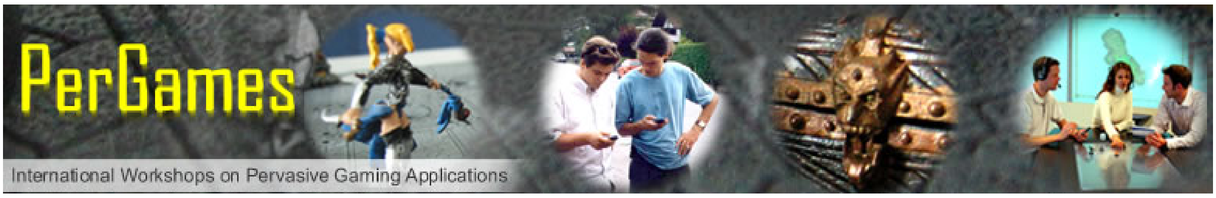


Proceedings of

PerGames

2006

Third International Workshop on Pervasive Gaming Applications

Carsten Magerkurth
Fraunhofer Integrated Publication and Information Systems Institute (IPSI),
Darmstadt, Germany.

Matthew Chalmers
Dept. of Computing Science, University of Glasgow,
Scotland.

Staffan Björk
The Interactive Institute: GAME Studio,
Göteborg, Sweden.

Leonie Schäfer
EU Commission - DG Information Society & Media,
Brussels, Belgium.

www.pergames.de

Third International Workshop on Pervasive Gaming Applications - PerGames 2006

Carsten Magerkurth[1], Matthew Chalmers[2], Staffan Björk[3], Leonie Schäfer[4]

1. Fraunhofer IPSI, Darmstadt, Germany. magerkurth@ipsi.fraunhofer.de
2. Dept. of Computing Science, University of Glasgow, Scotland. matthew@dcs.gla.ac.uk
3. The Interactive Institute: GAME Studio, Göteborg, Sweden. staffan.bjork@tii.se
4. EU Commission - DG Information Society & Media, Brussels, Belgium. leonie.schaefer@cec.eu.int

Pervasive Gaming – Digital Entertainment in the Physical World

Pervasive Computing technologies introduce a radical paradigm shift to computer entertainment. In recent years, the immersiveness of gaming experiences had to be created and conveyed through keyboard and screen alone. Now, the computer as a medium steps back and weaves itself into the fabric of our physical and social environments creating potentially richer experiences. For entertainment and gaming, this holds the chance of reclaiming social and physical aspects to create new and revolutionary forms of play that bridge the gap between the real world and digital entertainment.

The International workshops on Pervasive Gaming Applications (PerGames) are dedicated to discussing results, sharing experiences, and publishing respective research papers in the field of Pervasive Games. In 2004, the workshop was held at the PERVASIVE International Conference in Vienna, Austria. In 2005, PerGames took place at the PERVASIVE conference in Munich, Germany.

PerGames events are supported by international journals such as ACM Computers in Entertainment or the Journal of Virtual Reality and Broadcasting that publish the best contributions to the workshops. Additionally, the PerGames website at **www.pergames.de** hosts a growing number of pervasive gaming research papers and is a frequently visited resource for this exciting application area.

This year's PerGames workshop at PERVASIVE'06 features an interesting selection of full paper talks, a poster session, and various live demonstrations that foster the exchange of ideas and stimulating discussions. Again, the workshop aims at bringing together researchers who are interested in interactive entertainment and the opportunities that pervasive computing introduces to it. We want to discuss results from this emerging field and share our experiences and visions to identify relevant research questions and future research directions.

The following papers from PerGames 2006 exemplify the latest trends in Pervasive Gaming and illustrate the potential that the integration of pervasive computing with the field of entertainment applications opens up.

PERGAMES

Papers 2006

Exploiting Seams in Mobile Phone Games

Gregor Broll[1], Steve Benford[2], Leif Oppermann[2]

[1] Institute for Informatics, Embedded Interaction Research Group,
Amalienstr. 17, 80333 München, Germany
gregor@hcilab.org
[2] Mixed Reality Laboratory, The University of Nottingham,
Nottingham, NG8 1BB, United Kingdom
{sdb, lxo}@cs.nott.ac.uk

Abstract. Seamful design is a novel approach to Ubiquitous and Mobile Computing systems that reveals and exploits inevitable technical limitations and boundaries as well as their effects on seamless interaction rather than hiding them. In this paper we want to introduce its general ideas, point out common seams on the mobile phone platform and show how people might accommodate to seams and use them for their own advantage as useful features of an application. We apply the approach to seamful design to our own location-based mobile game called Tycoon and incorporate different seams into its gameplay for better interaction and usability through the exploitation and appropriation of these seams.

1 Introduction

Despite the efforts of seamless design, integration and interaction, Ubiquitous Computing systems still have technical limitations and boundaries. Especially devices and applications for mobile communication and computing suffer from patchy network coverage, fluctuating signal strength, deviations in positioning and the generally limited resources provided by mobile devices. Their users experience these limitations indirectly as sketchy and slow mobile internet access, variations in the quality of speech transmission or even loss of a connection in cold spots in network coverage.

The concept of seams and seamful design is a rather new approach to Ubicomp systems whose design is usually ruled by the notion of seamlessness. Both seamless and seamful design are inspired by Mark Weiser's vision of Ubiquitous Computing and the idea of "literally visible, effectively invisible" [1] tools that don't intrude on the user's consciousness but let him focus on a task and not the tool itself (see [1]).

Chalmers and MacColl point out that "this notion of invisibility has been translated into requirements for seamless integration of computer system components, as well as the interactions supported by those components" [2]. As a result, seamless design knits the different heterogeneous and distributed components of Ubicomp systems tightly together in order to hide the complexity of its infrastructure. It comprises both seamless integration of different components as well as seamless interactions with them through the entity they form. Adjoining GSM-cells and their infrastructure for example form a ubiquitous system that allows mobile communication. The invisible handover between different cells provides seamless interaction with this system through its different cells and components when people use their mobile phones.

Seamful design on the other hand is supported by Mark Weiser's recommendation of seamful systems with "beautiful seams" which don't sacrifice the uniqueness of its heterogeneous components for the goal of a "lowest common denominator" (see [3]). Instead different parts of a system are seamfully integrated and still provide seamless interaction with the whole system while retaining their individual features.

We want to turn our attention to such seams in mobile applications and show how to take advantage of them through seamful design. The "Bill"-game [4] already showed how to turn the seams in a mobile application supporting GPS and 802.11 into helpful features of a game, how seamful design can drive its gameplay and how players exploit them to succeed in a game. We would like to extend the ideas of seamful design to applications for mobile phones, explore which seams occur on this platform and apply the approach to seamful design to our own seamful multiplayer-game called "Tycoon". Thus we try to evaluate the benefits of exploiting seams on this platform – especially in cell-based positioning and network coverage - for better gameplay, usability, interaction and appropriation.

In the following sections we give a short introduction to our understanding of seams and seamful design, provide examples of seams in mobile applications and describe how we try to incorporate them into the design for our own seamful game for mobile phones.

2 Seams and Seamful Design

Just as seamless design refers to both the tight joints between infrastructure-components and the overall experience of smooth, seamless interaction, the idea of seams comprises the technical cracks and bumps in these joints as well as their effects on the users' experience. Seams can be seen as deviations in actual use from a notional ideal of technological continuity or uniformity including discontinuities in technologies themselves and discontinuity between what actually happens and what the system observes. They are mostly caused by technical limitations and constraints of the underlying infrastructure. They come to the users' attention as these interact with a supposedly seamless system and reveal themselves as uncertainties, ambiguities or inconsistencies. Seams are most common in applications for mobile navigation and communication where technical constraints include inaccurate positioning, sketchy internet-access, local variations in signal strength (e. g. in tunnels), delays in GSM networks or patchy network coverage. There they cause uncertainty about the current position, disturbance or even temporary loss of mobile communication signals.

Contrary to seamless design, which tries to hide these constraints in Ubicomp systems with costly investments in better and more reliable infrastructure-technology, seamful design embraces these inevitable limitations, reveals them, increases the awareness for them and exploits its otherwise neglected yet useful information for better interaction-design and user experience. In order to accomplish the goal of "seamless interaction but seamful technology" Oulasvirta outlines seamful design as "understanding which seams are important", "presenting seams to users" and "designing interactions with seams" [5].

People often accept seams, adapt to them and even exploit them. They might use their knowledge about varying signal strength or sketchy network access in certain areas as an excuse for interrupting or dismissing a phone-call since such technical constraints are commonly accepted reasons for doing that. Seamful design now tries to support and model this process by revealing and presenting information about seams to users and thereby increasing their awareness for the influence technology can have on user-interaction. Giving users the opportunity and freedom to explore seams and exploit them in new ways may ultimately lead to the more general concept of designing for appropriation. This aspect of seamful design allows users to interact with seams individually, take advantage of the gaps and limitations in Ubicomp infrastructures and develop new patterns of behaviour around them in ways, that were not considered during the initial design of the system.

3 Seams in Mobile Phone Applications

We want to exploit three seams in mobile phone applications which we consider to be characteristic for this platform: dynamic cell-coverage, expensive internet-access and data-inconsistencies. These seams will guide the seamful design for Tycoon - our mobile seamful game.

Mobile phone users are usually unaware of the cell or location area their phone is using, since the handover between different cells is handled seamlessly. Fig. 1 shows coverage and propagation of GSM-cells in an area of London based on samples of cell-ids and their GPS-positions. Apart from not being visible, cells neither have fixed boundaries or propagation nor share exact borders with adjoining cells. The coverage of a cell is depending on many factors and their invisible boundaries and propagation are rather dynamic and fluctuating. As Fig. 1 shows, cell-coverage has irregular shapes and adjoining cells often overlap. These aspects can be a problem for location-based mobile applications relying on cell-id positioning where users or the application's behaviour are dependent on knowing about the current location.

Mobile internet-access for cell phones via GPRS is still rather expensive. Yet it is indispensable for synchronising data between mobile clients and a central server. Despite the above definition of seams, costly internet-connections are neither rooted in technical limitations nor show themselves as uncertainties or ambiguities and may therefore be considered as some kind of made-up artificial seam. Still they disrupt the uniformity and continuity of a mobile application and we think that's why they can be treated as a considerable seam in mobile applications.

An immediate consequence of insufficient synchronisation between a server and its clients are data-inconsistencies. They occur when individual, independent clients have to synchronise data with a central server that maintains data which is globally shared with several other clients. When one of these clients synchronises its local data with the shared server and thereby updates globally shared data, local copies of the same data on other clients become inconsistent with the updated, shared data.

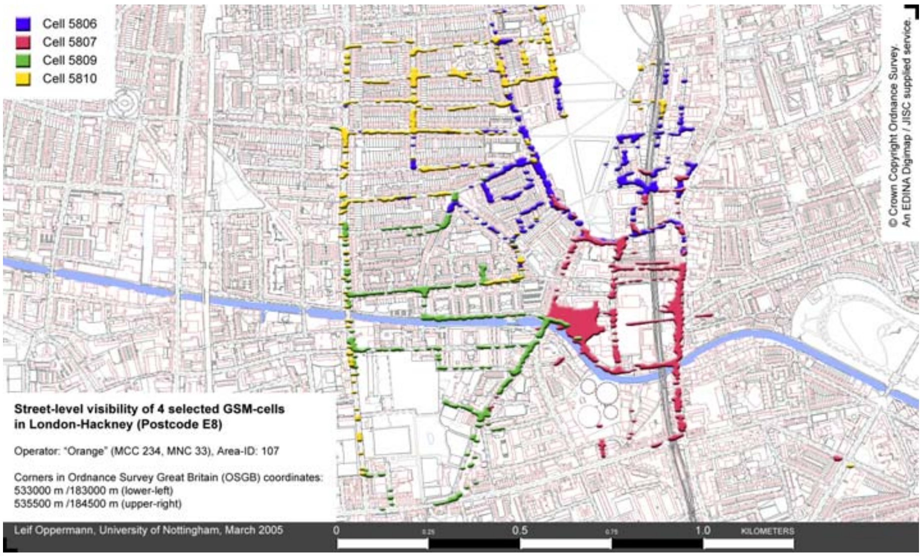


Fig. 1. Samples of cell-ids and their GPS-positions in London

4 How to play Tycoon

Tycoon is our approach to seamful design for a multiplayer-game for mobile phones which tries to incorporate the seams mentioned above and use them to enhance its gameplay. Tycoon is a location-based trading game with a simple producer-consumer-cycle that uses the different GSM-cells of a service provider network within a designated gaming-area, e. g. the centre of a city (see Fig. 1). Each of these cells in the physical area is virtually mapped to either a producer or a consumer in the game. The game uses the metaphor of a wild west scenario to communicate its central mechanisms of collecting resources from producers which are called "mines" and using them to buy objects from consumers which are called "brokers" and are named after cities or counties in California.

During the game players are travelling between the cells in the gaming-area, collect local resources in mines by staying in them for some time, use them to buy global objects from brokers and get credits for claiming them. Each mine produces an unlimited amount of one of the three local resources in the game – gold, silver or copper. They are called local resources because players can collect them independently of each other and don't compete for them. Each broker has a list of global objects e. g. different buildings or estates in towns and counties that players can buy with their local resources. There is only a limited number of global objects in the game, each of them is unique (e. g. there is only one saloon in the city of Sacramento) and players compete against each other for claiming them, since every global object can only be claimed once by one player. Each global object has a combined price of two local resources and a value in credits. Players have to enter a broker's cell and pay an object's price in order to claim it and earn its value in credits in case that price in order to claim it and earn its value in credits in case that object is still available. The objective of the game is to gather as many credits as possible. It ends when all objects are sold and the player with the most credits wins.

5 Tycoon's Approach to combine Gameplay and Seamful Design

Tycoon uses the unique cell-id of the current GSM-cell to tell players where they are, help them navigate through the gaming-area and supervise their collecting of local resources. Instead of providing players with a complete map of the area showing them exactly where to find mines and brokers, we want them to start the game by having to explore the area, gather their own knowledge about it and discover mines, brokers and their locations themselves.

