

Witches, Warlocks and Traffic Encounters

Designing the interaction for an ad hoc
multiplayer gaming experience

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NOMENCLATURE

API	Application Program Interface
DOF	Degree Of Freedom
GAPI	Game Application Program Interface
GPS	Global Positioning System
HCI	Human Computer Interaction
HMD	Head Mounted Display
PC	Personal Computer
PDA	Personal Digital Assistant
RAM	Random Access Memory
WLAN	Wireless Local Area Network

1. ABSTRACT

This thesis explores the problems and possibilities concerning the interaction between players physically located in different cars during temporary meetings in a gaming situation. The thesis is part of a study set out to investigate how traffic encounters can be used as a resource in a mobile, multiplayer game intended as entertainment for children travelling in the backseat of cars. The multiplayer capabilities are realised by using wireless networks in ad hoc peer-to-peer mode, GPS positioning and a digital compass.

Designing the interaction for an ad hoc, mobile multiplayer experience introduces several design challenges, such as how to adapt to the temporality of traffic encounters and how to establish a connection between the digital game and the physical context. The nature of traffic encounters inspired us to take a new approach to the interaction. The interaction is accomplished using a device, which enables direct interaction between players physically located in different cars. A prototype game was constructed within the frames of the project, which this thesis was part of, to test the functionality of the game concept. The prototype has been tested in its real setting, i.e. inside a car.

The study and the work on this thesis was initialised and supervised by Liselott Brunberg and the work was carried out at the Mobility Studio at the Interactive Institute in Stockholm during late spring and summer 2003.

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3. INTRODUCTION

Travelling in a car provides a compelling experience created by the motion, accompanying traffic and the passing scenery [7]. The environment is unpredictable and the scenery passing by the window is ever changing. Contingent encounters are central in the highway experience [3]. Meetings in a traffic situation are opportunistic and temporal. Some encounters are just a brief meeting, such as when two cars travelling in opposite directions meet. Yet, others last for a longer period of time, such as when cars end up driving behind each other or get stuck at a red light. Sometimes, the scenery will be made up of a constant flow of cars in both directions. At other times, the road will be empty with other cars appearing just once in a while.

But travelling can also be boring and annoying, especially for children travelling in the backseat of the car. To amuse themselves, they chat with each other, play games or let their fantasy drift away while watching the scenery outside the window. Sometimes they make up games according to the current road context, using the surrounding as a “game board”. For example, while travelling on a busy highway, the goal of the game could be to “spot all red cars passing by”. Also common as car-travel recreation are digital games played on mobile game consoles, such as mobile phones and Nintendo Gameboy. The digital games bring exciting elements to the journey, but at the same time, the contact with the physical environment is reduced. By integrating the two worlds, some of the natural real world interaction present in pre-computer games could be regained, and at the same time, the exciting elements offered by computer games could add to the experience [7]. Essentially, this is the essence of augmented reality: to extend or supplement the real world by integrating virtual objects into a real world environment [4].

The interactions in pre-computer games consisted of two elements: human to physical world interaction and human to human interaction. In computer games, the interaction has been reduced and replaced by an indirect human to virtual world interaction [9]. Augmented reality spans past these boundaries by allowing the users to interact with real, physical objects or humans in a virtual environment, or with virtual objects added to the physical environment. Backseat Gaming was a successful example of a prototype for a new kind of mobile game, which explored the possibility of using the road context for creating a “light version” of an augmented reality experience [7]. In the game, objects from the game world were tied to physical objects along the road, such as a house or a tree.

In this project, we have taken a new approach to the use of the road context by using contingent traffic encounters as a resource in a mobile multiplayer game. The multiplayer capabilities are realized by using wireless networks in ad hoc peer-to-peer mode, GPS positioning and a digital compass. A multiplayer opportunity arises when two players are in proximity of each other, approximately 150 m. The multiplayer events provide a means for the users to interact (Figure 1).

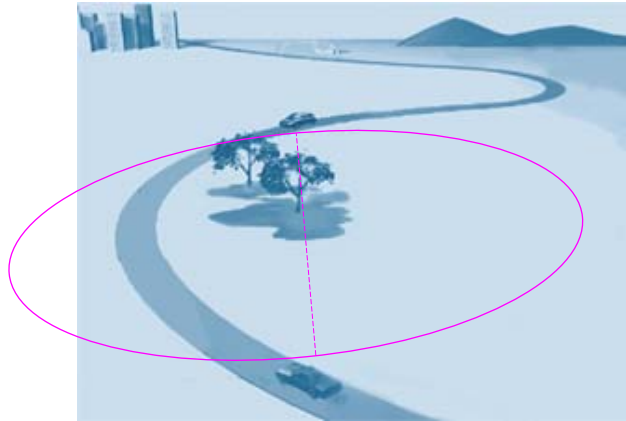


Figure 1: Multiplayer event

Using the real world context for creating an ad hoc multiplayer experience introduces several design challenges, such as how to adapt the game to the unpredictability and speed of the meetings, how to establish a link between the game and the real world and how to spur social interaction between the players.

3.1. Problem statement

This thesis aims to explore the interaction between players physically located in different cars in a multiplayer gaming situation; how the interaction should be designed and implemented to benefit from the highway experience and to spur social interaction between the players. The thesis is part of a study set out to investigate how traffic encounters can be used as a resource in a mobile, multiplayer game intended as entertainment for children travelling in the backseat of cars.

3.2. Structure of the report

The next chapter describes the background and sources of inspiration for the work on this thesis. First, the reader will be introduced to the concept of Backseat Gaming. Backseat Gaming was the first part of the study concerning the use of the road context as a resource in a digital game. Next, section 4.2 will provide the reader with an overview of related work in the field of mobile, multiplayer, context aware games and tangible interfaces. Chapter 5 presents the approach taken to the design of the game and the interaction between the players. The description of

the work on the prototype starts with a presentation of design challenges described in chapter 6.

Chapters 7-8 describe the work process for designing the interaction and the construction of a device, which enables the interaction between the players. Last, chapter 9 presents the result of an initial testing of the functionality of the game prototype and chapter 10 presents a list of future work. Finally, conclusions and results from the work on this thesis are discussed in chapter 11.

4. BACKGROUND

4.1. Backseat Gaming

In autumn 2001 members of the Mobility Studio at the Interactive Institute initialised the Backseat Gaming project. Backseat Gaming is a prototype for a context-dependent mobile game, which uses the changing scenery and sense of motion created during car travelling to generate a compelling game experience [7]. The target group were children travelling in the backseat of a car. The project aimed to investigate the fictitious connection between the game and the surrounding world and how this spatial relation was interpreted, explored and manipulated when playing the game.

Backseat Gaming was implemented on a Pocket PC (PDA) equipped with a GPS receiver and a digital compass mounted on the back of the Pocket PC. The gaming device and the hardware are shown in figures 2 and 3. The GPS was used for positioning of physical objects and the digital compass was used for locating virtual objects in the physical context. For testing purposes, the prototype game was constrained to a certain stretch of a road.



Figure 2: Hardware



Figure 3: The Gaming device

The game consists of a framing story, which introduces the player to the plot of the game and local stories and manipulative events that are triggered at predefined places along the road. The local stories, which are triggered at certain physical locations along the road, provide the player with further information and instructions for the manipulative events. Manipulative events play a central role in the game by providing the user the opportunity to interact with objects located along the road. The physical locations (GPS coordinates) that trigger the local stories and manipulative events are stored in a database in the Pocket PC. The events are triggered when the player are in the vicinity of the physical location connected to the event. During the manipulative event, the appearance of the graphic display of the device instantly transforms into to a “virtual window” with which the player can aim at objects in the physical

environment (figure 4). The virtual object appears on the screen when the player aims at its virtual position in the physical world. The player can attack or pick up the object by pressing buttons on the device [7].



