architecture [13]. Using the Pick-and-Drop interface, a person can "pick up"

objects on one display using a pen, and then “drop” them onto another display by tapping with the pen on that display. The system used custom-designed software which connected the computers in a peer-to-peer network. The Pick-and-Drop architecture is asynchronous and only supports events being sent between peers, such as “picking up” and “dropping” objects. The choice of an asynchronous and event-based architecture would make it difficult to extend the platform with applications such as interactive computer games, or controlling events on another display interactively. Pick-and-Drop was thus later evolved into a system for interacting between displays and physical environments, such as described in [14].

One of the key motivations for designing systems with shared displays is to allow several users to interact with the same data set. One example of this is the *Diamond-Touch* technique [6], where multiple users interact with the same display using location-dependent modulated electric fields. DiamondTouch is based around one large, front-projected horizontal display where several users can interact simultaneously. Another similar system is the *PointRight* [9] system where several users interact with several displays using a peer-to-peer pointer and keyboard redirection system. The major difference between systems such as these and our Collaborative Games is that users of mobile displays share their own *personal* displays with other users. When a person moves around in the room, so does the display. If people want to interact with objects on the user’s display they have to move close to that person so they can see the contents of her display. Other differences are that Collaborative Games does not depend on any infrastructure or custom-designed hardware to operate.

The use of shared displays is often related to the use of multiple displays (as described in [8] or [15]). Technically, systems such as these comprise multiple monitors connected to one personal computer, where the desktop simply spans more than one monitor. With Collaborative Games it is possible to achieve a similar effect using peer-to-peer network technology, but also to provide the opportunity for users to dynamically re-arrange the displays as they see fit. Dynamically re-arranging displays in a stationary environment is more problematic due to cable restrictions and the sheer size of the displays.

2.2 Shared Displays in Mobile Environments

The *Pebbles* project [11] explored how handheld computers can serve as a useful adjunct to stationary computers. One set of applications supported meetings where the participants are co-located. Using the Pebbles software, all participants' PDAs are in continuous two-way communication with each other, and with the main computer. Output from the main computer can be projected on a screen to serve as the focal point of the discussion. The active work area for all users is restricted to that of the stationary PCs. In many cases, Pebbles is similar to systems for shared displays in pervasive environments. The option for peer-to-peer communication using the PDAs hints of a possible potential outside the meeting room. However, the architecture is server-based, and since Pebbles requires the use of actual cables to connect the PDAs to the server, moving about when using the system is very restricted.

An example of a collaborative educational application on handheld computers for children is *Geney* [5]. Here, children can explore genetic concepts through the use of multiple Palm devices and a central personal computer. The game differs from other similar games in that an entire class can play it, collaboratively, using multiple devices. Playing the game, students work together to produce, say, a fish with a particular set of genetics. They accomplish this goal by "beaming" genetic data between devices, producing offspring that comes closer to the end result. Each device only shows the local fish, and to send genetic data between devices students have to "beam" the information by aligning the infrared ports. While Geney might seem similar to our Collaborative Games by using an ad hoc wireless network, Geney differs that it requires an infrastructure for the "registrar" that manages all the clients. Furthermore, Geney does not support synchronous interaction on shared displays.

The closest to our model of shared displays is probably the context-aware game *Pirates!* [4]. This was played on a PDA equipped with a short-range radio and a medium-range Wireless LAN network card. The WLAN connection was used to communicate with the central server. The short-range radios were used to determine position, by detecting other radios in the vicinity (up to a range or 3-5 meters). In this way, devices could both detect when they were close to other players, and when they were close to "islands", which were represented by fixed radio beacons in the physical environment. To accomplish all tasks in the game, players had to travel to different islands by physically visiting them. During play, they could encounter other players and enter into combat with them. While this model frees the players from sitting at a stationary computer encouraging them to encounter each other face-to-face, preliminary user studies showed that most interaction was still being mediated by the screens of the individual players' devices.