Whenever a player changes from one cell into another, an alert is triggered and he gets a notification about him entering a new cell. Afterwards Tycoon displays the name of the new cell (Fig. 2) in its GUI. This alert-mechanism provides interaction with the seam of dynamic cell-coverage and is more flexible than a rather static map of the gaming-area. It also improves the visualisation of cells' boundaries and propagation and decreases the players' uncertainty about their location without revealing too much information about it. Players can use their spatial knowledge about the gaming-area to adopt their own strategies of how to move between cells and how to find the most efficient tactics of which resources are needed to buy which available objects and where to find them in nearby mines. They can also exploit ambiguities caused by dynamic cell propagation and boundaries more effectively when they find a area where adjoining cells overlap and flip after some time without moving.

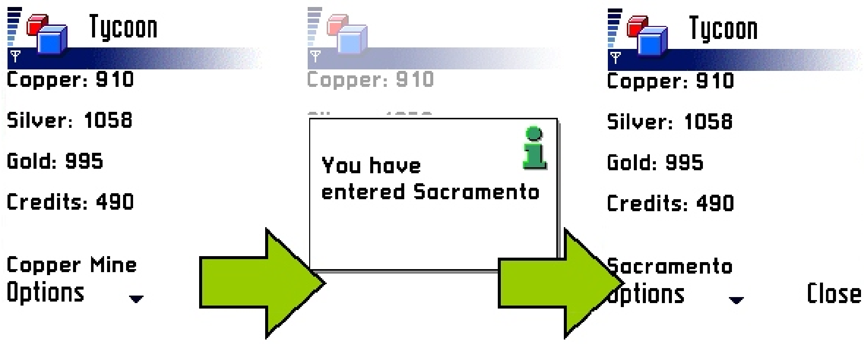


Fig. 2. The main screen of Tycoon's GUI which is updated whenever a player crosses boundaries between adjoining cells.

In order to cope with the seams of expensive internet-connections and data inconsistencies, Tycoon encourages players to spend more time offline and synchronize their local game-state (individual clients' knowledge about available global objects) less often with the game-server's global game-state (the overall availability of global objects). Therefore Tycoon's trading-mechanism features a simple economic model that gives players an incentive to engage in extended offline-play and spend more time on collecting a greater number of (more valuable) resources.

As mentioned before, global objects have a price in local resources and earn a player a certain amount of credits for claiming them. Both values are related to each other as the credit-values of objects rise with their prices in local resources. The local resources have different values themselves which are indirectly expressed by the time it takes to collect one unit of each one. Collecting a gold-nugget takes longer than collecting a silver-nugget which again takes longer than collecting a copper-nugget. That way the credit-value of a global object is also related to the time it takes to collect the resources that are necessary to buy the object. But the values of resources and objects as well as their prices don't rise proportionally. The economic model is tuned in a way so that the more time a player spends offline to collect more and more valuable resources in order to afford more and more valuable objects the more credits per second could he possibly earn than by collecting less resources for smaller, less valuable objects during the same time. Additionally a player gets a discount for successfully claiming several objects from a broker with the same request to the game-server. In order to afford buying several objects, players have to spend even more time offline to collect more and more valuable resources. The goal of this economic model is to give players an incentive to spend more time offline between connections to the game-server and collect local resources which is more profitable than spending less time offline collecting less and less valuable resources for claiming less valuable objects.

But extended offline-play increases the danger of inconsistencies between the game-server's global game-state and a player's local game-state which are different views on the overall availability of global objects. Players can claim objects which become no longer globally available but are still shown as available on other players' clients. Since players can't rely on getting constant updates of the global game-state which would require regular expensive connections to the game-server, they have to consider the growing probability of inconsistencies between local and global game-state when deciding how much time they spend offline for collecting local resources.

This is where the gambling-feature of Tycoon comes into play: It recognizes these inconsistencies in the gameplay and awards players not only for spending more time offline but also for taking the risk of inconsistencies. Players are free to collect as many local resources as they want but can only turn them into credits when they successfully buy and claim global objects with them. The more time they spend offline, the more profit is possible but the greater becomes the probability of inconsistencies and missed claims. Players have to adopt their own individual strategies and consider their chances of earning more credits during the same time against the risk of data inconsistencies which is also dependent on their knowledge of where to find the required local resources to claim a desired object.

In order to soften the possible inconsistencies in the availability of global objects between the game-server and the mobile clients, players can also ask the game-server for an update on the overall availability of global objects anytime and anywhere, but have to pay a certain charge of local resources for doing so since the update gives them an advantage in the game.

6 Conclusion

As Ubicomp systems are still affected by seams we see seamful design as a rewarding amendment to seamless design. Revealing and exploiting seams provide new views on the design of Ubicomp systems other than seamlessness. Different ideas and approaches to the design of Ubicomp systems will be even more important as future mobile devices and applications will offer more sophisticated and demanding services e. g. for multimedia and entertainment, where seams in both technology and interaction-design are even more likely to come to the users' attention and affect their interactions and experiences.

7 Acknowledgements

This project was supported by EQUATOR, an Interdisciplinary Research Collaboration (IRC), funded by the UK Engineering and Physical Sciences Research Council.

We would like to thank Mauricio Capra (MRL, University of Nottingham) for collecting the sample data used in Fig. 1. We would further like to thank Albrecht Schmidt (Institute for Informatics, Embedded Interaction Research Group, Munich) and Holger Schnädelbach (MRL, Nottingham) for their support and making this project possible.

References

1. Weiser, M.: The world is not a desktop. ACM Interactions 1(1) (1994) 7-8.
2. Chalmers, M., MacColl, I.: Seamful and Seamless Design in Ubiquitous Computing. Technical Report Equator-03-005, Equator [Technical Reports] (2003)
3. Weiser, M.: Creating the invisible interface (invited talk). ACM Conf on User Interface Software and Technology (UIST94) (1994), 1
4. Chalmers, M., Bell, M., Hall, M., Sherwood, S., Tennent, P.: Seamful Games. http://www.ubicomp.org/ubicomp2004/ adjunct/demos/chalmers.pdf (2004)
5. Oulasvirta, A.: Notes on Seams, Seamfulness and Seamlessness. http://www.hiit.fi/u/oulasvir/Haninge (2004)

’Ere be Dragons: Heart and Health

Stephen Boyd Davis[1], Magnus Moar[1], Rachel Jacobs[2],
Matt Watkins[2], Chris Riddoch[3], and Karl Cooke[3]

[1] Lansdown Centre for Electronic Arts, Middlesex University,
Cat Hill, Barnet, EN4 8HT
{s.boyd-davis, m.moar}@mdx.ac.uk
http://www.cea.mdx.ac.uk/
[2] Active Ingredient, Broadway Media Centre, 14-18 Broad Street,
Nottingham NG1 3AL, UK
{Rachel, Matt}@i-am-ai.net
http://www.i-am-ai.net/
[3] London Sport Institute, Middlesex University, The Archway Campus,
Highgate Hill, London N19 5LW, UK
{c.riddoch, k.cooke}@mdx.ac.uk

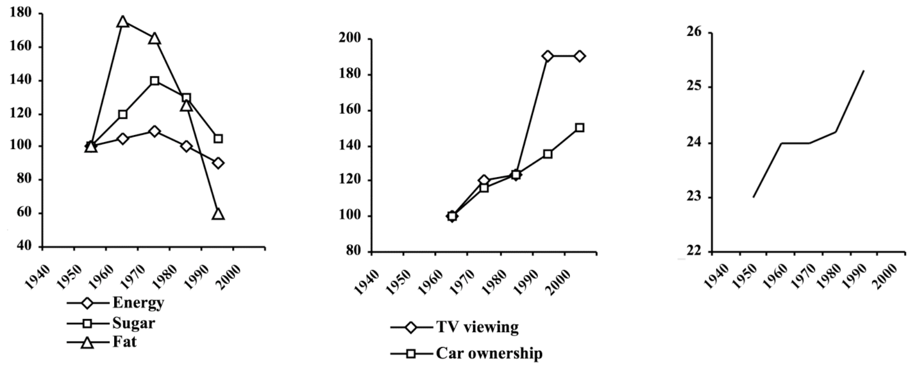
Abstract. The paper describes an innovative pervasive game which uses both GPS and heart-rate monitoring in a mobile device. The objectives of the game’s development include a health science agenda concerned with the player’s well-being and physical activity, prompted by increasing concern over the health consequences of modern ways of living. Game design issues concerned with the use of heart-rate data are discussed, focusing on the meanings which can be extracted from the data and how these may be represented for effective gameplay.

1 Introduction

’Ere Be Dragons integrates a health-science exploration within a playful experience. It is a pervasive game which uses a pocket computer to combine heart-rate monitoring with GPS data in one engaging interface. The emerging map, created by the player’s actions, responds to the player’s journey through the physical world and to the state of their body. As the player explores the real world, a fictional world is created on the mobile device, formed and influenced by their heartbeat. We wanted to construct both an aesthetic experience and a window on the body, sensitizing the player to their own health and body processes. Working collaboratively with health scientists the artists in the team have incorporated metrics which allow the device to respond appropriately.

2 The Health Background: a Serious Issue for a Game

There is increasing interest in the relationship between health and digital games, partly because of a current public health crisis. There is a strong relationship between physical activity and several aspects of health. For some health problems, including coronary heart disease, type-2 diabetes and osteoporosis, activity is far more beneficial as prevention than as cure [4]. Health scientists consider it urgent that the public become more aware of the issues and how these relate to personal behaviours, and a variety of strategies has been tried with little effect. The alternative we wanted to explore was to engage people with the interior world of their own bodies in a playful context and in so doing perhaps incite them to behave differently.



Figs. 1a-1c. Obesity in Britain: gluttony or sloth? *1a:* Energy consumption, percentage in relation to mean. *1b:* Inactivity, percentage in relation to mean. *1c:* Obesity, Body Mass Index data. Based on Andrew M Prentice & Susan A Jebb. British Medical Journal. 1995. Vol 311. 437-9

Obesity in developed countries has roughly tripled since the 1980s. It is common to blame diet, but it is the balance between energy consumption (from fats and carbohydrates) and energy expenditure (physical work, exercise and sport) which is crucial to the trend. In Figure 1a, overall energy consumption can be seen not to have increased since the 1970s – in fact to have declined. However, if television viewing hours and car ownership are plotted as indices of inactivity (Figure 1b), there is an obvious similarity to the growth in obesity over the same period (Figure 1c). Furthermore, someone may be slim but still unhealthy through lack of physical activity.

However much fun it may be, videogame playing at consoles is systemically unhealthy. Limiting interaction to mouse or game-pad presses does little to promote a healthy lifestyle [11], but a requirement for physical movement may actually repel hard-core gamers [8]. Nevertheless these were among our target audience. The players we aimed to engage were *not* those already interested in sport or health issues, who are increasingly well catered for by mobile technologies, such as the combination of Nokia mobile phone, Polar heart-rate monitor and Fitness Coach software [9].

Interest in health-related games has converged with activities in interfacing novel devices, including bio-sensors, to interactive digital systems. Raposa [13] created a game to tackle asthma symptomatically by combining a modified games console, heart rate and respiration monitoring. A commercial product, *Journey to Wild Divine* [14], uses three sensors on the finger-ends connected to a PC. By controlling their heart-rate players achieve a range of experiences within the virtual world. Nold has tracked emotional states in a landscape using galvanic skin response data which is uploaded to a mapping interface at the conclusion of each journey [12].

Many games which combine interactive digital experience with physical body action derive from familiar competitive sporting games – which may be repellent to those whom we would like to attract – and recent projects have tended to aim at those already committed to fitness. For example *Virku*, which connects an exercise bike to a virtual environment, is intended as ‘a *fitness computer game* which aims at making *the exercise session* more motivating and rich in experiences’ [10] (emphasis added). *Shadow Boxer* [6] – which includes heart rate monitoring but does not use it as part of the game – is also aimed at those explicitly interested in increasing their fitness.

3 The Player’s Experience

Players of *Dragons* do not have to engage in any activity resembling conventional sport, nor are they under any extrinsic pressures to perform well. From the player’s point of view, the experience in its simplest form is as follows. At the start of the game the player inputs his or her age. On this basis, an optimal heart-rate is calculated (Figure 2c). Now the player proceeds to walk, whether towards some goal such as their workplace, or freely for the sake of walking.

Figs. 2a-2c. Scenes from the landscape of *Dragons*, showing different characters of terrain resulting from the player’s heart-rate performance. *2c:* The opening screen of Version 1

During the walk, an on-screen landscape is built up which maps the player’s real location (Figures 2a-b). If the player turns right, they see the trace of their journey make a rightward turn. If they take a walk which returns to a place already visited, the new path intersects the old. If the player does well, the landscape blossoms and becomes lush; if they do badly then it becomes impoverished or darkly wooded. Feedback includes sound, and a sense of responsiveness is maintained throughout. If a player repeatedly fails to maintain their heart-rate in the optimal range, the game draws to a premature close. A simple point-scoring system is used to log their overall performance. The player’s motivation is to keep the game world alive and flourishing. We describe later in the paper the changes brought about by introducing social interaction into the second, multi-player version of the game. Players are not expected to control the device in any overt way: it responds transparently to their behaviours. Its response derives solely from the sensor and GPS streams; manual operation is kept to a minimum.

3.1 Delivering the Experience

We needed to develop a playable game within the timeframe of a short research project. Others had integrated bio-sensing with location data in a game: for example Headon and Curwen [5] developed such a system to drive the game Quake, but this was tied to an indoor location while we needed to integrate these data in a device as portable and free-ranging as possible.

The project has been developed using Hewlett Packard iPAQ Pocket PCs fitted with GPS receivers. We made use of work already done in the UK by Hewlett Packard and Bristol University for the ongoing Mobile Bristol project. Their framework [7] has three parts: an XML-based specification language for laying out the virtual world of the application and defining how client devices respond to events; a PC-based graphical authoring tool for creating application specifications in this language; portable client hardware and software that can download and interpret such specifications. Our principal use for the Mobile Bristol architecture was to enable access both to GPS data and heart-rate data from within our chosen tool for rapid-prototyping (Figure 3). Our preliminary research had revealed that most of the proprietary systems for interfacing pocket computers, PDAs or smart phones to external sensors were closed systems which we could not easily program ourselves. The Mobile Bristol architecture by comparison is designed to facilitate work of this kind.