Figure 4: Virtual window during a manipulative event in Backseat Gaming

4.1.1. User feedback on Backseat Gaming

In order to acquire feedback on how players enjoyed, understood and handled the game, a test was conducted on the first game prototype. The test group, which consisted of five children aged five to ten years, was filmed while playing the game in the backseat of a car. The children in the test group generally understood the game concept and managed to handle the manipulation of the virtual objects. Additionally, they seemed to enjoy playing the game.

The test showed that the intention of establishing an engaging fictitious connection between the game and the surrounding physical roadside was successful even with a light version of augmented reality technology. But the test also indicated that the game could benefit from a different sort of interface and better non-visual feedback in order to cope with the different contextual situations and to preserve the fictitious connection to the real world. This was indicated by the way the children handled the game and how they adopted different gaming strategies depending on the type of object involved in the interaction. There was a noticeable difference in how they moved the device and where they concentrated on looking during different types of manipulative events. When a singular virtual object was placed in close proximity of a specific physical object, e.g. a virtual document dropped at an old oak tree, the player looked back and forth between the screen and the physical object to make sure they aimed in the right direction. During game events that consisted of several virtual objects spread over a larger physical space, the players adopted a different strategy. They focused either on the screen waiting for objects to show up, or out through the window, firing rapidly and randomly without checking whether there were any virtual objects on the screen or not. The youngest girl sometimes had trouble with handling the rather heavy device and her arms seemed to be tired from the weight. The evaluation also indicated that the audio feedback was an important feature of the game [7].

There are only a few examples of other games that exploit different aspects of mobility within a gaming situation. Using the context of

travelling in a car on the highway or along a road as a resource in a mobile game is a completely new concept.

4.2. Related Work

At present, there are no other examples of games or game prototypes that support interaction between players in different cars. However, there are several examples of games that explore different ways to connect the real world and the digital world and how this can be used to create mixed reality, multiplayer games.

The game interface is inspired by the concept of physical, graspable and tangible interfaces, which have been the subject of much research over the last decade.

What these types of interfaces have in common, is the intention of establishing a direct link between digital representations and human users by using real world objects as interfaces.

4.2.1. *Mobile context aware multiplayer games*

A number of research projects explore the possibilities of bringing the real world closer to digital games. What many of these projects have in common, are that they explore interaction between human-to-human and human-to-physical world interaction within a very enclosed space, such as that of a room, relying on pre-set infrastructures.

Touch-Space [9] is an example of a computer entertainment system that incorporates tangible interfaces in a mixed reality, multiplayer game to allow the users to interact in environments ranging from physical environment (human-to-human and human-to-physical world), to augmented reality and virtual environment. The system uses the traditional features of a virtual reality system (acoustic tracking system, HMD and a wand) to support tracking of body movements and exploration of the game space. In addition, the system incorporates real, physical objects in the game space. The result is a system that integrates the physical and social aspect of traditional game play with fantasy features of digital computer entertainment. User studies of the Touch-Space system showed positive reactions towards the use of a tangible interface.

Pirates! [6] is a wireless multi-player game exploring novel ways to maintain social aspects of traditional game play in a computer game. The game arena is located within physical space and proximity to locations or other players are used to activate events in the game. The game takes place in a fantasy archipelago, where each island can be explored in search for treasures and commodities. Goods can be traded with other players and sometimes a battle between captains of rivalling ships or with monsters will occur. To explore an island or trade goods, the player have to physically move to the location that represents the island, or stand close to the other player in a battle. The game is implemented on handheld computers connected to a wireless network. Proximity to

locations is detected using proximity sensors connected to the handheld computers and placed on different locations in the game arena.

Exploring the possibilities of using travel experience as a resource in a gaming situation involves different design challenges than the ones in a pre-set room, including need for a truly mobile setting, the inability to control the environment and how to adapt to the speed and temporality of the road context. Since fewer resources are available outdoor, computation, sensors and power are limited to what a user can carry [20].

Can you see me now? [1], *Bystander* [16] and *Botfighters* [26] are all examples of games that are based on positioning of other players in an outdoor environment. The *Citywide* [16] project explores ways in which technology can provide people with rich and engaging mixed reality experiences. Their approach includes exploration of different interfaces for detecting, revealing and experiencing events that take place in a virtual world hidden behind, but available from physical space (the real world) [16]. *Can You See Me Now?* [1], and *Bystander* [16], which are part of the *Citywide* project, aim to explore the collaboration between online participants and mobile players physically located in an outdoor game arena. The games were staged as public events with participants from the research team as well as novel users. In *Can You See Me Now?*, three runners were physically located on the street and up to twenty players could log on to the game using the internet. The players and runners shared an online map from which the players could follow the runners and the runners could locate the player's current positions. The runner's goal was to catch the online players by physically running to the location of the player's avatar. In *Bystander*, the roles were reversed, i.e. the online players chased the runners across the online map. *Can You See Me Now?* and *Bystander* both used the internet to accomplish the connection between the players, which is too slow for our setting.

Commercially available *Botfighters* [26] from *It's Alive* uses location and proximity of players as resources in the game. In the game, the player takes the role of a robot ("bot") and the goal is to shoot other bots. A fired shot will hit the other player's robot if the two players are sufficiently close to each other. All commands are sent using sms and the location is determined by GSM mobile phone positioning. The setting is truly mobile, but too inaccurate for the purpose of our research.

4.2.2. *Tangible user interfaces*

The key characteristic of tangible user interfaces, as defined by Ullmer and Ishii, is the use of physical artefacts as representations and controls for digital information [17, 18]. Ullmer and Ishii list the following four characteristics of tangible interfaces [17]:

1. Physical representations are computationally coupled to underlying digital information.
2. Physical representations embody mechanisms for interactive control.
3. Physical representations are perceptually coupled to actively mediated digital representations.
4. The physical state of tangibles embodies key aspects of the digital state of the system.

Examples of digital representations include screen-based graphics and audio. Physical representations are persistent, e.g. they do not disappear if the power is switched off, as opposed to the digital representations that rely on the power supply to the computer. In the earlier works by Ishii et.al., the interfaces are called graspable interfaces rather than tangible interfaces [13]. Tangible interfaces strive to bring computers closer to the real world by turning the physical world into an interface and to make computational resources available in a way that enables us to use the skills we have developed for manipulating ordinary physical objects.

5. METHOD

The method we have used for the project is called prototyping [34, 35]. Prototyping is a commonly used method for development of systems or part of a system. We have taken an iterative approach to the prototyping technique. New features are added to the system step by step; the most important features first and details later. The aim of this project was to create a prototype suitable for testing the functionality of the game concept.

5.1. Approach

The approach taken to the development of the prototype is outlined in figure 5. This report describes one iteration of the chain of actions in figure 5. The process of designing and implementating the interaction are part of all steps described.

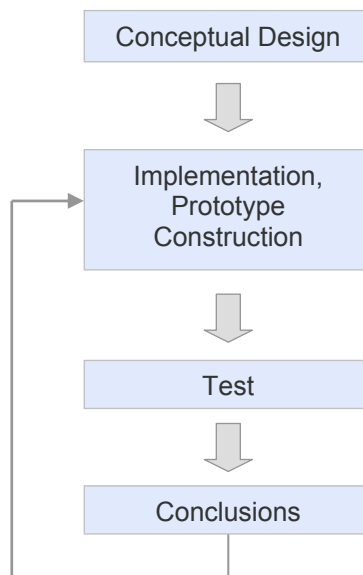


Figure 5: Our approach to prototyping

To concretize our ideas and to identify key features of the game, we started by setting up a conceptual design for the game. The conceptual design process included several steps, which are described in detail in section 5.1.1.