3 Collaborative Games

For two years we held a course in software development on mobile devices at a local university. Using our *OpenTrek* platform [17], students were instructed to create games that required people to collaborate to succeed. An important requirement was that the games should not be playable as "normal" multiplayer games in stationary environments, where people use a personal computer and are often not even in the same location. The purpose was to create games that encouraged people to talk to each other while playing. For this reason, ordinary communication channels such as chat windows and voice-over-IP libraries were not allowed.

In each class the students created 12 different games, and after the second year we had a total of 24 games. To encourage people to talk to each other while playing the games, most of the students separated parts of the game interface and placed these parts across the displays of the different devices (c.f. [18]). For instance, in a game called "Earth Defenders", one display was assigned as the "map" device – showing where the players and the enemy ships are located. Other displays were assigned different roles such as "star fighters" and "orbital defense". To succeed in the game, the user with the map display had to look at the displays of the other players to see the status of their health, and if needed coordinate them to a safe place away from

battle. The other players in turn had to keep an eye on the map to see where the enemies and other players are.

Every device participating in the game session had a locally stored database that was regularly synchronized with the other devices over a wireless network connection. Players could join any game at any time, at which time the database on their device got synchronized with one of the other devices in the session. In the following we will describe a typical Collaborative Game – Pac-Man Must Die.

3.1 Sample game: Pac-Man Must Die

Pac-Man Must Die (Figure 2) is a game for two or more players. The game is a "reversal" of the classic arcade-game Pac-Man, which had the main character (Pac-Man) chased by ghosts of different colors. Here, each player instead controls a ghost and must collect "dots", while at the same time avoiding being captured by yellow Pac-Man monsters. To win the game, the player must collect all the dots matching the color of her own ghost. However, some of the dots are located on the displays of other players' devices! The player can enter another person's handheld display by using "doors" at the edges of the map. Each door has a unique color, matching the color of another player's ghost. When a player has entered the display of another computer she has to look at the other user's display to control her ghost.

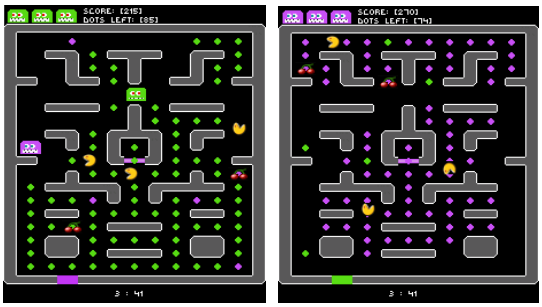

Fig. 2. Pac-Man Must Die running on two displays simultaneously

There are a total of ten different levels in the game, each with a unique layout. Each handheld device represents a unique virtual world to the other devices. If a player joins or leaves the game while others are playing, the colored dots are automatically redistributed across all displays. The game is entirely peer-to-peer, so players can join and leave the game session at any time (upon which the dots are re-distributed across the displays).

4 Collaborative Games in Use

To see how people would respond to and use Collaborative Games, we installed the game Pac-Man Must Die on six HP IPAQ Pocket PCs with Wireless LAN PC-Cards. The handheld computers were handed out to high school students (ages 16-18) at a student café, and no instructions on how to play the game were given. Since the games were designed to encourage people to communicate with each other while playing the game, we recorded everything that was said during the evaluation. For two weeks, two researchers sat at the café, handed out handheld computers, recorded audio and took pictures of the high school students playing the games [10].

Fig. 3. Running away with another player's display

Having transcribed the recordings we filed them into separate sessions, where a session in this case is a game of Pac-Man Must Die where people can join and leave the game ad hoc. The session ends when all players have left the game, one player has collected all her dots, or when the players where unable to collect all dots on all displays before a count-down timer was set to zero.

Below we highlight some of the interactions that took place during the sessions. We chose four categories that we believe represents the novel interactions that have resulted from the use of Collaborative Games: how displays become an active part of the interaction; how users share the display with others; understanding the Collaborative Games application model by example; and verbal definition of virtual places. In the transcripts, P1 refers to the first player, P2 to the second and so on.