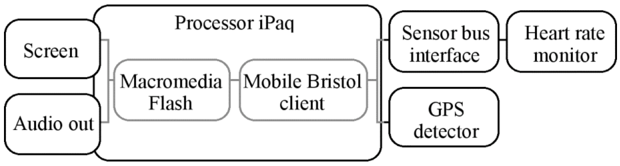


Fig. 3. The architecture of the mobile component of *'Ere be Dragons*

Location-awareness is fundamental to Mobile Bristol, so the interfacing of a standard GPS device was relatively simple. A number of innovative projects had already been created by others [2][6]. No previous project involved heart rate monitoring.

The data streams were interpreted, and the graphics and sound created, using Macromedia Flash. This was not ideal in terms of speed and capability, but allowed affordable rapid development. At one stage we experimented with three-dimensional imagery in the visual interface, but this proved prohibitively slow. The solution, using a quasi-three-dimensional isometric view, added a nostalgic aspect to the graphics, evocative of earlier digital games.

3.2 Integrating Heart Rate Data in a Game

The integration of HR data into a pervasive game raises some interesting issues. Heart rate responds to the demands of exertion. For any individual, it is possible to define an *optimal heart rate*: that rate at which players are exerting themselves, but are not putting their heart under undue strain. Not all players' heart rates will respond in the same way to the same demands: those who are fittest will exhibit the smallest increase in rate. Importantly, the normal heart rate of the player when not exerting is also very varied, being dependent principally on age and fitness. It is therefore impossible to specify a single optimal heart rate applicable to all players. The standard method of compensating for the differences outlined is to establish the individual's *resting heart rate*. This is ideally done early in the day before the player has risen, but a reasonable figure can be ascertained by obliging the player to rest for a while before a reading is taken. Since either of these methods presents some obvious practical problems, an alternative is to ignore the individual fitness component and derive the optimal heart rate solely from a simple age-related formula. The insensitivity of this method may be compensated for by allowing personal history factors (for example, concerning illness or heart condition) to be included in the calculation through manual input.

After establishing the optimal heart rate, what kinds of changes in heart rate can be usefully monitored? Increase in heart rate from physical exertion is not instantaneous: there is typically a one-minute delay between the exertion and the peak. Alterations in heart rate arising from psychological factors, however, are almost immediate. Finally, as with any other sensor technology, there are breaks in the signal, noise and errors. This has been noted as a primary issue in the design of many pervasive games [1].

In considering all these factors, we were not devising a system for medical use: there was no need for high levels of accuracy or very fast response. From the game design point of view, even a simple response to the heart rate data would be likely to facilitate an interesting game. However, a number of criteria had to be satisfied for the heart-rate data to be used successfully.

Setting an Optimal Heart Rate for the Game. Given the wide variation in players' ages it was essential to establish optimal heart rates rather than use a single rate. If such variation was ignored, there could be consequences for the player's safety. From the game design point of view, it would also be counter-productive to set a target heart rate that, for a given player, was either too easy or too difficult to achieve, which could easily happen using a single, standardised target rate. In the first version of *Dragons*, trialled at the ACM Multimedia Art exhibition in Singapore in November 2005 [3], players started the game by inputting their age. Our software calculated their optimal heart rate using standard formulae. For the second version, at the Radiator Festival in Nottingham in December 2005, an area was set aside where players could rest prior to play and their resting heart rate was the basis of the calculation. This threw up wide variations between individuals even of the same age, confirming the value of using real resting HR data rather than the age-based formula.

Representing Heart Rate Data for Gameplay. In devising an audiovisual representation of the heart-rate data, it was necessary to avoid excessive subtlety. There would be no point in a large number of visual or aural mappings of heart-rate levels, if these could not successfully be exploited in the design of the game, taking into account the ability of the player to understand what was going on.. We chose five bands. At either extreme, the graphics disappear after two minutes and the game ends. In the low optimal range, desert is seen; around the central value grass, trees and flowers; in the high optimal range, forest. To use as few as three visual outcomes might seem unreasonably crude, but two factors compensate. First, the incoming heart-rate data is time-based and, as the player is moving, successive readings are mapped consecutively on screen along the route. What the player therefore sees is not a single momentary reading, but a landscape whose overall character – predominantly dark, luxuriant or bare – captures the character of the player's overall recent performance. Secondly, the mapped, created landscape is not the only representation of the player's performance. The player can see their current heart rate in an indicator at the top of the screen, where both a number and the position across the screen give a finer level of representation of the incoming data. The animation of this indicator also serves to reassure the player that the system is live and working. The aural design also responds to the five bands: 1. quiet, slow; 2. with more melody; 3. complex melodies; 4. industrial-sounding; 5. fast. We originally used a heart-beat sound, but quickly discovered that this imitated too closely the feeling of a panic attack and created an adverse feedback effect on the player! The final sound design was created by composer James Flower.

A Representation to Cope with Imperfect Data. The mapping of the data from the heart-rate sensor must not be misleading, or unsatisfactory from a game point of view, as a result of signal interruptions and false readings. ECG monitors, such as the inexpensive bipolar sensor we are using, work by measuring the natural electrical activity of the heart. The physical sensor consists of two electrodes embedded in a semi-rigid chest strap. The ScienceScope sensor we selected (range 0 to 240 beats/minute; resolution 1 beat/minute) communicates wirelessly to a logging device. It is not intended for clinical use but was fully satisfactory for our purpose. We used the prototype Sensor Bus (developed by ScienceScope in collaboration with Mobile Bristol) between the sensor and Pocket PC.

During use the electrodes may lose contact, leading to missing or nonsense data. The firmware of the device gives some inbuilt smoothing, but it was important not to allow accidental spikes to be represented in the game (for example, if they were, the sliding indicator would suddenly leap to one end of its scale or the other), and so some additional smoothing was undertaken. For this game, we were primarily interested in the grosser changes in the heart rate arising from physical exertion. However for a project where the more transient changes caused by psychological factors may be of greater interest, it is important to set the smoothing threshold so as not to eliminate potentially interesting rate changes.

The player can chose at any stage to continue the current session or to start a new one. In our present version, each session begins afresh. There is no attempt to build up a longer-term representation of the player's performance over more than one session. This would raise interesting design issues concerning the effective audiovisual representation of both intra-session and inter-session patterns, especially within limited screen space.

4 Preliminary Evaluation

Evaluation of the Dragons project continues; we offer here only preliminary findings. Effects on health behaviours will require a longer study. For Version 1, in Singapore, the heat and humidity militated against prolonged use of the game. Approximately 20 people played, but mostly for no more than 5 minutes. Nevertheless, visitors gave a very positive response to the integration of health issues and the player's awareness of heart rate activity within an engaging game experience. The graphical imagery and responsiveness of the game were well liked. It might seem that the use of an ECG belt and a package of equipment joined by cables would be an alienating experience, but players very much enjoyed this aspect. The 'liveness' of the heart rate data changing the virtual landscape created fascination and provoked some very interesting discussions about health, psychology and engagement.

For Version 2 of the game, at the Radiator Festival in Nottingham, staff of the Mixed Reality Laboratory at Nottingham University created a global interface for audiences to view the players live whilst they went on their journeys, and a client-server system to send and receive data between the global interface and the players. This altered the game significantly by allowing social aspects which had been absent from the earlier versions. Evaluation was carried out using a questionnaire comprising closed and open questions, by direct observation, and with the help of a roving camera which an evaluator used to follow individual players. There were 32 players of the game, the majority playing in twos and some in threes. The project outcomes were very pleasing. Technical difficulties included the fragility of GPS connections and interference between heart-rate monitors when two players approached each other. As with most portable electronic devices, battery-life was a problem. In terms of usability, in the shared version of the game, not everyone understood the direction they were going in and how to find other players, and some refining of on-screen messages was required to make the experience as direct and engaging as possible. Most players understood the metaphors and symbols within the game. People enjoyed feeling that they were engaging in scientific exploration through technology without having to learn how to use it.

Offering a multi-player version meant that some players chose to compete with one another. However, it appealed to others as a personal experience and players liked the fact that they could play the game as they pleased.

An important aspect arising from our evaluation is not unique to this project: the tension between attending to the display and attending to the real world. One player was mugged (but not harmed) during play, probably as a result of concentrating too hard on the game. Another strayed from the pavement and had to be warned of the danger by one of our observers who was filming the event. An obvious partial solution is to transfer more of the communicative burden from the visual to the aural channel. However auditory experiences bring their own problems of navigation and user understanding. Our intention was always to awaken people's interest in their environment, not to substitute the virtual world for the real.

This ongoing project is in a state of transition. Originally a small project which created an experience between a lone user, a device and the environment, the project had no need to deal with the issues of scale outlined by Capra et al [3]. These issues will become increasingly important.

5 Acknowledgements

We gratefully acknowledge the support of the Wellcome Trust. We are indebted to Richard Hull of Hewlett-Packard's Bristol (UK) research laboratories, Tom Melamed of Mobile Bristol and David Crellin of ScienceScope, Bath, UK for access to prototype technologies and expertise, to Robin Shackford for additional programming, and to the Mixed Reality Laboratory at the University of Nottingham, in particular to Leif Oppermann and Mauricio Capra.

References

1. Benford, S., Magerkurth, C. and Ljungstrand, P. Bridging the physical and digital in pervasive gaming, Communications of the ACM, 48, 3 (2005) 54-57
2. Benford, S., Rowland, D., Flintham, M., Drozd, A., Hull, R., Reid, J., Morrison, J. and Facer, K. 2005. Life on the edge: supporting collaboration in location-based experiences. Proc. CHI2005 (2005) 721-730
3. Capra, M., Radenkovic, M., Benford, S., Oppermann, L., Drozd, A., and Flintham, M. The multimedia challenges raised by pervasive games. In: Proceedings of the 13th Annual ACM international Conference on Multimedia (Hilton, Singapore, November 06 - 11, 2005). Multimedia'05. ACM Press, New York, NY, 89-95 (2005)
4. Department of Health. 5 a week: Physical activity and health outcomes: a review of the Chief Medical Officer. Department of Health, London (2004)
5. Headon, R. and Curwen, R. 2002. Movement Awareness for Ubiquitous Game Control. Personal Ubiquitous Computing. 6, 5-6 (2002), 407-415.
6. Höysniemi, J., Aula, A., Auvinen, P., Hännikäinen, J., and Hämäläinen, P. Shadow boxer: a physically interactive fitness game. In: Proceedings of the Third Nordic Conference on Human-Computer Interaction (Tampere, Finland, October 23 - 27, 2004). NordiCHI '04, vol. 82. ACM Press, New York, NY (2004) 389-392.
7. Hull, R., Clayton, B., and Melamed, T. Rapid Authoring of Mediascapes. Proc. UbiComp 2004 (2004) 125-142.
8. Lankoski, P., Heliö, S., Nummela, J., Lahti, J., Mäyrä, F., and Ermi, L. A case study in pervasive game design: the songs of north. In: Proceedings of the Third Nordic Conference on Human-Computer Interaction (Tampere, Finland, October 23 - 27, 2004). NordiCHI '04, vol. 82. ACM Press, New York, NY (2004) 413-416
9. Mobiletech News. 2005. 26 April 2005. Web Market, Inc. http://www.mobiletechnews.com/info/2005/04/26/113110.html (accessed 15 February 2006)
10. Mokka, S., Väätänen, A., Heinilä, J., and Välkkynen, P. Fitness computer game with a bodily user interface. In: Proceedings of the Second international Conference on Entertainment Computing (Pittsburgh, Pennsylvania, May 08 - 10, 2003). ACM International Conference Proceeding Series, vol. 38. Carnegie Mellon University, Pittsburgh, PA (2003) 1-3.
11. Muelller, F. and Agamanolis, S. 2005. Sports over a distance. Computers in Entertainment. 3, 3 (2005), 1-11.
12. Nold, Christian. Bio Mapping. http://biomapping.net/index.htm (accessed 25 March 2006)
13. Raposa, Jan. Biofeedback in Educational Entertainment. MA Dissertation. Interaction Design Institute, IVREA. http://people.interaction-ivrea.it/j.raposa/thesis/jan%20raposa%20-%20masters%20thesis%20(low-res).pdf (2003, accessed 15 February 2006)
14. Wild Divine. http://www.wilddivine.com/ (accessed 15 February 2006)

Haptic Feedback in Pervasive Games

Martin Faust[1] and Yong-Ho Yoo[1]

Laboratory for art, work, technology (artecLab)
University of Bremen, Enrique-Schmidt-Str. 7(SFG)
28359 Bremen, Germany
{faust, yoo}@artec.uni-bremen.de
http://www.arteclab.uni-bremen.de

Abstract. Physical interaction is a key aspect of pervasive games. Although physical affordances are exploited, games are missing certain kinds of feedbacks on the interface and/or interaction levels: Haptic feedback in pervasive games is still an open issue. This paper discusses feedback in pervasive games. To illustrate the ideas, our work on Haptic Airkanoid, an extension to Airkanoid, is presented. Finally, the impact of the haptic interface is discussed and our early observations are highlighted.

1 Introduction

Pervasive games merge real and virtual elements offering a new interaction space fostering bodily action (compare Magerkurth et al. [1]). *Our bodies are what give us access to the experience of space in the first place, through our sensorium, nervous system and brain.* O'Keefe as cited in [2]. Feedback is an essential concept not only in computer games [3], but also for our physical interaction with the environment. Touch and physical interaction are among the fundamental ways in which humans understand the world and effect changes in it [4]. Haptic feedback therefore offers an advanced interaction concept for games.

Haptic feedback in virtual environments is manifold. For example, Lindeman and others investigated how vibrotactile feedback improves task performance [5]. Four kinds of feedback are identified, with two of them relevant: First, they can be used to provide a sense of virtual contact; and second it can be used to increase the overall realism of a simulation by improving the *user experience*. Haptic feedback in pervasive games is different. Whereas in virtual environments haptic feedback had to be explicitly created through technical devices, pervasive games offer an implicit feedback as well.