5.1.1. Conceptual Design

Figure 6 is a summary of the approach taken to the conceptual design. The first step in this process was to identify the design challenges associated with the new game concept, which set up the frames for the user interaction design and implementation, the interface design and the game design.

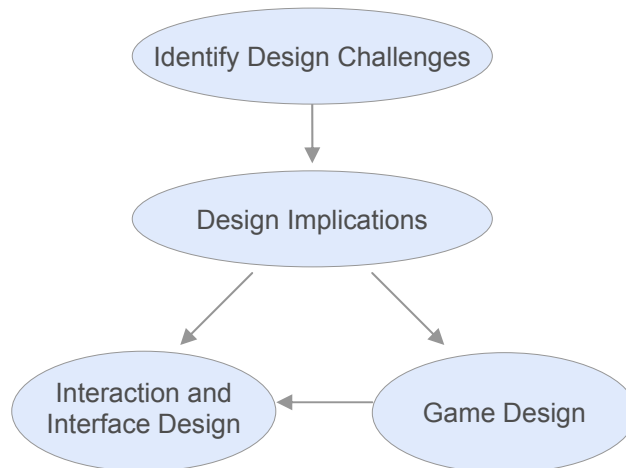


Figure 6: The conceptual design process

The user interface and the ability for the users to interact, must adapt to the theme of the game as well as different gaming situations and strategies adapted to the physical context. Hence, it is important that the interface and interaction design adapt not only to the frames set up by the game setting and the physical context, but also to design decisions concerning the game design. When desinging games, the ideas and desicions made in the design process are often summarized in a design document or concept paper [10, 22]. The conclusions made during the conceptual design process are summarized in chapter 7, which could be considered the design document for the prototype.

Inspiration for the idea generation and identification of design challenges was found in the intended setting of the game, i.e. in a car, driving on the roads of Stockholm city and surroundings. However, primarily, the identification of design challenges is based on reported experiences from the previous prototype and study of related work. The pre-study on related work covered material concerning game design, physical interfaces, real world interaction and related applications. The material consisted mainly of published papers on related research projects. The papers provided knowledge of the most recent research results in related fields. In addition, the pre-study included a visit to “Spelforum”, which was held at the IT University in Gothenburg in April 2003. The pre-study and concept development phase of the project resulted in part of a workshop paper for the workshop on real world user interfaces at Mobile HCI’2003 in Udine, Italy [8].

5.1.2. *Implementation and test*

The construction of the prototype was based upon the result of the conceptual design process. When implementing the game, the features were prioritized according to their importance for the functionality of the game and the interaction. For example, since the functionality of the game is not directly dependent on the story, the story was not implemented in the prototype. Furthermore, functions which resembled the old game, such as the ability to interact with objects found along the road, were given low priority during implementation. High priority were given to functions related to the following areas:

- The interaction between players.
- WLAN communication.
- Feedback on interaction.
- Awareness of other players.

This thesis primarily concerns the implementation of the interaction possibilities. This also includes insight in the implementation of the sound feedback and graphical feedback. The solutions to the gaming activities relying on the network capabilities are not part of this thesis, but will be briefly described to help the reader understand the construction of the prototype.

Testing the prototype is a very important part of the work process. By testing the prototype, weaknesses and technical flaws in the system can be detected and corrected [35]. The initial tests of the game prototype was performed in the Mobility Studio and a final test was conducted in the real game setting, i.e. while played in a car.

The very final step in the prototyping sequence would be to carry out an evaluation including children playing the game. A user study is necessary to answer questions such as: “*is the game fun to play*” or “*does the use of a non graphical interface spur social interaction*”. To carry out a user study, a complete game prototype must be implemented. The game must not only be functional, but also include stories to make playing the game fun. A user study and evaluation of the game will be conducted by members of the Mobility Studio in a near future.

6. DESIGN CHALLENGES

Contingent encounters such as rapid meetings, protracted overtaking or gatherings i.e. traffic jams or red light accumulations constitute an essential part of the travel experience. Encounters can occur anywhere and anytime during the journey, or sometimes not at all. When travelling at high relative speed, people meet for a very short period of time. Other encounters persist; two vehicles might, for example, end up driving behind each other towards the same direction for a longer period of time. It is difficult to predict when an encounter will occur and end. Designing the interaction for such an unpredictable and temporal, yet inspiring, environment introduces several design challenges.

6.1. Interaction Design

Crucial for the success of the game is the design of the interface and the ability for the users to interact, in single as well as multiplayer mode, during game-play. The interaction must support different game situations and strategies adapted to the physical context. A major difference between the interaction that occurs in single player mode and the interaction between players during multiplayer events is that the user interacts solely with virtual objects located in the physical surrounding in single player mode, but mainly with real, physical, players in multiplayer mode. We argue that, for a physical object appearing in the game context, screen-based graphical feedback would not be the best solution. In multiplayer events, the competitor is a real, physical object, visible to the player. We believe that split attention between the screen and the real world will, in this situation, be cumbersome and rather impair than augment the interpretation of the link between the virtual and the real world. For short meetings, such as when two cars travelling in opposite directions meet, the user must be able to instantly spot the other players and react instantly without losing sight of the other player.



Figure 7: The players' view in a multiplayer event

The nature of contingent encounters inspired us to explore an alternative interface and ability to interact in order to benefit from the highway experience when playing the game.

Fantasy fulfilment is a very important motivation to play games [21]. The game design should cultivate the player's imagination of the game world and at the same time preserve the connection to the real world. It is important that the connection between the screen interface and the use of the physical interface is clear. Another critical point in the game design is the transition between story mode and physical game locations or multiplayer events. The transition from single player mode to multiplayer mode is especially challenging.

While playing the game, the user's ability to move freely is constrained by the enclosed and limited space inside the car and by the safety belt. The context of travelling in a car introduces new challenges concerning the safety of the player and other passengers travelling in the car. It is important that the player is not encouraged to take the safety belt off when playing the game to benefit from the ability to move more freely inside the car. In addition, it is important that the interface is designed to limit the risk of hurting anyone or anything inside the car and that the use of the interface does not disturb the driver.

6.2. Multiplayer Play Design

Integrating encounters as a resource in a mobile game involves a play design that take into account the sudden appearance of potential players, momentary and continuous encounters as well as sudden and unexpected interruptions between players. When designing the game play under these conditions, the following must be considered:

- Playing the game should not affect the driving of the vehicle
- A player should not gain advantage by intentionally breaking the connection with another player by driving out of reach.
- Playing the game must adapt to sudden interruptions caused by approaching players

When players come within proximity of each other, approximately within 150 meters, a multiplayer event will be triggered. The game should be designed in such a way that a multiplayer session can be played regardless of the duration of the encounter. The rules of the game must be designed in such way that a player will not lose or gain anything by becoming disconnected from another player. Neither should a player gain any advantage from intentionally breaking the connection with another player trying to escape from an enchantment, nor disadvantage if one vehicle happen to drive in a different direction at a crossing. The game must be designed so that it is not possible for the user to take advantage of encouraging the driver to change driving behaviour in order to fit in with the game context.

7. DESIGN IMPLICATIONS

This chapter summarizes the design decisions concerning the game design and the user interface design, which are a result of the design challenges set out in chapter 6. Section 7.1 provides the reader with an understanding of how the game is set out to work in practice and Section 7.2 provides a description of, and motivation for, the user interface design.

7.1. Game Design

The game concept has four distinguishable parts: a framing story, local stories, manipulative events and multiplayer events. The concept for single player mode is similar to Backseat Gaming and will not be further described. Focus of the game design described in this chapter is on the interaction that takes place when two players meet during a multiplayer event.