4.1 Displays become an active part of the interaction

In one of the first sessions, four girls were playing the game. The girls had previously played several sessions, and knew how the Collaborative Games application model worked. During this session, the students did not try to coordinate where to stand in order to view each other's displays. They did however at several times make it difficult for each other by not allowing other people to access their displays.

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[P3] -Asking P1- "Is Myra [P2] over with you?"
[P1] -Showing her display to P3- "Check, check this out!"
[P3] "Ok!!"
[P2] -Not being able to see her character that is residing on P1's
display- "THIS IS NOT FUN AT ALL!"
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While playing the game, the girls regularly ran away with their displays, effectively preventing other players from playing the game when their ghost was located on that player's display (as shown in Figure 3). In another session with the same four girls,

the girls express their issues with the sharing of the displays and how their actions of entering another display with their character could be synchronized.

[P1] -*Asking P2*- ”Wait… Can you stand still with your display? Thank you!” *laughing*
[P3] ”Why can’t I move?”
[P3] ”Now I’m entering a new here…”
[P2] -*To P1*- ”Watch it! I can’t see!
[P1] -*To P3*- ”Now I’m going into Jennifer… Give me the display!”
[P3] *laughing*
[P1] -*To P3*- ”Give me the display!”
[P3] -*To P1*- ”I’m not giving you any display!”
[P1] -*laughing*-

Thus, we could see how the physical properties and configurations of the devices became a vital part in playing the game. This is a feature of Collaborative Games interaction model, and is something that is not possible in traditional applications for shared displays.

4.2 Sharing Displays

Each device participating in a session of Pac-Man Must Die is assigned a unique color. The students playing the game did not know beforehand by what color each person was represented in the game – they had to figure this out through trial-and-error and asking each other. Colors are used for two purposes: the first is to indicate which other players have dots left on a person’s display, and the second is to show where a player will end up if she enters one of the portals located at the edge of the map (i.e. moves her ghost to another display). Knowing which other players have dots left on one’s own device is a strategic advantage, as those players sooner or later must enter that display to finish the game. As the following transcript shows, some of the students did not know each other by name before playing the game.

[P1] ”Who is blue?”
[P3] ”It’s she!” -*Points with her hand on P2*-

After identities had been established, all players in the sessions seemed to remember what color each person was represented by. Furthermore, players often helped each other out when the player whose color was asked for was too busy to answer, as can be seen in the following transcript from another session:

[P1] ”Who is blue, who is blue? Who is BLUE? WHO IS BLUE?! Are you blue?! Who IS BLUE?!”
[P1] ”Hellooooo, who is bluuuuue!?”
[P3] ”Alexandra!”
[P1] ”Alexandra is blue… And then…” - *moves her ghost to Alexandra’s display*- “I’m with you now Alexandra!”

Players also tried to help each other out when they thought they had mixed up each other’s colors.

[P2] ”Who’s red?”
[P1] ”Julia!”
[P3] ”No, I’m white!”
[P1] ”No, you’re not! You are… Who is…” *looking at P2’s display* ”You mean purple!”

Sometimes however, helping each other out proved to be not so successful.

[P1] ”Who is… Who is… Jennie, what color are you?”
[P3] ”I am pink!”
[P2] *-Answers simultaneously-* ”Like, the orange…”
[P1] *-Repeating what P2 said-* ”Like, the orange…”
[P3] ”But I am pink!”
[P1] ”Aaaaah…”

Another aspect of sharing displays is if several people are playing the game and one person suddenly has to leave the game. That happened in one session where two girls were playing and a male student joined the game. Unfortunately the male student had to quickly move on for a class, and both girls were then playing on his display (as seen in figure 4-b). He then simply left the display behind so that the girls could continue playing (Figure 4-c) without disrupting the game session.