Following Nilson's discussion in [6] we'll take over their categories of game experience: A games **physical** aspect includes the physical feeling of playing the game, the physical skills a player must use, and the games use of physical artefacts. The **mental** aspect of a game concerns problem solving, deductive thought, and reason. The **social** aspect of a game is the way in which players play with each other. See [7] for a discussion if a high quality visual presentation can compensate for the missing physical proximity between players in shaping their social experience. **Emotional** concerns the way a game affects a player emotionally, by the sympathies they develop with game characters or players and the emotions brought forth by immersion in the game world.

The physical aspect of a game includes two aspects: Use of the real world as a gaming environment and/or use of physical objects for interaction. Examples of games using reality as an environment are: Pirates!, ARQuake and CanYouSeeMeNow?. Interaction is taking place in the real world using dedicated devices like PDAs and Joysticks. Games using physical objects as interaction elements are: STARS[8] and Airkanoid [7]. The STARS platform uses augmented reality technology to enhance traditional interaction in tabletop gaming. Players are represented using graspable models on the tabletop surface with the virtual game board. In addition, handheld devices are used for private communication between real players and for character configuration. In most cases the interaction space is limited to a room. An exception is CanYouSeeMeNow? which utilizes cite-wide gaming.

Tangible user interfaces in general provide multimodal feedback creating a deeper sense of "being" in control of the game. Especially through the use of real objects haptic feedback is implicitly provided, but this kind of feedback is not always directly related to game actions.

After introducing related work, the concept of Airkanoid is presented. Section 3 focuses on our ideas on haptic feedback. A final section highlights the conclusions and summarises the further development plans.

1.1 Related Work

Players like to get some bodily feedback, be it vibration, movement, or even electro shocks. Vibration feedback joysticks are widely used input devices in current games. Walters describes in [9] the technical background of haptics and games: i.e. mechanics, design, and programming libaries. The article is interesting as it shows the first steps of integrating haptics in PC based games. He concludes positively by stating: *Force-feedback devices are now readily available to consumers looking for good force response in their games.*

The *PainStation* [10], based on the all time favorite Pong, was developed by the German artist group fur. Instead of incrementing a virtual highscore, physical punishment (heat, electro shocks, and beats) is used. *Tekken Torture Tournament* [11] was developed by C-Level, an American group of artists. They modified the Tekken game and replaced the vibration functionality of the joypads with electro shocks. *Haptic Battle Pong* [12] is a pong clone with haptic control through the Sensable Phantom device. Force-feedback is used to haptically render the contact between the ball and the paddle. Although it povides force to the user it does not allow free bodily action because of the device's restrictions.

Jiang et al. [13] modified Half-Life and added force and vibration feedback. Their aim was to find out the effectiveness of feedback in a virtual reality training environment. The study concluded that haptic feedback plays an important role as it reduced the error rates of the players. In *Haptics Techniques for Media*

Control [14] Snibbe et al. describe a set of techniques for manipulating digital media with force feedback. Hayward et al. [15] provide an introduction to *haptic interfaces* and a summary of devices. A recent article from Salisbury et al. [16] surveys haptic systems and discusses some underlying *haptic-rendering algorithms*.

2 Airkanoid

Back in 1985 Taito released Arkanoid, an arcade game based on the Breakout idea. It is a ball-and-paddle game where you hit bricks in a wall with a ball. When a brick is hit, it disappears and the ball is reflected. When all bricks are cleared you advance to the next level. A user controlled paddle prevents the ball from getting lost.

Airkanoid[1] is a mixed reality remake. It takes over the main concept of bricks and paddles, but extends it with a more general and natural interaction style. Graspable Airbats are used as interfaces for controlling the virtual paddles. In contrast to Breakout and Arkanoid, the horizontal movement restriction is released. Bats can be moved up-down as well as left-right at any orientation. In addition Airkanoid is a collaborative multiplayer game for up to 4 players (two at each local site).

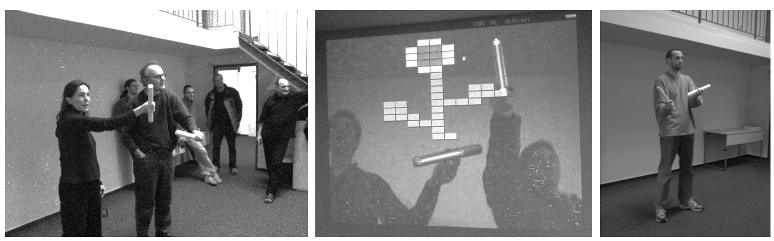


Fig. 1. Airkanoid: Two Airkanoid players with Airbats, the projected screen and one player with two bats simultaneously. Images taken at the Animotion Festival, 20.11.2005, Bremen, Germany

The most obvious difference is that the player is no longer sitting still in front of a computer screen. Instead he has to act in reality to control the game. The position and pose of the bat are directly mapped onto the virtual paddles. A player may even play with two bats at the same time (see Figure 1). The tangible AirBat allows a huge degree of freedom that can be exploited by the user. It utilizes a physical mapping: position and orientation of the physical object directly relate to the virtual bat. Therefore, it removes a level of indirection that occurs from mapping symbols of real devices (e.g. Joystick) onto virtual actions. Additional players can join the game on-the-fly as they only need another bat

[1] Airkanoid's Website can be found at http://www.e56.de/Airkanoid.html

Fig. 2. Airkanoid Photo Highscore

and the software does not restrict the number of players. In Airkanoid a bat made of rolled colored paper is a sufficient and working interface device.

2.1 User Comments

Airkanoid was showcased on several occasions including the Animotion Festival in Bremen. The overall feedback was very positive. Some remarks from the users:

- There is no feeling of the ball impact / A ball-bat-hit should have a noticeable sound effect.
- It was unusual that the ball was reflected at the bottom of the screen.
- More features (i.e. enemies, speed change) after some time.
- Airbats had the right size and weight.
- Highscore photo is a good idea (See Figure 2).
- Smashing of the ball would be nice to have.
- Extra points for speed were motivating.

One major improvement was the photo highscore which was very attractive for players. They tried to express themselves in the photos by being funny, acrobatic, or cool. Players were frequently looking at the images to see if someone they know is better than them. Last but not least, the highscore is published on the Internet combining the data from all showcases. It follows the idea of CanYouSeeMeNow? that used images of the real place where the player was caught to connect distant players with the town the game was played in.

3 Haptic Feedback

In his discussion on AR^{2}Hockey Nilson states: *Despite the fact that it was missing haptic feedback players were able to play it as naturally as in the physical game* [6]. The same holds true for Airkanoid. The graspable interface of Airkanoid provides an easy and convenient way to interact with the game although haptic feedback is missing. So why should we use haptic feedback?

Feedback in pervasive applications in general is different compared to mainstream computer games. Through the integration of the real world, new kind of concepts and possibilites are available. Bodily action itself offers a lot of feedback like touch, exhaustion, and sweat.

Following the interaction model introduced by Ullmer and Ishii [17] two different kinds of haptic feedback can be identified. The physical representation itself provides haptic feedback through the objects (also referred to as tokens) of the interface. Grasping a bat or a figure (e.g. in the STARS environment) creates immediate feedback through the body's sensory organs. In contrast, the digital representation alone is intangible. The focus is to provide feedback at the interacion level where physical objects and digital information are interacting. Airkanoid for example requires the players to hit a virtual ball with a graspable bat. When the ball is hit, a sound is played with the ball being reflected. Visual and aural feedback is utilized but the user does not feel the impact. Haptic feeback serves for two purposes: to bring in another dimension into the interface by simulating the impact and to create a stronger bonding between real objects and digital information. The following subsections are describing two different ways of improving feedback not only in Airkanoid but also in other games.

3.1 Sound

Sound is an important feedback channel. For example non-breakable bricks have a special sound associated with them that indicates that they are unbreakable. A simple and easy solution is to make use of bass sounds. Bass sounds have a special impact on the player. Psychoacoustics[2] distinguishes between:

- LOW BASS - 1st & 2nd octaves (20Hz to 80 Hz)
  Gives sound fullness and power: explosions, thunder, heavy traffic, dinosaurs.
- UPPER BASS - 3rd & 4th octaves (80Hz - 320 Hz)
  Sound produced from instruments like drums, bass, cello, tuba.

Low bass sounds can be felt by the player through his body. This fact is used to provide a hard hit that normally occurs in bat-ball-hits (i.e. in Tennis). Although the real sound of the impact may be at a higher octave this solution simulates the impact quite well but still misses the force aspect. The currently used sound for ball-bat-collision was not sufficient as it does not fall into one of the mentioned categories. A full and saturated bass sound brought us nearer to our goal.

3.2 Haptic

If a ball hits a bat we feel the rebound of the impact. Following Nathan's discussion on the physics of baseball [18] we know that hit energy is also converted into vibrations. Vibration is a practical and important way of providing haptic feedback to users. It requires a minimal interface design and has low complexity and cost. Nevertheless, the vibration bat can transform a reaction force –rising from a collision between the virtual ball and the (virtual) Airbat– into a real vibration torque.

[2] Compare Steve Donofrio: Psychoacoustics and the Grammar Of Audio, http://www.natf.org/documents/psycoa.pdf

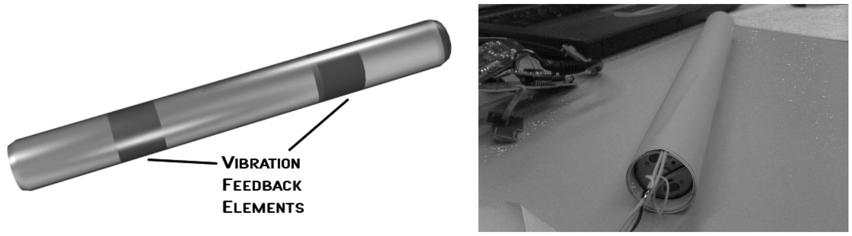


Fig. 3. New Airbat Concept and Prototype

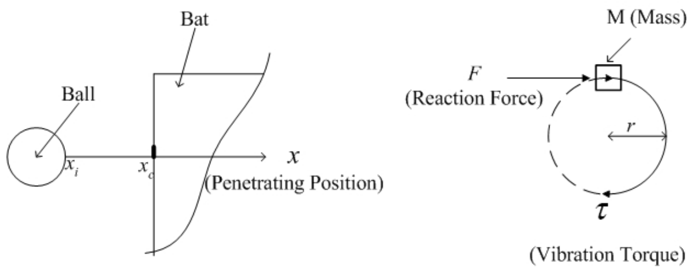


Fig. 4. Impedance Haptic Mechanism and the Transform from Force into Vibration

Figure 3 shows the concept of the modified Airbat. It contains two vibration elements to provide a sense of haptic feedback. Tracking the bat is still done optically to enable cordless interaction. This allows also a mixed configuration of the old and new devices with participants joining even using rolled paper bats. In the following paragraphs the physical foundations of our concept (force feedback through vibration) are derived.

Haptic interfaces in virtual environments have been intensively studied in the past decade. A distinction of haptic interfaces is their intrinsic mechanical behavior (compare [16]). Admittance type haptic is based on the principle of sensing force and generating position or velocity. It offers distinct advantages, such as high damping and stiffness display, particularly in applications requiring precise motion control. In the impedance type haptic, position or velocity is captured and force is generated. This kind of haptic is most common because it measures only position or velocity and does not require an additional force sensor.

The impedance haptic mechanism is used for calculating the reaction force of the bat. Reaction force F, which rises from a collision between the virtual bat and the ball, can be calculated by:

$$F = \begin{cases} K(x - x_c) & : \quad x > x_c \\ 0 & : \quad otherwise \end{cases} \tag{1}$$

Where F is the reaction force of the bat, K the average stiffness of the ball and bat, x_i the initial position, and x the behavior of the ball. Therefore, the key value of the reaction force-rendering algorithm is how far the ball has penetrated into the bat.

The haptic bat (Figure 3) contains two vibration feedback elements. The relation between penetrating position x and vibration torque of the motor τ can be described as: $\tau = M \cdot \frac{d\omega}{dt} + D \cdot \omega = r \cdot F = r \cdot K(x - x_c)$. Where M is mass, ω angular velocity, and D the damping coefficient of the motor.

The implementation is designed based on this model. A problem is that dt is high because the camera operates at 30Hz. Therefore we were not able to provide the high update rates that are normally required in haptic-rendering. Instead of measuring constantly the force F we are evaluating it only when a hit occurs. The calculated torque is scaled to match the DirectX interface and then sent to the motor to excite vibration.

3.3 Early Observations

Haptic Airkanoid is a work in progress. We informally evaluated the early protoype with students and colleagues in order to improve the design and implementation. We used a two player setting with an old Airbat and the new haptic version. Two rounds were played, switching bats after the first round. Afterwards, we interviewed them and asked them for their impressions of the game and the interface.

Feedback was very positive, and in addition many ideas of improving the interface were named. All participants agreed that it was more fun playing the haptic version. They mentioned that this version provides a more direct interaction scheme with the feeling of hitting the virtual ball. A negative aspect were the wires that restricted bodily movement too much. Nearly all players compared the feedback with real sport bats (i.e. tennis or table tennis) and stated that the vibration feedback is good but not realistic.

4 Conclusion

This paper focused on haptic feedback in pervasive games. It was discussed on two levels, interface and interaction, in relation to Ullmer and Ishii's model-control-representation model. Whereas haptic feedback is inherent in the interface, it is missing at the border between reality and virtuality. In Airkanoid the graspable Airbat provides haptic feedback to the user on the interface level, but there is no feeling of the ball impacting the bat while interacting with virtual objects.

Two approaches for providing feedback were introduced: use of low frequency sounds and vibration. In the first step, a deep and saturated bass sound made the impact more noticeable. In the second step, a haptic Airbat was developed with vibration for haptic-rendering. The second idea was play tested for early feedback from users. A common agreement between test players was that Haptic Airbat provides a greater sense of immersion. The feeling of the hit provided an additional clue beside sounds and graphics.