Multiplayer events are characterized by the existence of human opponents or co-operators, which lead to competition and cooperation in the game. According to Zagal and colleagues, this feature distinguishes multiplayer games from single player games [22]. Even though the characteristics of multiplayer games are quite different from the characteristics of single player games, it is only recently that inherent design approaches developed especially with multiplayer games in mind have evolved [22]. According to Zagal and colleagues, there are two things that basically define a game concept: the rules and goals and the props and tools. The rules define what kinds of actions the users are allowed and can choose to perform, thereby setting up a frame for the interaction that can take place in the game [19]. The goals of the game should be clear, but the outcome of the goal should be uncertain [21] and achieving the goal should require that the user make an investment in effort in playing the game [19]. Tools are objects which the players use for playing a game, while props are objects that are used solely as decoration [22]. A multiplayer game involves interaction among the players to some extent. The interaction can be either natural interaction that occurs spontaneously in the game, or stimulated interaction that is necessary to the game and enforced by the rules [22].

The following sections are a summary of the game design described in terms of its goals and rules, tools, cooperation/competition and interaction.

7.1.1. Goal and topic

The topic of the game is “magic”. The player’s goal is to gain as much power, counted in power points, as possible before getting to the big yearly meeting for witches and warlocks. High power will benefit the witch or warlock with high status at the meeting and will bring certain advantages to the proprietor.

In the game, the player takes the role of a witch or a warlock of his/her own choice. The witches and warlocks have different magical specialities. The character always carries a sack to collect objects in. The objects can be found along the road, exchanged with or even stolen from other players. What object the character initially carries in the sack depends on the chosen character’s speciality. The player can choose between the following characters and specialities:

Role:	Speciality:	Starts with:
<i>Witch / warlock one</i>	<i>Bombs</i>	<i>A bomb</i>
<i>Witch / warlock two</i>	<i>Magical brews</i>	<i>A recipe</i>
<i>Witch / warlock three</i>	<i>Languages</i>	<i>The key to the anti-spell</i>

Table 1: Character characteristics.

7.1.2. Rules

- Successfully completing the following actions will reward the witch or warlock with power-points:
 - Casting a spell (even if the target player was not enchanted)
 - Brewing a magic brew
 - Picking up an object
 - Planting a bomb
 - Enchanting a witch or warlock
- If a witch or warlock has become enchanted, priority number one for the enchanted player is to break the spell. The enchanted player cannot cast spells on other players until the enchantment is broken. To break the spell, the player must throw an anti-spell or drink a magic potion.
- A maximum of four items can be stored in the sack at the same time.
- The player can only use one weapon at a time, but may swap active weapons at any time during play.

An encounter will result in a battle between the players, with the purpose of enchanting the other player’s character, thereby capturing some of the other characters skills or power. If a battle is ended earlier because of disconnection, the character with most hits will simply be rewarded with power points. When one character has become enchanted, the battle will end and the players can involve themselves in exchanging

objects with each other or fight for objects found on the roadside. By getting hold of the right objects, a character can break a spell put on him or her.

Due to the unpredictable nature of traffic encounters, a multiplayer event can be triggered at any time during game play. When a multiplayer event is triggered, all other actions will be cancelled or put on hold. We considered the possibility of giving the player the opportunity to choose whether he or she wants to take part in the multiplayer event or not. Both players would then have to approve to start the battle before the multiplayer event could be triggered. However, this would be a time-consuming procedure and for shorter meetings, the players might be out of reach for the network connection before both participants have even approved starting the battle. Therefore, we have designed the game so that the multiplayer event is automatically triggered when another player is approaching. In addition, a multiplayer event will always provide an opportunity for the player to become more powerful faster than possible in single player mode.

7.1.3. Tools

Different tools can be used to help the witch or warlock to gain power. The tools are virtual objects that can be picked up from the roadside, stolen or exchanged with other players during the multiplayer events. The following table provides a summary of tools that can be included in the game and their functions.

Tool	What / how	Use
Recipe for a magic brew	Written on a piece of paper	Guide to what tools to look for (the ingredients)
Magic spell	Written on a piece of paper or an audio spell enclosed in a virtual bottle	The magic spell can be used to enchant other players
Key to the magical language spoken by ancient magicians + corresponding spell written in the ancient language	Code (cipher) and corresponding cipher key written on a piece of paper (found at separate locations)	Translate the spell by using the key. The spell could be used to break other spells
Map or a piece of a map	Piece of paper	Reveals hidden tools along the road
Ingredients needed for the magical beverage	<ul style="list-style-type: none"> - Frog's slime - Hair from a goat - A dove feather - Two pieces of wood from an old oak tree 	Brew the magical brew and enchant other players
Bombs	An object	Running into a bomb leads to loss of points

Table 2: Summary tools used in the game and their functions

7.1.4. Cooperation and competition

The multiplayer events will initially lead to competition between the players. The character of competition adapt to the nature of the meeting. During longer meetings, the initial battle will possibly lead to a situation where one of the players is enchanted. This will introduce a cooperative aspect of the game where players can involve themselves in exchanging objects with each other. The cooperation involves exchanging objects and the competitive aspects of the game involve fighting for objects found by the roadside, stealing objects and casting spells.

7.1.5. Interaction

According to Zagal and Nussbaum, the interaction in a game is affected by the players, rules, goals, tools and in some cases the spatial incidence of the game can be a key element for the interaction [22]. As previously described, the interaction can be either natural or stimulated.

For this game concept, the interaction is dependent on the presence or non-presence of other players, i.e. the players must be present within the same physical space (no more than 150 m. apart) to interact. If the players are within this distance, they cannot choose not to participate in the multiplayer event. Thus, the interaction in the game is stimulated and the spatial incidence of the game is a key element for the interaction. The rules and tools are designed to stimulate social interaction during the multiplayer events.

7.2. User Interface Design

The purpose of the interface is to support the connection between the digital world and the real world and to provide a means for the users to interact in multiplayer events. With this in mind, we set out the following prerequisites for the design of the interface:

- The interface should augment the fictional connection between the game and the surrounding road context and at the same time cultivate the player's fantasy and imagination.
- The interface should support interaction with other players during momentary as well as continuous encounters.
- The interface should support awareness and social interaction between players.
- The design should relate to the theme of the game.
- The interface should provide clear feedback on interaction and other actions.

We believe that seeing the other player during interaction will enhance the gaming experience and spur social interaction. On the other hand, we believe that split attention between the screen and the outside world, would limit the social interaction possibilities of the game. Thus, to encourage the user to focus directly on what is happening outside the car

rather than on the screen during interaction, the current prototype has a non-graphical, physical, interface.

The user interface takes the form of three different weapons. The available weapons have different functions and are therefore suitable for different situations. One of the prerequisites when designing the interface was that it should relate to the theme of the game. The theme of the game is “magic” and while playing the game the players take the roles of witches or warlocks. To follow up on this theme, we have designed a magic wand, a magic hoover and a squeezer as a physical interface for the game.

The interface is realized by using the compass in combination with an external button connected to the Pocket PC as a sort of magical tool. The purpose of using a physical interface for realizing the interaction is to establish a direct connection between the real world and the digital world, i.e. between the participants in a multiplayer event. Further, the intention is to encourage the user to actively and physically take part in the interaction during the game.

7.2.1. The weapons and their functions

A crucial point in the game is choosing the right weapon for the current situation. The weapons are designed to adapt to traffic encounters of varying length. Thus, players can benefit from the ability to analyse the current traffic situation and predict the length of an upcoming multiplayer event. In contrast to the standards of traditional HCI, an enjoyable game should be easy to understand but difficult to master [21]. Hence, we have designed the weapons so that experienced users can benefit from learning to handle the weapons that are difficult to master.