Fig. 4. Sharing Displays: In one session two girls were playing where another student joined in. Unfortunately he had to leave early, and since both girls were playing on his display he had to leave it behind

4.3 Understanding the Collaborative Games Application Model

No student received instructions on how to play the game before the evaluation sessions started. Learning how to play the game also implies understanding how the Collaborative Games application model works, since displays have to be shared to complete the game. Students found it difficult to explain to each other how the game worked simply by explaining the rules, as can be seen in the following transcription:

[P3] ”Maybe you should begin by explaining how to play?” *-laughing-*
[P1] -laughing- ”I’m on her track”
[P4] ”Ah, I don’t give a damn about that, you have to explain how it is played first!”
[P1] ”I have tried to explain how it works!”
[P2] ”No, you have not!”

We found that students found it easier to teach each other the Collaborative Games application model by showing instead of telling.

[P1] ”No-one touches anything! Don’t touch anything Alexandra!”
[P2] *-to P4-* ”Alexandra!”
[P4] *-to P3-* ”Ok, explain then!”
[P3] ”So I am red ghost Jennie? Taking my red items… But then I see that I also have green, purple, and blue… And you are those colors… So when I have taken all that are mine I am entering either the green portal or…”
[P4] ”What happens if I take yours then?”
[P3] ”Silent! You can’t take mine!”
[P4] ”But…?”
[P3] ”No, you can’t take mine!”

[P4] ”But I have orange colors here…”
[P3] ”But you can’t take them!”
[P4] ”Umm, ok…”
[P3] *-showing everyone her display-* ”Then I enter… Then I enter a portal… I am entering the blue… Green! Or blue! I am entering yours!”
[P2] ”Can you enter the portals at any time?”
[P1] ”Yeah”
[P3] *-to P4-* ”Then I have to watch your display!”
[P4] ”Aha, and the one that gets… And since you got me with all your items you won?”
[P3] ”Mmm… Mmm…”
[P3] ”You basically enter each other.”
[P5] ”Now I want to try! Now that I have seen how it is done!”

Thus, despite this being a new interaction model, it seemed that the subjects of the study quickly caught on to the concept, even without any instructions.

4.4 Who Am I?

When playing the game, each player has to move their ghost to other people’s displays to finish the game. During the sessions, players most of the time referred to the displays as the person using the display. Since both their devices and their virtual character in the game were referred to as “I”, in some occurrences this caused some rather odd exclamations, such as when four players simultaneously were playing on one girl’s display:

[P4] ”Why is everyone inside me?!”

In all sessions, most of the students new to the game referred to the physical device or display when talking with other players (“I am entering yours”). However, experienced players (who had played several sessions) and some of the new players always referred to the display as ”he”, ”you”, or ”someone”. Transferring the player’s ghost to another display was always referred to as ”coming over to you” and ”coming in to you” by experienced players, which is exemplified below:

[P3] ”Who’s green then?”
[P1] ”I am!”
[P3] ”Ok, then I’m coming over to you!”
[P1] ”Ah, ok… Now stay here…”
[P2] *laughing* ”But where am I coming then?”
[P3] ”But he’s upside-down?”
[P1] ”Ah, it was my fault …”
[P2] ”Where am I?”
[P5] ”Eeeee… I don’t know where you are …” … ”Damn… Now I am inside someone else …”
[P3] ”You’re with me… Hang on a moment…”

Closely integrating a personal display with game mechanics has been previously explored (such as in Pirates! [4]). The difference with our approach is that the player provides an always “open door” to other players where they can use the display of that person any time, and it is up to the player using the display to allow that or not.

5 Discussion

Evaluating our Collaborative Games at the students' own local café probably had an impact of the results of the study. If we had setup a custom environment at a trade show or a conference to get feedback on the games, not only would most of the people evaluating the games not have know each other beforehand, they would also be limited in the way they could move around while playing the game (since we naturally would not want anyone to run away far with our handheld computers). We do not believe that evaluating the games this way had a negative impact on our results – in fact our choice of environment was based on how we believe Collaborative Games would be played if they were bundled with an off-the-shelf hardware device. We will now discuss some topics related to the evaluation: the use of ad hoc peer to peer networks in the study, the use of "I" when the students were relating to their devices and some of the issues related to knowing what person is using what device.