In conclusion, we think that vibration is an easy to use and very powerful feedback element that can also be applied to other games (i.e. baseball or tennis). Although it only provides a sense of haptic feedback, the performance of the interface is significantly improved. For the near future, it is envisaged to build a wireless Airbat for unrestricted body movement.

References

1. Magerkurth, C., Cheok, A.D., Mandryk, R., Nilsen, T.: Pervasive games: Bringing computer entertainment back to the real world. ACM Computers in Entertainment **3**(3) (2005)
2. Schnädelbach, H., Penn, A., Benford, S., Koleva, B.: Mixed reality architecture: Concept, construction, use. Technical Report Equator-03-001, Equator (2003)
3. Salen, K., Zimmerman, E.: Rules of Play. Game Design Fundamentals. MIT Press, Cambridge (2003)
4. Wilson, F.: The Hand: How Its Use Shapes the Brain, Language, and Human Culture. Vintage (1999)
5. Lindeman, R.W., Sibert, J.L., Mendez-Mendez, E., Patil, S., Phifer, D.: Effectiveness of directional vibrotactile cuing on a building-clearing task. In: CHI 2005, Session Touch & Such, Portland, Oregon, USA (2005) 271–280
6. Nilsen, T., Linton, S., Looser, J.: Motivations for ar gaming. In: Proceedings Fuse, New Zealand Game Developers Conference, Dunedin, New Zealand (2004) 86–93
7. Cermak-Sassenrath, D., Faust, M., Rosch, H.: Airkanoid. visual presentation vs. physical proximity in mixed reality entertainment applications. In: PerGames'05 Second International Workshop on Gaming Applications in Pervasive Computing Environments, Munich, Germany (2005) 2–11
8. Magerkurth, C., Stenzel, R., Streitz, N., Neuhold, E.: A multimodal interaction framework for pervasive game applications. In: Workshop at Artificial Intelligence in Mobile Systems, Seattle, USA (2003)
9. Walters, C.: Cop a feel....with haptic peripherals. Gamasutra (1997)
10. Morawe, V., Reiff, T.: (Painstation) http://www.painstation.de.
11. C-Level: (Tekken Torture Tournament) http://www.c-level.cc/tekken1.html.
12. Morris, D., Joshi, N.: Haptic battle pong. In: Experimental Gameplay Workshop, Game Developers Conference. (2004)
13. Jiang, L., Girotra, R., Cutkosky, M.R., Ullrich, C.: Reducing error rates with low-cost haptic feedback in virtual reality-based training applications. In: Proceedings worldHAPTICS, Pisa, Italy (2005) 420–425
14. Snibbe, S., MacLean, K., Shaw, R., Roderick, J., Verplank, W., Scheef, M.: Haptic techniques for media control. In: 14th Annual ACM Symposium on User Interface Software and Technology (UIST), Orlando, Florida, USA (2001)
15. Hayward, V., Astley, O.R., Cruz-Hernandez, M., Grant, D., Robles-De-La-Torre, G.: Haptic interfaces and devices. Sensor Review **24**(1) (2004) 16–29
16. Salisbury, K., Conti, F., Barbagli, F.: Haptic rendering: Introductory concepts. IEEE Computer Graphics and Applications **24** (2004) 24–32
17. Ullmer, B., Ishii, H.: Emerging frameworks for tangible user interfaces. In Caroll, J.M., ed.: Human-Computer Interaction in the New Millenium. Addison-Wesley (2001) 579–601
18. Nathan, A.M.: How does a Baseball bat work? The physics of the ball-bat collision. In: Proceedings of Nuclear Chemestry Gordon Conference, Colby-Sawyer College, New Hampshire, USA (2003)

Smart Playing Cards – Enhancing the Gaming Experience with RFID

Christian Floerkemeier and Friedemann Mattern

Institute for Pervasive Computing, Department of Computer Science,
ETH Zurich, 8092 Zurich, Switzerland
{floerkem,mattern}@inf.ethz.ch

Abstract. The idea of pervasive gaming, where traditional, tabletop games are enhanced with wireless computing devices, has recently received increased attention. In this paper, we present a card game that is augmented with information technology to advise novice players and to relieve the players of mundane tasks, such as score keeping. The paper outlines in particular our efforts to build a system that preserves the assets of conventional card games. The paper shows how appropriate RFID system design results in a portable solution which requires minimal changes and disruptions to the conventional game flow and which works reliably. We also illustrate how the players' mobile phones can be used as user interfaces, thus reducing the overall system costs.

1 Introduction

In his seminal article Mark Weiser imagined information technology that vanishes in the background and seamlessly integrates into the world of physical objects [13]. The notion of computer-augmented tabletop games [1, 8] embodies this vision by providing the best of both worlds – the dynamics and rich social interactions of traditional tabletop games and the computing support that can relieve the players of mundane tasks, such as score keeping, and can enhance the game with visual and audio effects. Sensing technology is used to unobtrusively detect human-to-physical-world and human-to-human interaction, while mobile devices and large displays are used to interface with the players.

In this paper, we present a computer-augmented card game. In such a smart card game, the embedded information technology can provide a number of useful services to the players. These include automated score keeping, advice to novice players, and alerts of wrong moves. Our work builds on earlier work by Römer et al. [10], who initially proposed the idea of a smart card game and also built an early prototype that uses radiofrequency identification (RFID) to capture the game state. We focus in this paper in particular on the development of a smart card game that addresses the limitations of the early work by Römer et al. The main contribution of our paper is thus an implementation of a smart card game that does not disrupt or modify the game flow of a conventional card game, is portable and low-cost, and works reliably. The paper also presents the results of user testing.

(a) Overview of Smart Card Game

(b) Playing Cards and Mobile Phone

(c) Display of Score on Mobile Phone

(d) Unobtrusive Integration of RFID Tags

Fig. 1. Smart Card Game.

The paper is organized as follows. In Section 2, we discuss usage scenarios and requirements. Section 3 features a detailed description of the system design. We focus in particular on the design of the sensing and the user interface component. In Section 4, we present the results of user testing and outline future work. Before we conclude in Section 6, we present related work in Section 5.

2 Usage Scenarios and Requirements

A card game augmented with information technology removes some of the annoying tasks required during a gaming session. It eliminates the mental arithmetic at the end of each game, when the individual value of each card won needs to be added up to determine the winner and the exact score. Such a smart card game can also relieve players of bookkeeping the overall score throughout the gaming session (cf. Figure 1). For novice players, who are quickly confused by the variety of game rules, it provides an additional benefit, since the system can advise the player on the moves allowed and the (presumably) best action to take. This will make the game more enjoyable for both beginners and experts. While these use cases apply in principle to any card game, those that feature a rich set of game and scoring rules will benefit the most from the computer support.

The added value of the automatic scoring and advice functionality should not come at the expense of the characteristic values of a card game, though. These include the dynamic nature of the game, the rich social interactions, the fact that it takes almost no effort to set up a game of cards, and its low cost nature. A computer-augmented card game that requires significant changes to the normal run of events, that slows down the card game, or that requires a significant set-up time will thus not be accepted by the players even if it provides additional functionality. This has been confirmed by previous work [10], where the initial part of the card game is modified to suit the limitations of the sensing technology. The interactive nature of the card game thus mandates a sensing technology that detects the movements of playing cards nearly instantly and reliably. The entire solution including sensing technology and user interface also needs to be portable, easy to set-up, and low cost. In the remainder of this paper we discuss the system we developed and show the extent to which we were able to satisfy these requirements.

3 System Design

In this section, we outline some of the detailed design decisions we made regarding the system components that are responsible for sensing the card game state and communicating the computed results to the players (cf. Figure 2 for the architecture of the smart card game). We begin by illustrating how RFID technology and the appropriate system design can satisfy the requirements presented in the previous section, and continue by outlining the value of mobile phones with short range communication capabilities as user interfaces.

3.1 Capturing the Game State

The identification of the cards belonging to each player and of the cards placed in the current trick requires a fast, short range automatic identification technology. Common identification techniques, such as vision systems or contact-based systems, which require either line of sight or physical contact to the object, are not well suited to the application domain because the cards are often placed partly overlapping in a heap. Vision systems also require a configuration of a camera that limits the portability of the system [12]. Passive RFID solutions are a much better alternative, since they require neither line of sight nor bulky components on the cards. The limited positioning precision of RF solutions is not an issue here because the system only has to distinguish between a few different locations – the space immediately in front of each player and the trick in the middle of the table (cf. Figure 1). Since card decks typically feature up to 60 individual cards, the required address space poses a challenge for low-cost chipless RFID solutions. Instead, we chose to use chip-based RFID technology operating at 13.56 MHz,

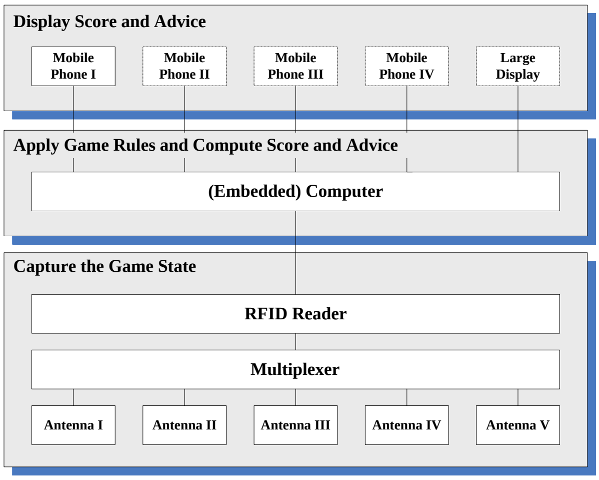
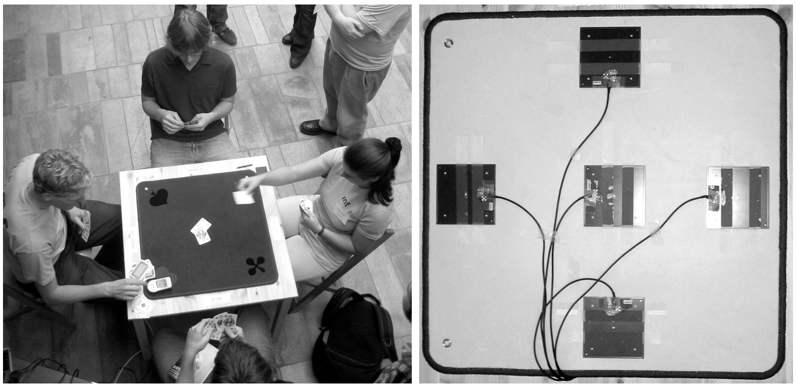


Fig. 2. Architecture of the Smart Card Game. The figure shows the different components and their corresponding roles.

which permits the unobtrusive integration of the RFID labels in each playing card (cf. Figure 1(d)). RFID technology operating in this HF-band also features a well-defined read range due to the operation in the near-field of the reader antenna. The technology is thus ideally suited to distinguish between different locations in close proximity. The limited range and small reader antenna size imply that we are operating well within the radio regulations in the HF-band. This allows us to improve the identification speed by choosing a reader-to-tag data coding scheme with increased sideband signalling.

To reduce the cost of the system, we use a single short range RFID reader (Feig ID ISC.MR100) together with a multiplexer (Feig ID ISC.ANT.MUX-A) that switches five different antennas (cf. Figure 2). The more expensive option would have been a design with five readers, each connected to one of the antennas. The antennas are integrated into a cover that is commonly used to facilitate the playing (cf. Figure 3). This cover can simply be rolled up to provide portability. We minimize the time it takes to detect card movements by dynamically eliminating antennas of no interest. Initially, we only poll the four “player” antennas because the central antenna is of no significance during card distribution. After the system has determined the owner of each card, the outer antennas are deselected and the multiplexer polls the central antenna only. This dynamic antenna multiplexing is facilitated by the RFIDStack [5], an RFID middleware platform that abstracts from the low-level details of the implementation and provides a convenient publish/subscribe interface.

The reliability of the identification process can suffer when RFID tags are placed in close proximity to each other [4]. This phenomenon – known as tag detuning – is due to the fact that the mutual inductance and parasitic capacitance



(a) Top View of Smart Card Game (b) Reverse Side of Cover

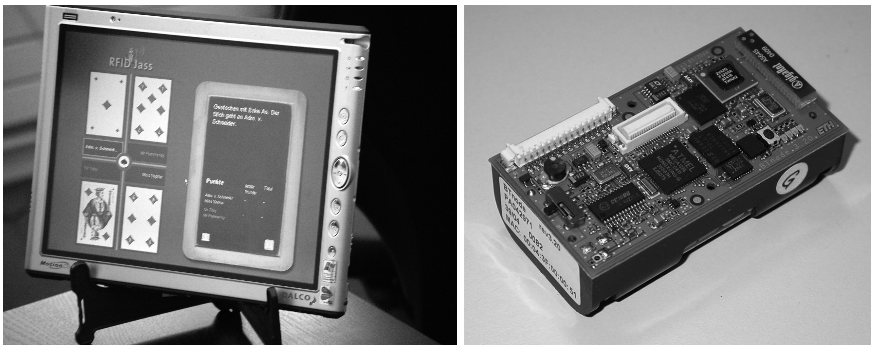
Fig. 3. RFID Reader Antenna Set-up. The five antennas are integrated into the cover that is placed on the table surface.

resulting from tags in close proximity change the resonance frequency of the tags. This means that the operation frequency of the carrier signal transmitted by the reader no longer coincides with the tag resonance frequency – effectively reducing the read range. In [4], it was shown that this makes the identification of cards placed in a stack a challenge. We address this problem by choosing tags that are tuned to a resonance frequency greater than the operating frequency. Placing them in close proximity will then reduce the resonance frequency to a value close to the operating frequency of 13.56 MHz.

One of the most difficult aspects of the system design is to capture the human-to-human interactions during the card game. This includes for example announcements during the bidding process and during the run of the game. While we have managed to build a system that requires no changes to the normal run of events to capture card movements, we do rely on explicit interaction with the computer system to replicate the verbal announcements. We facilitate this explicit interaction with the use of specialized tokens that feature an RFID tag. Placement of the corresponding token on the reader antenna indicates the appropriate announcement to the computer system.