The wand can be used to cast magic spells on other players. To cast a spell, the magic wand should be swung to follow a predefined pattern. This is a difficult and rather slow procedure suitable for encounters that last for a longer period of time, such as when two vehicles end up driving behind each other in the same direction. Casting a spell is not easy, but those who learn to master the magic wand will become very powerful. The wand is also intended to incite social interaction by gestures.

The hoover can be used to exchange things with, or steal things from, other players. It is designed to be fairly easy to use and it can be used in almost any kind of traffic encounter. The squeezer is preferable for very brief meetings when the interaction time is limited. To fire the squeezer, the interface should be squeezed. Squeezing the interface is easier and much less time-consuming than moving the interface to follow some predefined pattern. Consequently, the squeezer is suitable for encounters that last for a very short period of time, possibly less than a second.

The magical tool is intended to spur the users to interact socially by gestures during the longer meetings. In swift meetings, when the period of time for interaction with other players is limited, the player could concentrate on spotting the other player and act instantly without looking

at the display. The weapons and their functions are summarized in the following table:

Weapon	Action	Function	Traffic encounter	Players	Duration
Squeezer	Squeeze	Reduce other player's power and increase own power	Passing cars	Multiplayer	Fast
Hoover	Point	Pick up objects	Caravan (from the roadside in single player situations)	Single or multiplayer	Medium
		Plant objects at the roadside (bombs etc.)	Caravan (if the other car is about to pass)	Single or multiplayer	
		Exchange objects	Queue, caravan, passing car	Multiplayer	
Magic Wand	Circle	Put spells on the opponent	Queue, caravan, passing car	Multiplayer	Slow

Table 3: Description of available weapons and their functions.

7.2.2. Graphical user interface

Screen-based graphics are used to reveal the identity of the other character in multiplayer events and will be used to show the local stories before physical game locations. Graphical feedback showing the result of the interaction and other information, such as objects in possession of the player, is displayed on the screen during and after the interactive events.

7.2.3. Sound feedback and awareness

To further encourage the player to interact directly with the physical world, we have used sound rather than graphics as feedback on the interaction. We have also used sound as a two-sided feedback, meaning that both players taking part in a multiplayer event will hear a sound as a result of an action. The feedback was designed with the purpose of increasing the awareness and feeling of the presence of the other player. Sound is also used to make the players aware of an approaching player. As two cars come within proximity of each other, the players will hear a sound as an indication of the other player's presence. Since the weapons are not designed primarily as shooting devices, we tried to avoid using sounds that associate to shooting when implementing the game. For example, both players will hear a witch laugh as an indication of a successful spell.

8. CONSTRUCTION

This section of the report describes the technical solution for, and the construction of, the game prototype. The purpose of the game prototype was to test the technical solutions necessary for realizing the multiplayer capabilities. The test gives an indication of whether it would be possible to implement a complete multiplayer game prototype based on this concept or not.

8.1. Equipment

To play the game, each player needs a PDA equipped with a GPS receiver and a wireless network card and a digital compass. In addition, each device has an external button connected to the PDA through the communications port at the underside of the Pocket PC. We have used Hewlett Packard iPAQ 5450 Pocket PCs with Microsoft Pocket PC 2000 as operating system. These Pocket PCs have 64 MB of RAM, 400 MHz processor and a 240x320-pixel display capable of producing 65,000 colours [24].



Figure 8: Hardware

8.1.1. Choosing the sensor

The previous version of the game was implemented using a digital compass from Honeywell (HMR3000). The compass was connected to the PDA through a cable and the energy source was a battery mounted on the back of the compass. In order to adapt to the context, the compass had to be calibrated inside the car before use. The compass gave a three-dimensional output (pitch, roll and direction), which was used for orientation. The direction in which the compass is heading depends on the magnetic fields of the earth. This feature is crucial for the functionality of the game. In both prototypes, GPS is used for positioning

of the players. When used in combination with GPS positioning, a digital compass can be used to locate objects and other players along the road. The ability to locate objects and players along the road was a desirable feature for the new prototype as well. Moreover, we intended to use the sensor for a simple form of motion tracking.

In virtual environments, motion tracking and orientation is accomplished using sensor systems with 6DOF. The commercially available tracking systems fall into three categories: inside-in systems, which employ sensors and sources that are both placed on body parts; inside-out systems, which uses external sources as reference frame for sensors placed on the body; and outside-in systems work in the opposite way compared to inside-out systems, i.e. where an external sensor senses the output from artificial sources on the body [14, 30]. All of these systems rely on settings including multiple sensors to accomplish the motion tracking. The tracking technologies could be mechanical, acoustic, optical or magnetic and are generally developed to suit stationary, *indoor*, virtual reality settings. Another issue of importance is that most of these systems suffer from degraded performance when used in the neighbourhood of metal objects. Furthermore, these sensors are *very* expensive.

Movements can also be detected using inertial sensors, such as gyros and accelerators. These sensors give a 3D output, which could be used for orientation, but they do not sense the magnetic fields of the earth. Consequently, neither a gyro nor an accelerator can be used to locate other players or objects. Few efforts have been made to build effective outdoor augmented reality systems [5]. Azuma and colleagues suggests a system in which a rate gyro is combined with a compass and tilt orientation sensor to produce a hybrid tracker [5]. InterSense [25] and Ascension Technology [31] builds commercial hybrid trackers, but direction measured according to the magnetic fields of the earth is generally not featured by these systems.

Our final decision concerning the choice of sensor was based on the following criteria:

- When used in combination with GPS, it must be possible to locate objects and players along the road.
- It must be possible to connect the sensor to a Pocket PC.
- Possibility to perform a simple tracking of circular or other motion.
- Reasonable price.

To mount sources or reflectors inside the car did not seem like a realistic choice. Due to the limited space inside the car, disturbing noise and the presence of obtrusive objects, such as other passengers and seats, a setting including stationary sensors was not plausible. What we needed was a small, mobile sensor system for outdoor use. We came to the conclusion that perfect tracking of motion would not be of top priority for the game to be functional and fun to play, whereas orientation and the

ability to locate objects and players along the road was an important feature. Thus, we came to the conclusion that the best choice of sensor would be a digital compass.

8.1.2. *The digital compass*

The new prototype was implemented using a TruePoint Digital Magnetic Compass from Point Research Corporation. When we first started implementing the game, we used the Honeywell compass for testing. It soon became clear that the compass did not respond to value changes as fast as we had hoped. The TruePoint Compass was much better suited for our purpose as it responded much faster than the Honeywell compass.



Figure 9: TruePoint Digital Magnetic Compass

The output from the compass has 3DOF: heading, pitch and roll. The heading gives the direction in which the compass is pointing and the pitch and roll indicate the tilt angle in x and y direction (up-down and left-to-right rotation).

Like the Honeywell compass, the TruePoint compass must undergo a magnetic compensation procedure to determine corrections for magnetic influences from the environment. The magnetic compensation process is implemented in the module's software. According to the manual, the compass should provide accurate readings even if it is mounted on a steel device, such as a car. However, azimuth errors can still occur due to large magnetic objects, such as other cars or pipes buried in the ground, that were not nearby when the compass compensation process were carried out [23]. The compass communicates with the host computer, the PDA in our case, using the RS232 serial format. The default baud rate¹ is 9600 and this is the rate we use in the game. A 9V battery is used as power supply for the compass.

¹ Baud rate is a measure of the number of times per second a signal in a communications channel changes state. The state is usually voltage level, frequency, or phase angle [29].