The Collaborative Games were all designed as peer-to-peer applications for ad hoc wireless network connections. Thanks to our OpenTrek platform [17], this has the effect that games can be played simply by turning on two devices and choosing what game to start and what people to play with on one device, and the game is then started automatically on all other devices, similar to Instant Messaging [7]. The ease-of-use and lack of infrastructure requirements made it possible for the students to move about freely when playing the games. While many systems for distributed and decentralized data sharing has been presented previously (such as Rendezvous [12] and GroupKit [16]) most of these systems are not applicable to the mobile realm since they still depend on central coordination to operate.

The students playing the game Pac-Man Must Die! often referred to their character in the game as "I" (e.g. "Ok, then I'm coming over to you!"). Using the Collaborative Games application model, each device had its own, unique labyrinth on the display. During play, this labyrinth also came to represent oneself, as expressed by one student "Why is everyone inside me?!" This apparent "personal connection" between the ghost, the device, the labyrinth and the player may have been strengthened due to the use of the Collaborative Games application model. By simply walking away with the PDA, a player is able to physically relocate the map as well as the representations of all other players in the room and on the same map in one simple movement.

When sharing the displays, the students needed to know what person was responsible for each device. Representing players by colors instead of names was chosen simply because we wanted the game to be playable if the people did not know each other beforehand. As seen in the evaluation, the connection between a color and a person required much verbal communication between the players. In other studies of recreational activities, unnecessary "coordination talk" between people who already knew each other well was not considered to be a positive thing [1]. In our case the need to communicate served as an "ice breaker" which forced people to talk to each other even if they did not beforehand know each other. With the new camera-enabled PDAs and phones that are now becoming available, it will be possible to begin each game session with the students taking pictures of themselves and allowing this picture to represent them in the game. While it would solve the question of what display was

represented by what person, some of the communication between the players might also be lost at the same time: ”Who is blue?” – ”It’s she!”

6 Implementation

We will now briefly describe some implementation details. All Collaborative Games were developed and tested on HP IPAQ Pocket PC devices with Wireless LAN expansion cards. These devices feature a large display and several input channels, such as button presses, pen input, and audio input. The provision for attaching a standard W-LAN card makes them well suited for prototyping of networked applications.

All games were written in C++ using two of our software platforms: *GapiDraw* and *OpenTrek*. GapiDraw (www.gapidraw.com) is a graphics toolkit for fast graphics, originally for PocketPC devices. It has now been extended to also support devices such as Palm and Symbian devices, and is today the most widely used graphics SDK for handheld computers and smartphones. Using GapiDraw, it is possible to create fast graphics on handheld computers without considering the differences between different graphics hardware implementations.

A complementary platform, OpenTrek [17] is primarily intended to assist the development of multiplayer networked games on handheld devices. Creating peer-to-peer networking applications for handheld computers can be difficult, since there are many hardware issues to consider. One example is limited network buffers, which require the developer to write meticulously timed programs with multiple threads managing incoming and outgoing network queues on the device. Developers also have to consider issues such as broadcasting information to other devices, forming game sessions on the wireless network, and showing the user what other people have their devices switched on. OpenTrek is specifically designed to abstract issues such as these.

7 Conclusions and Future Work

We have presented results from the use of Collaborative Games – computer games for mobile devices that require players to coordinate their activities physically. Based on the results from using the Collaborative Game Pac-Man Must Die!, we argue that Collaborative Games has the potential to introduce new forms of interaction between people. In times when almost every handheld device is equipped with some wireless connection (Wireless LAN or Bluetooth) we believe that the Collaborative Games interaction model may have significant impact on future mobile applications.

Future work involves exploring the use of different devices and different wireless connections, to enable the use of Collaborative Games on other devices than PDAs. We already have most of the games running on Smartphones, and we are in the process of creating network protocols that can be used for Bluetooth connections. We are also planning a more long-term study with several games involved, where different groups of people will be able to use the games in various situations and environments.

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