3.2 Computing the Game Score and Advice

In the previous subsections, we discussed the design of a fast and reliable sensing system that captures the game state. This allows a computer attached to the reader to determine the current score, the subsequent player, and any wrong moves. It also enables services such as memory helpers, which inform the players of the cards remaining in the game and advise on the next move. We currently still rely on a Tablet PC to interpret the RFID data, to keep the game state, and to compute score and advice (cf. Figure 4(a)). The use of a Tablet PC also



(a) Tablet PC (b) BTnode

Fig. 4. Computing Platform. The game score and advice are today still computed on a Tablet PC. This provides a built-in display, but increases the cost of the system significantly. Future versions will be implemented on a Bluetooth enabled computing platform, such as the BTnodes [2].

provides us with an additional display, but increases the overall cost significantly. In the future, a simple Bluetooth computing platform, such as the BTnode [2], can provide the computing functionality to reduce overall system cost (cf. Figure 4(b)). The implementation currently supports a number of different trick taking card games, such as Jass and Doppelkopf.

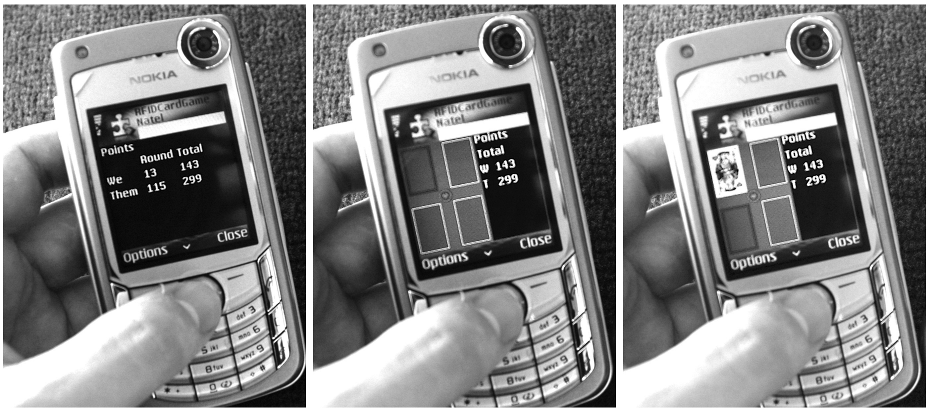
3.3 Interfacing with the players

To communicate information such as scores and advice, we chose to use the individual players' mobile phones. The main rationale for using the mobile phone was that it eliminates the need for a costly custom-built display. It also facilitates the set-up of the computer-augmented card game because no display needs to be installed. The use of the mobile phone displays also avoids the problem of making the game information available to all players without having multiple displays facing in different directions. Figure 5 shows the mobile phone display during various stages of the game.

Our solution relies on Bluetooth-enabled mobile phones that support the Java Mobile Information Device Profile [6] and JSR82 [7]. The mobile phones communicate with the computer, which keeps track of the game state, using the Bluetooth RFCOMM interface. The implementation on the mobile phones does not keep any state. This allows the players to connect to the "game server" with their mobile phones at any time during the game. The result is that a lost connection will not interrupt the current game.

4 Evaluation

The smart card game has been extensively tested on a number of occasions. This includes two days of user testing at an open day at the university. The tests



(a) Score (b) Trump/Turn (c) Card Detection

Fig. 5. Mobile Phone Display. The three figures show different use cases. In Figure (a), the total score and the winner of the last round is shown. In Figure (b), the display indicates the current trump and whose turn it is. In Figure (c), the first card placed in the trick is displayed.

illustrated the reliable and fast operation of the entire system. The evaluation showed that it takes only a fraction of a second before a card placed in the current trick also appears on the display of the mobile phone. The system also worked reliably over long periods of time. There were very few missed reads and most resulted from cards that were placed far away from the centre of the table. The central antenna which monitors the cards placed in the current trick was then not able to detect these cards. The Bluetooth communication and the software on the mobile phones also worked reliably and the delay the players experienced was minimal.

During the initial card distribution phase, the identification latency is increased, since the multiplexer polls one of the four "player" antennas at a time. This was intended during the design phase to alleviate the need for multiple readers. During this initial distribution phase, the identification rate occasionally suffered, when players placed the cards in a stack immediately after distribution. This happened although we use RFID tags that are deliberately detuned to enable stack reading. In such a case, the software would ask the player to briefly place his cards spread out on "his" antenna in order to identify the cards missed.

The user feedback also indicated a number of interesting observations and suggestions for future work:

Audio output. Some of the players that tested our system recommended using audio feedback as well. They mentioned that they were initially not convinced that the system would reliably detect card movement. As a consequence, they were distracted by watching the cell phone to verify that the system did pick up everything correctly. They recommended an option of using a short beep to indicate the successful detection of a trick. Some players also preferred an audio alert to indicate a wrong move.

LEDs in the cover. The tests also showed that some novice players would prefer LEDs integrated into the cover to indicate whose turn it is. They mentioned that a check on the mobile phone was inconvenient.

More variants. Card games, such as Skat, Doppelkopf, and Jass, allow for a number of variants and special game rules. Players commonly agree on a set of rules and sometimes even modify the rules during a game. Our solution currently supports only a single set of rules. The players that tested our system recommended that future versions should provide more flexibility by allowing the players to select their personal favourite rule set. Since it will be difficult to implement all variants, there should ideally be a simple way for players to program new rules or at least download rules from a repository. The creation of novel rules using the limited input capabilities of a mobile phone will remain cumbersome, however.

Availability of compatible mobile phones. While there are a number of mobile phones that support Java and Bluetooth, the number of mobile phones that support access to the Bluetooth stack via JSR82 is still limited. However, we believe that this will change in the foreseeable future with the proliferation of the Java platform on mobile devices.

5 Related Work

The work presented by Römer in [10] is closely related to the work in our paper. It presents the initial idea and an early prototype of an RFID enabled card game. The system relies on a single, large reader antenna to capture the game state. It uses handhelds that communicate over a wireless LAN access point with a central server. Our work differs from the early work by Römer because our design effort focuses on developing a portable, low-cost solution that minimizes the modification to the normal game flow and works unobtrusively. The prototype developed by Römer et al. relies for example on a special distribution procedure that allows the computer to determine the owner of each card with a single reader antenna. This not only requires the players to adapt their behaviour to the limited capabilities of the computer system, but also leads to unreliable operation as described in [10].

There are also computer-augmented card games that rely on a vision system to capture the game state. For example, the system described in [12] uses a set of cameras to sense the card movements during a game of Blackjack. Because of the significant infrastructure required, the applicability of this approach is limited to use within casinos. Due to the portability of our system, the card game can be played wherever there is enough space for the cover and there is a power connection.

The potential of RFID as a viable technology to bridge the gap between the physical and the virtual world has been demonstrated previously within the pervasive gaming research community [3, 9]. The STARS platform developed by

Magerkurth et al. [9] integrates a number of sensing technologies to capture the game state, such as vision, touch screens, but also RFID. This platform features an RFID antenna integrated into the table surface to detect the presence of physical tokens, which alleviate the need for a mouse or a keyboard. In [3], Bohn presents a smart Jigsaw Puzzle that also relies on RFID technology to provide a convenient method to interact with the computer. Players can place jigsaw pieces in front of a handheld RFID reader and the computer will provide some advice on a display. However, there is no use of RFID to automatically sense the current state of the game without explicit interaction from the players. The use of mobile phones as a viable technology to interface with users in ubiquitous computing applications has also been discussed in [11].

6 Conclusion

Computer-augmented tabletop games have recently received considerable attention. In contrast to the most common form of pervasive gaming, where computer games are mapped onto real-world settings, augmented tabletop games build on old-fashioned (board) games that are enriched with unobtrusive information technology. This paper presents a conventional card game that is augmented with information technology to automate score keeping and to advise novice players. We show how RFID and mobile phones can be used to combine the best of both worlds – the dynamics and rich social interaction of a conventional card game and the ease of score and advice computations that information technology provides. The paper outlines in particular our efforts to build a system that preserves the assets of card games. The paper shows how appropriate RFID system design results in a portable solution which requires minimal changes and disruptions to the conventional game flow and which works reliably. We also illustrate how the mobile phones of the players can be used as user interfaces, thus reducing the overall system costs. The results of an evaluation indicate that players appreciate the additional functionality especially because it does not come at the expense of the ordinary benefits of a card game. Future work should include audio alerts and the implementation of alternative gaming and scoring rules.

References

1. Steve Benford, Carsten Magerkurth, and Peter Ljungstrand. Bridging the physical and digital in pervasive gaming. *Commun. ACM*, 48(3):54–57, 2005.
2. Jan Beutel, Oliver Kasten, Friedemann Mattern, Kay Römer, Frank Siegemund, and Lothar Thiele. Prototyping Wireless Sensor Network Applications with BTnodes. In *1st European Workshop on Wireless Sensor Networks (EWSN)*, volume 2920 of *Lecture Notes in Computer Science*, pages 323–338, Berlin, Germany, January 2004. Springer-Verlag.
3. Jürgen Bohn. The Smart Jigsaw Puzzle Assistant: Using RFID Technology for Building Augmented Real-World Games. Workshop on Gaming Applications in Pervasive Computing Environments at Pervasive 2004, Vienna, Austria, April 2004.

4. Christian Floerkemeier and Matthias Lampe. Issues with RFID usage in ubiquitous computing applications. In Alois Ferscha and Friedemann Mattern, editors, *Second International Conference, PERVASIVE 2004*, volume 3001 of *Lecture Notes in Computer Science*, pages 188–193, Linz/Vienna, Austria, April 2004. Springer-Verlag.
5. Christian Floerkemeier and Matthias Lampe. RFID middleware design – addressing application requirements and RFID constraints. In *Proceedings of SOC'2005 (Smart Objects Conference)*, pages 219–224, Grenoble, France, October 2005.
6. Java Community Process. JSR 118: Mobile Information Device Profile 2.0.
7. Java Community Process. JSR 82: Java APIs for Bluetooth.
8. Carsten Magerkurth, Adrian David Cheok, Regan L. Mandryk, and Trond Nilsen. Pervasive games: bringing computer entertainment back to the real world. *Comput. Entertain.*, 3(3):4–4, 2005.
9. Carsten Magerkurth, Maral Memisoglu, Timo Engelke, and Norbert Streitz. Towards the next generation of tabletop gaming experiences. In *GI '04: Proceedings of the 2004 conference on Graphics interface*, pages 73–80, School of Computer Science, University of Waterloo, Waterloo, Ontario, Canada, 2004. Canadian Human-Computer Communications Society.
10. Kay Römer and Svetlana Domnitcheva. Smart Playing Cards: A Ubiquitous Computing Game. *Personal and Ubiquitous Computing*, 6:371–378, 2002.
11. Frank Siegemund, Christian Floerkemeier, and Harald Vogt. The Value of Handhelds in Smart Environments. *Personal and Ubiquitous Computing*, 9(2):69 – 80, October 2004.
12. David Talbot. The Digital Pit Boss. MIT Technology Review, Aug 2005.
13. M. Weiser. The computer of the 21st century. *Scientific American*, pages 94–100, September 1991.

Relying on Wireless Sensor Networks to Enhance the RC-Gaming Experience

Pablo Guerrero[1], Mariano Cilia[2] and Alejandro Buchmann[2]

[1] GK Enabling Technologies for Electronic Commerce, and
[2] Databases and Distributed Systems Group,
Dept. of Computer Science, TU Darmstadt, Germany
{guerrero, cilia, buchmann}@dvs1.informatik.tu-darmstadt.de

Abstract. The state of the art in pervasive computing technologies will slowly allow turning into a world full of smart objects, and remote controlled toys are no exception. Following the growing popularity of multi-player computer games, we envision a novel application that enriches the gaming experience by taking the digital multi-player interaction into the physical world of remote controlled toys. We propose the development of an infrastructure that relies on wireless sensor networks as the glue that enables using remote controlled toys with multi-player games, and provide a road map for its development.

1 Introduction

Advances in pervasive computing technologies are slowly allowing us to improve different aspects of our daily activities. One of such aspects is *entertainment*, which can be done either in the *physical world* (i.e., sports, table games, etc.) or in the *digital world* (i.e., by means of computer games).

A very entertaining activity in the physical world is to play with remote controlled (RC) toys, and nowadays many types are offered such as cars, trucks, airplanes, boats and even robots with guns. These RC toys differ in complexity, starting from small, ready to use toys for kids, to assemble-yourself more complex toys, to complete hobbies for demanding enthusiasts. The toys are operated remotely by their owners with a *controller*. The wireless radio connection is *unidirectional*, usually split in multiple channels at several frequencies

Playing with RC toys is very exciting, however *gaming mode* has not changed so far. The way they are used today consists basically of finding an appropriate spot (race track, open space, lake, mud, etc.) and play until no energy (i.e. battery, fuel, etc.) is left. Due to the toy's energy consumption, this is characterized by short playing sessions that vary from a couple of minutes to a few hours.

On the other hand, in the digital world, multi-player computer games (over a computer network) have gained increasing popularity among players since the release of Doom in 1993©. Single-player gaming modes, where the player fought against computer enemies, evolved into multi-player modes like Deathmatch or Co-operative. Computer opponents could be replaced with human player's characters, controlled from another side of the network. Later on, new gaming modes were conceived like Last Man Standing or Invasion. These gaming modes have definitively leveraged the playability of existing computer games.

Our idea is to enrich the RC players' experience by taking the digital multi-player gaming interaction into the physical world of the RC toys. Currently, there are many RC toys ready to be used with such games, however, no infrastructure is available that allows this kind of interaction. In this paper we propose the usage of wireless sensor networks (WSNs) as the gluing infrastructure that makes possible that RC toys can be played as a multi-player game.

2 Enhancing the Game Experience with Onslaught

In order to exemplify the infrastructure functionality, we show a concrete gaming mode called *Onslaught* [10], inspired by the popular game Unreal Tournament©. Within Onslaught, participants are divided into two opposing teams. The game-yard contains two *Power Cores* that act as base stations (e.g., the Red or the Blue Power Core). These, in turn, are linked to each other through several strategic points, called *Power Nodes*, forming a predefined *virtual network*. The team goal is to conquer the enemy's Power Core, while defending theirs'.