8.2. Program structure

The code was written in C++ and we used Microsoft Embedded Visual Tools for developing the game. The program consists of six main parts:

- Game engine
- The interface algorithms
- Sound API
- Game API
- Compass and GPS reading
- Network protocol

The game engine could be considered the brain of the game. The game engine is responsible for the control of the gaming activity. It receives values from the digital compass and the GPS, which are read using separate classes, and controls the network activity by accessing the network protocol.²



Figure 10: Development environment

We used the sound API Fmod to play sounds in the prototype [24]. Unfortunately, Fmod is not freeware if it is used in a commercial product, so it is not a subject for use in future versions of the game. However, it works very well with the game prototype. A sound API intended for use in the game is currently under development in the Mobility studio.

The graphics are displayed using the Pocket PC game API: GAPI. GAPI is a graphics library intended for use in game development for Pocket PC. It is a smaller version of the game API for PC, Direct X. GAPI is similar to the first version of Direct X in that it provides direct access to video memory, but it does not provide more advanced features, such as 3D acceleration, which are included in later versions of Direct X [15]. The stories (framing story and local stories) are not implemented in the prototype. The screen is only used for displaying the result of a battle, the current status of the opponents in a battle and to reveal the identity of the other player.

The gaming activity between players during multiplayer events is accomplished through peer-to-peer wireless ad hoc networking. The

² Liselott Brunberg at the Mobility Studio at the Interactive Institute implemented the game engine.

application uses a rapid mutual peer discovery protocol (RMPD) in order to quickly detect and connect the players when they meet [12]. The RMPD protocol has previously been used in two other prototypes developed at the Mobility Studio: “*Soundpryer*” and “*Hocman*”. The Hocman prototype uses a peer-to-peer architecture and wireless ad hoc networks to accomplish sharing of HTML documents, images and audio clips among motorcyclists [11]. Soundpryer is another example of a peer-to-peer application, which uses wireless ad hoc networks for streaming MP3 files among road users and eavesdropping on other people’s music [12].

The interface algorithms are described in separate sections, one for each weapon, below.

8.3. The Wand

The following goals were set up for the wand:

- The wand should perform a simple form of pattern recognition of a circle or some other motion
- It should be possible to make the motion slow or fast
- The “tracking” should be done in real time
- It should not be easy to cast a spell, but training should make it easier.

Tracking a motion, such as a circle, requires a common reference point set up by a reference frame for the calculations. In motion tracking systems, the reference frame usually consists of a set of sensors as described above. The digital compass, as it is used in the game, lacks a common reference frame. Each position of the digital compass will have its own internal reference frame, expressed in pitch, roll and direction (azimuth), but they lack a global coordinate system. The azimuth value is a number between 0 and 360 degrees and the roll and pitch are expressed as values between -180 and 180 degrees. The motion must be expressed using only these values.

The wand works according to the following principle: Five checkpoints are set up to describe the intended motion pattern. All of these must be passed before the spell is completed. Since it is not possible to predict in what direction the wand will point at the beginning of the spell, the direction must be expressed using relative values. Using relative values of the direction will also encourage the user to move the wand from one side to another. Different pitch values encourage the user to change the y-direction (figure 11 on the next page).

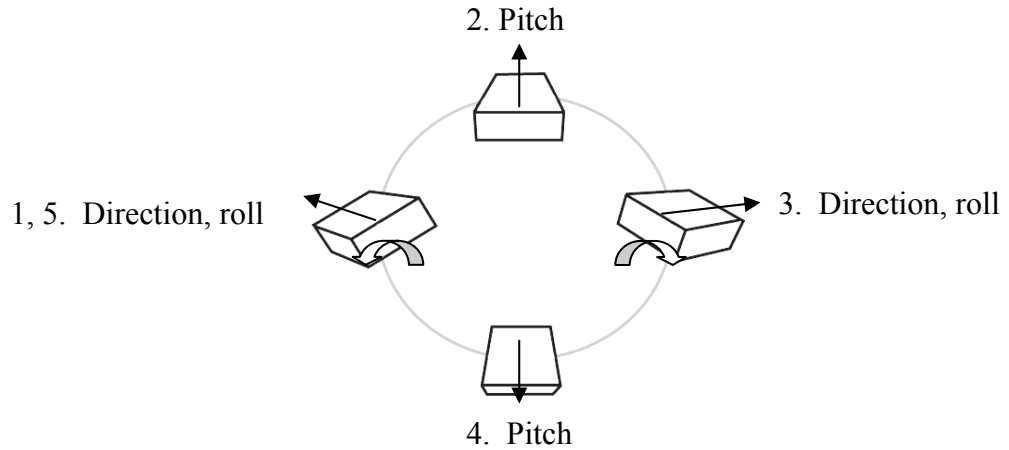


Figure 11: The wand

The direction in which the wand is pointing will be saved at positions 1 and 3 (see figure 11). The saved values are then used to calculate the angle between the first and third values and values at the third and fifth positions. The angles are used as a measurement for deciding whether the motion is accepted as a spell or not. If the player fails to get the right values at some point, he or she must start over from point 1.

A time limit of two seconds, that will pass the player back to point 1, is set for each of the five checkpoints, except the first. The time limit is set to prevent the user from getting stuck in the middle of a spell. For this situation, two seconds is quite a long time, so it will not limit the users' possibility to perform the motion quickly or slowly. As soon as the requirements for a checkpoint are fulfilled, the algorithm moves on to look for the next set of values. When all checkpoints are passed, the spell is complete and the player is rewarded with a considerable number of power points.

It is not easy to cast a spell correctly, but it should be easier once the player has gained an understanding of the spell principles, i.e. learned to cast the spell correctly.

8.4. The Squeezer

In the prototype, the Squeezer is implemented as an external button connected to the Pocket PC through the port at the underside of the device (figure 12).

The port has 22 pins, whose names and functions are listed in appendix A. The button was created using the RTS, RXD and GND (7, 10, 12) pins. Figure 13 shows a circuit diagram of the squeezer. We used a voltmeter to identify the correspondence between the pins and the cables. RTS gives a +/-5V input signal to the circuit. When the button is pressed, RXD and RTS are connected to ground, which will make RXD change state. The signal is passed on to the program that is set to wait for changes on RXD. The RTS signal is initially set high by the program and the resistor is used to pull up weak or flickering signals.



Figure 12: The button

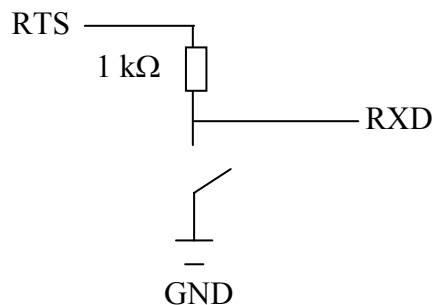


Figure 13: Circuit diagram for the squeezer.

Figure 12 shows the initial implementation of the button. The final solution consists of two plastic bricks separated by springs that are fixed to the digital compass (picture 14). The cable is connected to the brick on the underside and a conductive material is connected to the top brick. Essentially, the function of this solution is the same as for the button, but this is more “squeezable” than the button, which should be pushed.



Figure 14: The “magical device” and the PDA.

8.5. The Hoover

This section outlines the functionality of the hoover. Currently, the hoover is not completely implemented in the prototype and consequently it has not yet been tested. The Hoover is based on the same concept as the first game prototype, so much of the code and calculations from the first prototype could be reused for the implementation. The hoover differs from the first prototype in that the compass is no longer attached to the Pocket PC and that the objects are not only static objects found by the roadside, but also other players. Since the first prototype proved that the game concept holds for static objects, the new prototype was conformed to interaction with other players only. The intended use of the Hoover is to “suck up” or “blow out” virtual objects from or to other players.

The functionality of the hoover is based on calculations of the bearing between the players. Bearing is the angular compass direction from one geographical point to another geographical point (A and B in figure15).

The bearing is determined by measuring the number of degrees clockwise between north and the required direction [29].

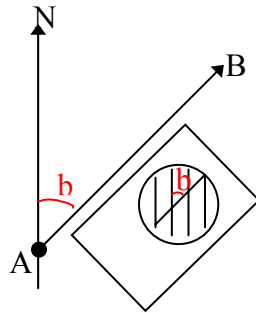


Figure 15: The bearing between the geographical positions of player A and player B.

To get hold of an object or leave an object, the user must aim the compass in the correct direction. For example, in order to steal an object from another player, the compass must be directed at the other player. The current bearing is calculated from the direction in which the compass is heading. The difference between the current bearing and a theoretical value of the bearing is calculated and if the difference is within a certain interval, the task is completed.

The positions of the players are determined using GPS. Fast and accurate distribution of GPS coordinates between the two players is essential for the calculation of the bearing and the functionality of the hoover. Since both players are moving, the values of the bearing (the theoretical and the real value) must be continuously updated. The calculation of the bearing is outlined in Appendix B.

9. TEST

The very first tests of the game functionality were carried out in the studio. These tests answered initial questions regarding the game functionality, but they did not tell us anything about the functionality of the game when played in its real setting, i.e. when played in a car. By directing a test in the real game setting, we wanted to find answers to questions regarding the networking capabilities and the functionality of the interface.

9.1. Test Setting

The test was conducted in the outskirts of Stockholm one afternoon and evening in August 2003. We used a setting with two cars for the test. In one of the cars, a game console was mounted at the driver's panel (figure 16). This game was not equipped with a digital compass and not actually played by a player. Three persons were located in the other car: the driver, one person playing the game and one person who captured the test on videotape. To get a good view, the test was filmed from the backseat of the car and the person playing the game was sitting in the front seat (figure 17).



Figure 16: Car one



Figure 17: People in the second car

The questions we wanted to answer by conducting the test was “*Is it possible to create a multiplayer game by using traffic encounters?*”. An encounter where two cars travelling in the opposite direction meet is a critical situation due to the short period of time the two cars meet. Additionally, if the meeting occurs on an open road, it is easy to decide the approximate distance to the other car. Hence, a short meeting was the best choice for testing the network capabilities. For this setting, the squeezer was the natural choice of weapon.

The test was staged using two cars travelling at the same speed, but in opposite directions on a straight road. The player started firing the squeezer as soon as the multiplayer event triggered. All events were recorded on videotape and the number of hits with the squeezer was noted after each test round. During the test, the test setting was kept constant. Two different versions of the game were used in the test. One of the games did not utilize a digital compass and the game was only used for receiving and updating the score (figure 16). In this version of the software, the communication ports were closed before the test. No other adjustments on the software were made. For the other game, the digital compass was connected to the game console, but not used during the test of the squeezer.

All together, the test consisted of fifteen test rounds at three different speeds: 30, 50 and 70 km/h. Five meetings were staged at each speed. The tests at 30 and 50 km/h were carried out on the same stretch of a road with the same setting. Due to the road conditions (speed limits, etc.), the tests at 70km/h had to be set on another road nearby. For each test, the final score was noted. The result is shown in figure 18. We were also interested in how fast (on what distance) the games became aware of each other, i.e. connected to the wireless network. The approximate location for the connection was noted during the test and could also be reviewed on the film after the test.

9.2. Result

The number of hits for each test round is summarized in figure 18.

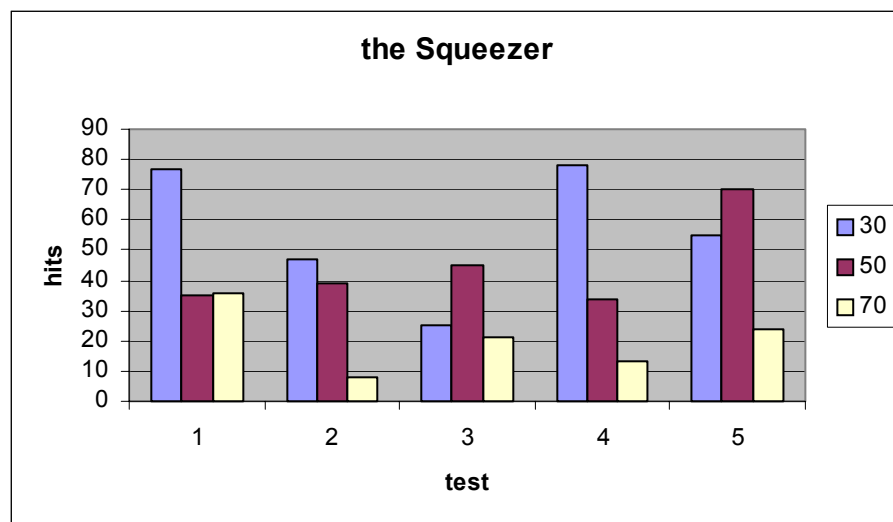


Figure 18: Test result

As expected, the number of hits was higher for the meetings that occurred at lower speed, when the cars were connected to the WLAN for a longer period of time. The diagram shows considerable variations in number of hits, especially for the longer meetings. Possible reasons for

the variations are technical problems and variations in the connection time to the WLAN. The technical problems and deflections from the requirements on the test setting experienced during the test are summarized and discussed in section 9.2.1. The human factor also plays an important role for the outcome of the test. Human factors include reaction time and variations in frequency of the use of the squeezer.

9.2.1. Requirements

During the test, notes were taken on deflections from the intended test setting, such as variations in speed of the car or technical problems. The comments on the test result are summarized in table 4. A test round was considered successful (“ok”) if all the following requirements hold:

- Both games connected to the wireless network before the two cars were located side by side and both games disconnected after the event.
- Both cars drove at the same speed during the whole multiplayer event.
- More than one hit was registered before the cars were located side by side.

		Test number				
		1	2	3	4	5
Speed	30	ok	1	ok	ok (2)	1
	50	1	ok	ok	ok	ok
	70	3	ok	ok	ok	3

Table 4: Comments on the test result

- 1 The game stopped responding after the meeting
- 2 Full score
- 3 One car driving at 60 km/h during part of the multiplayer event

Due to rush hour traffic, we experienced some problems with keeping the speed up during the test at 70 km/h. The game stopped responding three times during the test. A possible reason could be problems related to the sound function and caused by high activity as a result of extensive use of the squeezer.

No problems regarding the network connection were reported during the test. The games always connected before the two cars met and stayed connected for after the meeting. However, the road conditions seemed to have impact on the test result. In general, the rounds with the highest final score (figure 18, tests number three and five at 50 km/h and tests number one and two at 30 km/h) correspond to meetings that occurred at the middle of the road, in which both cars were located on a higher part of the road in the beginning of the encounter. When the cars were approaching each other on each side of a higher part of the road and the

meeting took place on top of the height, the games were connected for a shorter period of time.

9.3. The wand

The functionality of the wand was tested in a less formal way while playing the game on our way back to the office. Before starting the game, the wand was calibrated inside the car. The calibration must be performed on a stationary computer, which was rather cumbersome to handle inside the car. The test showed that it is possible to cast a spell on other players during medium to long traffic encounters.

9.4. Test conclusions

The test showed that it is possible to build a mobile, multiplayer game relying on temporary meetings during traffic encounters. In addition, the following conclusions could be made from the result of the test:

- Minor software bugs were reported, including:
 - The communication port did not close down after the multiplayer event, so the program must be restarted after each multiplayer event.
 - The program stopped responding three times during the test, possibly due to extensive use of the squeezer.
- The functionality of the wand and the squeezer are satisfactory, but further testing of the wand and the hoover is necessary.
- It is possible to use meetings for multiplayer events even at considerably high speeds.
- The multiplayer event triggered in advance of the meeting and the games stayed connected after the meeting.
- Using the squeezer is easy and it works even for very brief meetings.