The game rules are simple. A Power Node can be conquered when a toy *stays* for some seconds within a certain range around it. Moreover, a player can conquer a Power Node if and only if there is a path composed by other conquered Power Nodes connecting it with its team's Power Core. Power Nodes have a *strength* attribute representing the intensity with which they have been conquered, and indicated with a color light. An opponent can also neutralize and convert a Power Node to its team's color by taking the same action. Power Cores can be similarly conquered, however they can not be *healed* back.

Players' toys strategically advance across the gameyard towards the opponents' Power Core by conquering virtually connected Power Nodes. When, for instance, the Blue team has conquered a set of Power Nodes such that they form a path starting at their Blue Power Core and ending at the Red Power Core, the latter can be conquered. As long as this restriction is fulfilled, the Red Power Core's strength can be weakened. However, if a Red team member breaks the path connection by neutralizing one of the intermediate Power Nodes, then the Blue team must either reconquer it or use an alternative path.

Obviously, two or more RC toys could simultaneously try to conquer or defend a Power Node or Power Core, so players should expect impacts on the toys, in order to put each other out of the node's range. The game finishes when a Power Core is conquered, i.e., when its strength becomes zero.

Figure 1 shows a simple Onslaught map snapshot, as well as the described entities. By applying our knowledge in WSNs and multi-player games, we can offer new gaming modes to the participants. Our aim is to provide a gaming framework that enables deploying a broad spectrum of team-based, goal-oriented gameplay. Next, we describe the application requirements and provide a road map for its development. We finalize by providing a summary of related work and the conclusions.

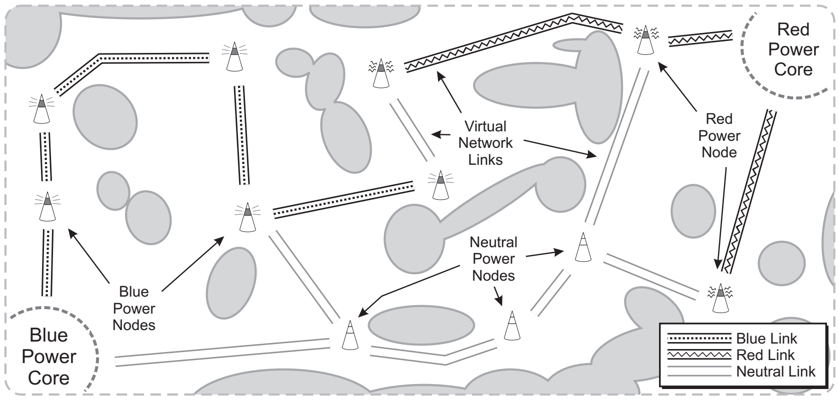


Fig. 1. A Simple Onslaught Map

3 Multi-player Real Life Games' Requirements

In order to allow RC toys to support gaming modes like the example shown in the previous section, an infrastructure is required. This work proposes the development of such an infrastructure, which binds three different domains, namely pervasive computing, multi-player games and toys. We have called this intersection *Multi-player Real Life Games*, or MPRLG for short.

The small set of rules for a game like Onslaught requires sensing and computing some data, as well as the ability to act on the sensory data. This is not only true for the RC toys, but also for the set of *game gadgets* like the Power Cores and Power Nodes deployed in the gameyard. *Game components* (i.e., both the RC toys and the game gadgets) enable the new gaming modes by signaling the different occurrences of the game (e.g., *Red Car #7 conquered Blue Power Node #3*) and of course need some type of wireless connectivity. This is where the infrastructure comes into play by providing:

1. a computational model to specify the game rules and assign them to the game components;
2. the means to disseminate the information between the interested parties, like game components or controllers; and
3. a placeholder at the game components that triggers these rules and executes the associated actions.

The first challenge is to enable the game components to sense, compute and communicate. We propose to *attach* a wireless sensor node to each game component and controller. In this context, a node consists of a processor, some memory, a wireless radio and a power source. This scheme presents the advantage of keeping unchanged the proprietary unidirectional channel between controllers and toys, used by players to manipulate them. The wireless sensor nodes use another radio frequency to convey game-related data that coexists with the remote controlling channel. We proceed in this section describing important non-functional attributes and constraints that challenge the infrastructure design.

3.1 Gaming Modes Acquisition, Configuration and Deployment

The gaming mode's *logic* can be expressed as a set of rules, which could be contained by a *Game Repository*, accessible through the web. A *Game Configurator* such as a PDA can be used to download a gaming mode. Normally some initial setup and configuration is required, which occurs at two different levels. First, given the unreliable communication nature of the WSN, participants want to check the proper operation of the network before the game starts. Nodes must organize themselves into an operational network, for instance, adjusting routing tables with local neighbors. Second, gaming mode dependent attributes must be set. The user interaction is required, for instance, to help provide unique identities (accessible by the application) to the game components, assign them with different roles, or setting fine-grained game parameters (e.g. overall game duration, maximum strength, etc.).

After players agree to a gaming mode, deployment of the corresponding role logic into the toys' and gadgets' nodes occurs, using the wireless protocol, although this is known to consume considerable energy from the node's power source. Participants could join the game dynamically, as long as the gaming mode rules are deployed into their toys' node first.

3.2 Game-Player Runtime Interaction

The infrastructure should allow participants to visualize the game state. For instance in the Onslaught game, participants could visualize the virtual network of Power Nodes conquered so far and their strength. Ideally for the players' mobility would be to embed a small size screen into the remote controllers, or have regular PDAs. This allows each player to monitor the information of his *personal* toy, such as the location or speed, and would give players within a team the opportunity to be physically distant. Through this interface, participants can also send strategic commands to other teammates, for instance, by indicating a meeting point in his screen's map with a pen. The command would be sent through the nodes mesh.

3.3 Beyond Onslaught

In general, information generated by further sensors like acceleration, temperature, light, orientation, wind and energy (e.g., battery, nitro, gas, fuel) sensors, signal strength indications, localization and context-aware algorithms, etc., could feed the game rules. In addition, toys could provide an I/O interface where the wireless node can be plugged to query its intrinsic hardware integrity. In this way, part malfunctions, engine temperature, or any other internal readings can also enrich the game rules.

The game logic, defined by means of rules, should clearly define which information can be shared with others and what must be made private (i.e., visible only by the player or its team), particularly since the transport mechanism could convey the events through any wireless node in the mesh (i.e., a team-mate or an opponent's sensor node).

4 Infrastructure Design and Challenges

The infrastructure required to support the described gaming modes must face many technical challenges. In this section we show the considerations that lead to our layered infrastructure design. These layers are illustrated in Figure 2.

Application Layer. Several key abstractions were identified in the top layer. The *Game Manager* provides an interface to handle deployment details as mentioned in Section 3.1. This component contains an *id* that uniquely identifies the node it resides in from the rest. The id can either be obtained from the operating system or an algorithm can be used. It also stores the node's *role*, which can be given by the properties of the node itself (e.g., has particular sensors).

This layer also deals with the gaming mode logic. We argue that a MPRLG can be modeled using an event-triggered rule language such as Event-Condition-Action (ECA) rules. These rules clearly specify when they should be triggered and what to do in reaction. For instance, in the Onslaught game we may have:

```
Event:     ON [ CarDetected(car) ]
Condition: IF [ ∃ neighbor Power Node pn /
                {CurrentTeamColor(pn) = TeamColor(car)} ]
Action:    DO [ AdjustStrength(TeamColor(car)); PublishState(); ]
```

This rule exemplifies the easiness with which the Power Node's logic can be described using ECA rules. The Event clause indicates that the rule must be triggered when the node detects a '*car*' in the proximity of the Power Node. The Condition clause states that the action must be executed only if there is a neighbor Power Node '*pn*' that is currently conquered by '*car*'s team color. Finally, the Action clause contains an list of activities, in this case the adjustment of the Power Node's strength attribute, and the dissemination of its state. Note that although this rule is triggered by an event sensed locally by the node, it could also by triggered by an event received from a neighbor node.

During runtime, a *rule engine* triggers the rules as a result of incoming events, checks the required conditions, and executes the associated actions. This architecture is based on an *Active Functionality Service* [4], which is platform independent [2]. Roughly, the ECA Manager component administrates the ECA-rule registration and activation, and relies on other elementary services when rules are triggered, like the Event, Condition and Action Services. This approach is

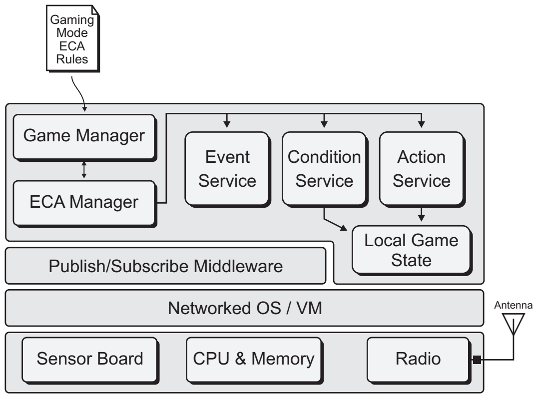


Fig. 2. Infrastructure Architecture

scalable to small embedded systems. However, although it has been proposed for WSNs [13], we are not aware of concrete implementations.

Finally, the rule engine is basically stateless, hence we provide a Local Game State component, which stores information required by the application services. Therefore, game ECA-rules must be adequately arranged such that only a minimum set of game state is kept in the sensor nodes.

Game components' logical communication. In order to update the game state, wireless nodes communicate with their peers, exchanging game-related events in a many to many relationship. The asynchronous communication between nodes can benefit from using the publish/subscribe (pub/sub) paradigm, since it naturally decouples producers and consumers, makes them anonymous to each other, and allows a dynamic number of publishers and subscribers. Generated data might be filtered, aggregated, and eventually disseminated towards interested consumers, like peers or controllers. Due to the spontaneity of the gaming field settlement, an ad hoc, infrastructureless communication is needed. Using an access point-like infrastructure would not only increase the deployment effort, but also require more power at the nodes to transmit data over longer distances. Instead, nodes route data to interested consumers across multiple short hops. In addition, game components are in constant movement. This implies that a) available neighbors at one time will likely change, and b) messages might be generated while a game component was not in reach of others. As a result, the nodes conform a mobile ad hoc network that must include some form of disconnected operation (e.g., buffering).

Foundation Layer. A foundation layer (e.g., OS, VM or simply embedded libraries) is required that provides an abstract interface to the underlying hardware, timers, task scheduling and so on. Also the medium access control (MAC) protocol is normally included in this layer. However, since WSNs MAC protocols typically trade off energy consumption for latency and fairness [5], therefore specialized protocols that consider mobility should be inspected, such as [11].

Physical Layer. An appropriate hardware platform must be identified for this infrastructure. Sensor hardware was already discussed in Section 3.3. We foresee that the first wave of WSN platforms (e.g., those with 8 bit processors) will not suffice our required processing capabilities. This is already being addressed, e.g., by [7, 12]. Finally, current WSNs' designs use one of the 802.15.x PHY layers, which dictate the theoretical data rates and energy consumption values. We expect to be able to decide for one of these by adjusting all the knobs with a top-down approach as described before.

5 Related Work

Interesting work has been done by investigators trying to bridge digital and physical games with pervasive technologies. In [1], an outdoor multi-player game called *Unmasking Mister X* is presented. Wearable computers and sensors are used to determine who is 'Mister X', based only on readings from his wearable sensors. In *Can You See Me Now?* [8], some players run around a real city's streets (tracked by GPS) while others move an avatar in an online 3D representation of the same city. Physical players attempt to 'catch' online players by chasing their (virtual) location. *Treasure* [6] is a game that exploits the lack of connectivity in wireless networks. Players move outside wireless coverage to collect virtual 'coins' and then move back into an area with high network strength to 'upload' the treasure to a game server. However, these games run on equipment with relatively large resources (for instance PDA's with GPS). *Trove* [9], in contrast, implements a multi-player game on a WSN, where participants try to reach a hidden treasure. Each player is assigned with a mote which transmits game packets to a base station. Players loose lives whenever their sensor readings values exceed a configurable threshold. A game supervisor exists which performs identification, sensor calibration and coordination of the game in a similar fashion to our Game Configurator. Another related project, although not meant for gaming, is *CotsBots* [3]. It integrates off-the-shelf motes with a commercially available mini RC car, whose RC functionality and other original electronics are extracted and replaced by an autonomic behavior board that controls the car's engine, providing an experimentation platform for distributed robot systems.

6 Conclusions

In this paper we have presented the idea of integrating the physical world of RC toys with the virtual world of multi-player computer games, which we have called MPRLGs. The gaming experience can be enhanced by providing goal-based, team-oriented gameplay to the participants. This entertainment is made possible by relying on a WSN gaming framework. Its requirements were sketched with an exemplary gaming mode, which introduced the concept of game gadgets and their ability to detect toys in their surroundings. This raised a pluggable WSN ad hoc approach that allows the specification, deployment and execution of rules at the game components, as well as the dissemination of game-related data. And later we have discussed an architecture facing its technical challenges.

Bearing some resemblance to how advances in computer games have pushed high-end computer graphics, we believe MPRLGs can also drive the evolution of WSN technologies. In particular, the project provides an interesting testbed to try, evaluate and measure different ideas and algorithms related to wireless sensor networks, reactive systems and publish/subscribe notification services.

7 Acknowledgments

We would like to thank to Patric Kabus, Kai Sachs and Jan Steffan for their collaboration and draft reviews. A particular thank to the members of the ESF Scientific Programme MiNEMA, where first steps of this research were discussed.