The test demonstrated very good results for the networking capabilities. In this test, each car was equipped with an antenna for the wireless network. It would be interesting to test in what ways the game would be affected if no antenna was used.

10. FUTURE WORK

The work presented in this thesis brings great challenges for future work in the area. We have created a prototype, which enables interaction between players in different cars during meetings of varying length. Yet, there are still several issues that need to be addressed, including:

- Formal testing of the wand and the hoover.
- Implementing and evaluating a complete game prototype, which includes the entire game concept (stories etc).
- Evaluating how the social interaction and awareness between players is experienced.
- How the game could be improved in order to not encourage the driver to change driving behaviour.
- Include other forms of interaction, for example possibility to communicate using text or audio messages.
- Possibility for the players to create a personal character.

Currently, the game works only for two players. In a future game, more players could be involved in the game play at the same time. This would open up for possibilities of creating teams including several players and for players to build strategies based on cooperation.

The prototype described in this thesis concentrate on the use of traffic encounters as a resource for a multiplayer game. The previous prototype was developed to explore how virtual objects tied to real objects along the road can be used to create a compelling gaming experience balancing between the real and the digital world. Combining the two game concepts could add a new dimension to the gaming experience. Furthermore, multiplayer events might never occur in a real setting. Thus, it would be interesting to investigate a game concept that emphasises the single player situations, but takes advantage of possible meetings with other players. This approach would introduce new challenges, such as:

- How the integration of the different game events could be improved.
- In what ways does the emphasis on different game situations affect the game?
- The possibility to resume the multiplayer game activity if two players meet more than once during the same game session.

The future work also includes issues that are primarily related to the investigation of the game in single player mode. These issues include:

- Possibilities to build more extended narratives based on roadside objects.
- How the game arena can be expanded, for example if it is possible to let the user build the game world.
- If existing databases can be used to connect the game to the physical world and to extend the game area so that it is not connected to a certain stretch of a road.
- If a camera mounted for example on the car or on the PDA could be used to incorporate the environment in the game.

Using the road context as a resource in a digital game represents a novel research area. The number of issues raised here shows that this is an emerging area, which needs exploration and development along several dimensions. Many challenging problems still need to be addressed from a technical, social and cognitive perspective.

11. DISCUSSION AND CONCLUSIONS

This thesis presents design challenges and implications introduced when designing the interaction for a multiplayer, mobile context aware game prototype. The overall result of the project is a first prototype of an ad hoc multiplayer game that uses a physical interface to accomplish the interaction and directly link the digital world to the physical world during temporary multiplayer situations in a mobile environment. The interface is realised as three weapons intended for use in different gaming situations.

The project has given insight in the use of prototyping as a research method and in the area of interaction design for context aware, mobile games. The implementation of the interface was a great challenge, since I did not previously know anything about C++ programming for Windows environments, and I had previously never done any programming for Pocket PC. Consequently, the implementation part of the project was rather timeconsuming.

In order to make the decision concerning the sensor, a study of the available motion sensors on the market was carried out. Using a 6DOF sensor system for tracking body movements was considered, but never put into practice due to contextual constraints, extremely high costs and lack of mobility.

Implementing and constructing the prototype also included constructing the “squeezer”, which, in reality, turned out to be a matter of connecting an external button to the serial port on the Pocket PC. Detecting the correct pins and finding out what pins to use in order to “steal” power from the Pocket PC, was quite tricky. At first, we tried using the circuit from a serial mouse with three buttons and benefit from the three buttons to completely manoeuvre the game from the physical interface. Unfortunately, the circuit did not work while connected to the Pocket PC. The mouse circuit needs an input voltage level of 5V to work properly. The output from a PC RS232 serial port is +/-12V. The circuit includes diodes and resistors to stabilize the power over the circuit to 5V. The output from the Pocket PC serial port is only 5V, hence the circuit did not work when connected to the Pocket PC serial port.

An initial test of the functionality of the game prototype has been carried out. The goal of the test was primarily to answer the question: *“Is it possible to create a multiplayer game by using traffic encounters?”* We concluded that the functionality of the game was satisfactory, however the hoover was never tested and no formal test of the wand has

been carried out yet. The result of the test showed that it is possible to create a multiplayer game based on the use of traffic encounters, which bring great challenges for future research in the area. Some of the issues open for future work are presented in chapter 8.

Since no user study has been carried out yet, it is impossible to answer questions such as: "*Was the interface a good way of realizing the interaction for this game setting?*", "*is the game fun to play?*" or "*Did the players spot each other during the multiplayer events?*". For example, spotting the other player was never an issue during the test, since we knew that the other car was approaching. It would be interesting to know how users would experience a multiplayer event in a situation where it is impossible to spot the other player, for example if the two cars get stuck in a traffic jam with one or more cars obstructing the sight between the cars. Before a user study can be carried out, the story must be implemented in the game prototype.

The last question we wanted to answer was: "*was the compass a good choice of sensor*". During the test of the wand, we did not experience any problems related to the digital compass, but more extensive testing is needed to know if the readings are correct and the accuracy sufficient. These questions will be answered when the hoover is tested in a near future. This autumn, the use of a three-axis MEMS-based accelerometer from STMicroelectronics will be tested [33].

Using traffic encounters as a resource for a mobile multiplayer game is a completely new concept and has previously never been investigated. We believe that the conclusions made within this setting could apply to other mobile situations and be useful for the design of future mobile, context aware multiplayer experiences. In the meantime, the exploration of the use of the road context as a resource in digital mobile gaming experiences will continue in the Mobility Studio.

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APPENDIX

A.

Pins on the pocket PC serial port

Pin	Name	Description	Signal direction
1	V_ADP		
2	V_ADP		
3	V_ADP		
4	V_ADP		
5	Reserved – Do not use		
6	RS232 DCD	Data Carrier Detect	Device to computer
7	RS232 RXD	Receive Data	Device to computer
8	RS232 TXD	Transmit Data	Computer to device
9	RS232 DTR	Data Terminal Ready	Computer to device
10	GND	System Ground	-
11	RS232 DSR	Data Set Ready	Device to computer
12	RS232 RTS	Request To Send	Computer to device
13	RS232 CTS	Clear To Send	Device to computer
14	RS232 RING	Ring Indicator	Device to computer
15	GND		
16	No Connect- Do not use		
17	USB Detect		
18	No Connect- Do not use		
19	USB UDC +		
20	No Connect- Do not use		
21	USB UDC -		
22	GND		

B.

The bearing, b , between two GPS points expressed in latitude and longitude, is calculated as [37]:

If $\sin(lon2-lon1) < 0$

$$b = \text{acos}((\sin(lat2) - \sin(lat1) * \cos(d)) / (\sin(d) * \cos(lat1)))$$

else

$$b = 2 * \pi - \text{acos}((\sin(lat2) * \sin(lat1) * \cos(d)) / (\sin(d) * \cos(lat1)))$$

$Lat1$ and $lon1$ is the latitude and longitude of the player's position, $Lat2$ and $lon2$ is the latitude and longitude of the opponent and d is the distance between the geographical positions of the players. The values of the latitude and longitude should be expressed in radians. The earth is nearly spherical, so distance between two points on its surface can be approximated as the great circle distance between the two points. The great circle distance between two points on the earth's surface is given by [38]:

$$d = \text{acos}^{-1}(\sin(lat1) * \sin(lat2) + \cos(lat1) * \cos(lat2) * \cos(long1 - long2))$$