References

1. S. Antifakos and B. Schiele. Bridging the Gap Between Virtual and Physical Games using Wearable Sensors. In *Procs. of ISWC'02*, Seattle, USA, Oct. 2002.
2. J. Antollini. Implementing an Active Functionality Service on Different Platforms. Master's thesis, Faculty of Sciences, UNICEN, Tandil, Argentina, July 2005.
3. S. Bergbreiter and K. Pister. CotsBots: An Off-The-Shelf Platform for Distributed Robotics. In *Procs. of IROS'03*, Las Vegas, USA, October 2003.
4. M. Cilia. *An Active Functionality Service for Open Distributed Heterogeneous Environments*. Ph.D. Thesis, TU Darmstadt, Germany, August 2002.
5. T. Dam and K. Langendoen. An Adaptive Energy-Efficient MAC Protocol for Wireless Sensor Networks. In *Procs. of SenSys*, pages 171–180. ACM Press, 2003.
6. M. Chalmers et al. Gaming on the Edge: Using Seams in Pervasive Games. *2nd. Intl. Workshop on Gaming Applications at Pervasive 2005*, May 2005.
7. R. Adler et al. Intel Mote 2: An Advanced Platform for Demanding Sensor Network Applications. In *Procs. of SenSys*, pages 298–298. ACM Press, 2005.
8. S. Benford et al. Can You See Me Now? *ACM CHI Transactions*, 2005.
9. S. Mount et al. Trove: a Physical Game Running on an Ad-Hoc Wireless Sensor Network. In *Procs. of sOc-EUSAI*, pages 235–240, Grenoble, France, Oct. 2005.
10. id Software Inc. UT 2004. `www.unrealtournament.com/ut2004/modes.php`, 2001.
11. H. Pham and S. Jha. An Adaptive Mobility-Aware MAC Protocol for Sensor Networks. In *Procs. IEEE Intl. Conf. MASS'04*, pages 558–560, FL, USA, 2004.
12. R. Smith, C. Cifuentes, and D. Simon. Enabling Java for Small Wireless Devices with Squawk and SpotWorld. In *Building Soft. for Pervasive Computing '05*, 2005.
13. M. Zoumboulakis, G. Roussos, and A. Poulovassilis. Active Rules for Wireless Networks of Sensors & Actuators. In *Procs. of SenSys*, pages 263–264, NY, USA, 2004. ACM Press.

This article was processed using the LaTeX macro package with LLNCS style

Paranoia Syndrome – A Pervasive Multiplayer Game using PDAs, RFID, and Tangible Objects

Guido Heumer[1], Darren Carlson[2], Sree Harsha Kaligiri[2], Supriya Maheshwari[2], Waqar-ul Hasan[2], Bernhard Jung[1], Andreas Schrader[2]

[1]Virtual Reality and Multimedia Group, TU Bergakademie Freiberg, Germany
http://www.informatik.tu-freiberg.de
[2]ISNM - International School of New Media, University of Lübeck, Germany
http://www.isnm.de

Abstract. In this paper we present Paranoia Syndrome as a novel hybrid game approach. Paranoia Syndrome combines classic multiplayer strategy game elements using 2D computer graphics on PDAs with location-based interaction paradigms in physical space using RFID technology and tangible objects. The combination of virtual and physical reality interaction in addition to a rule system, that encourages player cooperation, provides a powerful approach for social gaming experiences.

1 Introduction

With pervasive gaming, novel types of games have recently emerged. The general idea is to apply pervasive computing technology - which embeds computing and interfacing capabilities in real-world, everyday objects - to games. By bringing gaming back to natural, social interaction spaces, pervasive gaming aims to overcome some restrictions of conventional computer games: Players are no longer tied to computer screens and human-computer interaction is not constrained by graphical user interfaces (GUIs), which is a crucial aspect of traditional non-computer games.

A specific enhancement of pervasive game design is given by the usage of tangible user interfaces (TUI) [10][12]. TUIs support the use of graspable – not just pervasive – real-world objects as intuitive interfaces that follow familiar metaphors and allow for conveniently combining real and virtual worlds.

Recently, several pervasive games using advanced technology have been proposed. Cheok et al. [2] and Ulbricht and Schmalstieg [12] proposed augmented reality games using tangible interfaces. In the EyeToy system [11], a camera is used to track the movements of the user. The Nokia Xpress-on™ Fun Shells [9] have inbuilt accelerometer sensors and RFID readers, which can be used to control games on the phone display. A comprehensive discussion of tangible user interfaces in game design has been provided by Ullmer and Ishii [13]. In the EU project IPerG [5], board games have been analyzed for the potential of computer augmentation with a special focus on socially adaptable games. Board games and table-top games have been presented in a number of research projects, since classical board games show an explicit level of sociability [8].

Our previous work on pervasive gaming has focused on the aspect of tangible interfaces [6]: Guardian Angel [4] as a single-player game focused mainly on the tangible interface and Fruit Salad [3] as a multi-player game focused on the combination of graphics and tangible interfaces in a table-top game.

In this paper we propose *Paranoia Syndrome* as a new pervasive game approach; combining tangible interfaces in the form of physical objects, with mobile, context-aware functionality using Portable Computers (PDAs) and Radio Frequency Identification (RFID) to create a novel pervasive game experience. Social collaboration is strongly supported, since players work as a team by sharing tangible objects, game space and strategies while competing against a common opponent.

2 Game Concept

Paranoia Syndrome is a science fiction strategy game about the battle between players and an invisible alien race. The playing field is part of the real world. Players must physically move between locations to achieve their goals. Coordinating their efforts is crucial, with communication also taking place by real world means, e.g., real voice, telephones or other telecommunication infrastructure.

The game features two types of interfaces, which are used simultaneously:

- The *Virtual Interface* is realized as graphical user interface on the PDA of each player with functions for querying information about the game state and for invoking actions. The PDA interface is the only channel to the otherwise invisible aliens.
- The *Tangible Interface* is realized by integrating specially prepared real world objects. These objects can be bought, used and sold (for game money) by all participants during game play. Equipped with RFID labels, these *Tangible Object*s can be identified and operated by the user using the RFID scanner on the PDA.

2.1 Story

The story of Paranoia Syndrome revolves around a race of extraterrestrial beings, invading planet earth. These beings live in another phase of time-space and hence are invisible and untouchable to humans by normal means. Although they can only be detected with specialized scanner equipment, the aliens are nevertheless harmful to humans, as they feed on people's mental energies and can eventually drain them to the point of death. Since the number of these alien beings is ever increasing and their hunger for human energies is insatiable, they pose a deadly threat to humanity, which can only be countered by a band of bold heroes. Equipped with the newest developments in technology, the players set out to neutralize this alien threat.

2.2 Gameplay

In Paranoia Syndrome, players work together to fight a common artificial opponent, simulated by a central game server. Each player carries a PDA, serving as the main interface to the game world. Part of the gameplay takes place virtually on the PDA and the other part, such as moving around, communicating with team members, etc., takes place physically in the real world. The location of players is tracked (at room granularity) as players actively scan RFID tags, which are attached to each doorway. Players use their PDAs to perform scans of the rooms they are in, giving them a hint of the level of alien presence in that room. The PDAs are in contact with the central game server, which continually progresses the simulation, even if the players are idle, creating real-time pressure for the players.

Each player chooses one of three roles, which provides him or her specials skills that the other roles do not possess (see section 2.3). This feature intends to foster human-to-human interactions and helps players feel individual achievement through contributing their individual skills to the overall group in order to win the game. These simulated skills add to real skills, that players contribute, such as leadership skills, tactical skills, being a fast runner etc.

The player's means for fighting the aliens are tangible objects that act as weapons or tools in the virtual world (see section 2.4). These objects can be bought from a special shop room, using limited monetary resources. The mental energy of each player (player health) is monitored and displayed on the PDA. It is decreased by various forms of alien attacks and when it drops too low the player dies in the game. The game ends with a victory for the players when they have killed or trapped all aliens. Conversely the game is lost the moment the last player dies.

An ever increasing number of aliens of different types (see section 2.5), makes it increasingly difficult for the players to control their opponent, unless they take the right actions. Basically it is more effective for the players to aim for weak points in the alien strategy, instead of just blindly trying to kill them all. Additionally, as soon as the game starts, aliens start to build certain alien structures in the rooms, which aid them and hinder the players in the long term.

Overall, players have to think and act quickly and cooperatively in order to defeat the aliens and win the game. Players are facing an opponent that never rests and is only visible through their equipment, which creates a sense of pressure and paranoia.

2.3 Player Roles

At the beginning of the game, each player chooses one of three roles, which he or she retains during the course of the entire game. These roles determine the various skills and possibilities that a player has during the game. All these roles complement each other, thus players must communicate and coordinate their strategy to benefit from each available skill. Only in this way will they have all of the information about the current situation and the required means to win the game. The different roles are:

- *Scientist* – Of all roles, the scientist is able to collect the most detailed information from PDA scans. Scientist scans provide the exact numbers and – with the right equipment – the types of aliens in a room. In contrast the other roles only get a rough indication of the level of alien presence. Furthermore scientists can detect alien eggs, which are undetectable to the other roles.
- *Technician* – Technicians can install and use the most complex equipment, which is not available to the other roles, such as Toxin Emitters and Snare Traps (see section 2.4). Additionally, they are capable of checking the exact condition of equip-

ment and to perform quick fixes on damaged items. With special equipment a technician can also detect the presence of alien structures, which then can be destroyed.
- *Doctor* – A doctor is significantly less vulnerable to alien attacks, which makes him or her predestined to act in heavily infested areas and to back up the other team members. A Doctor's most significant ability, however, is to perform first aid on other players, restoring their lost health up to a certain degree.

2.4 Equipment

Players can buy or sell equipment at the shop, which is a specially set up room (see Fig.1). This equipment acts as weapons or tools in the virtual world and is the only means of fighting the aliens. Players are provided with a certain amount of starting money and are awarded more by certain achievements in the game. If a player's funds are low, and a specific type of equipment is needed, he or she can also sell owned equipment at a lower price, which is based on the condition of the equipment.

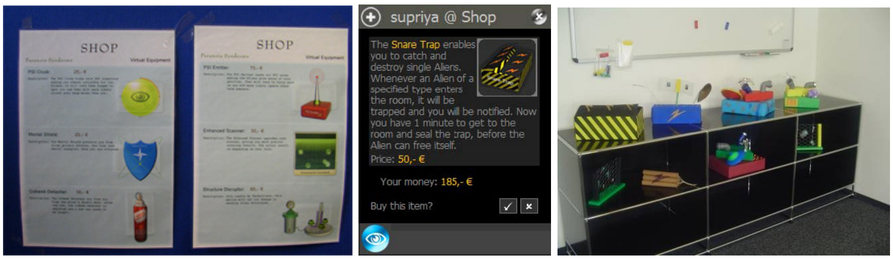


Fig.1. The Shop: posters (left), shopping interface on the PDA (middle), tangible equipment in shop (right)

The types of equipment can be classified in two broad categories:

PDA Equipment. This type of equipment can only be virtually installed on the PDA and has no physical representation. These items can be thought of as extension modules in hard- or software, which are built into the PDA. They are bought at the shop by scanning a poster, which is equipped with RFID tags (see Fig.1, left). The number of extension slots in the PDA is limited, forcing a player to make decisions about what items are most useful in the current game situation. PDA equipment is activated via a menu in the GUI on the PDA.
Among the various types of PDA equipment available are items like the *Enhanced Scanner* for more detailed scans, a *Mental Shield*, for protection against alien attacks, etc.

Tangible Equipment. In order to integrate tangible interfaces into the game, various physical objects have been designed. These objects act as physical representations of virtual weapons, which can be moved around game space. The six different types of tangible objects have been designed using materials like cardboard boxes, plastic pipes, wire mesh, thermacole balls, jute strings, drink cans, etc. The idea was to make the objects look abstract as well as match the name and purpose of the weapon.

Fig. 2. Tangible Equipment

As depicted in Fig. 2, these items are (from left to right):

- *Toxin Emitter* – emits different types of toxin, having a harmful effect on aliens.
- *Alarm Trap* – sounds alarm when the number of aliens nearby exceeds a threshold.
- *Snare Trap* – will trap a specified type of alien for a certain time period.
- *Energy Trap* – is placed near the door to restrict alien access to and from rooms.
- *Bomb* – explodes and destroys everything in a room after the set time expires.
- *Energy Drink* – is consumed by players to temporarily increase their health value.

Tangible Equipment is physically present in the shop, thus it is limited in number. The number of simultaneously usable items is also limited by the physical carrying capacity of the player. Items are bought by a player by going to the shop and scanning an RFID tag on the object. After purchase, players can physically carry the objects between rooms, set functional parameters and activate the objects using a graphical user interface. This interface is displayed on the PDA after scanning the attached RFID tag, after the object has been bought. Objects can also be sold at the shop, where they are repaired, if previously damaged by the aliens.

2.5 Aliens – the Opponent

The aliens are the invisible opponents of the players, simulated by the game server. Their goal to win the game is to (virtually) kill all the players, by reducing their simulated mental health. There are several different types of aliens, each with a specific function for the collective of the alien race, which is organized similar to an insect state. The alien race consists of eggs, terror flies, crawlers, workers and breeders (see Fig. 3), each with an individual simulated behavior:

- *Egg* **–** All aliens hatch from immobile eggs. The hatching time varies for different alien types. Eggs are very hard to detect and immune to traps.
- *Breeder* – The only type of alien that creates offspring. Breeders walk from room to room, laying eggs. They flee most threats and do not attack unless badly hurt.
- *Worker* **–** Builds alien structures with the intention of assisting and fortifying the alien spreading. Workers can also damage and destroy player equipment but cannot harm players themselves.
- *Terror Fly* **–** Small and fast moving soldier type which patrols in search of players. If a player is encountered, it tries to chase him while slowly feeding on the player's mental energy. A player can escape by changing rooms quickly.
- *Crawler* **-** Slow moving but powerful soldier type which can place cobwebs in rooms to ensnare players. The main objective of the Crawler is to protect weaker

aliens and alien structures. If a player enters a room with a Crawler, it will attack after a short time.

Fig. 3. Alien Types: Egg, Breeder, Worker, Terror Fly, and Crawler (left to right)

2.6 Alien AI

The artificial intelligence system used in Paranoia Syndrome is based on probabilities for certain actions, which are determined by the current game state. This creates a balanced, but not strictly deterministic game flow. Each possible action for a given type of alien, in a given situation, has a certain a priori probability of being chosen. This base probability is modified according to certain events or conditions during game play. E.g., the probability of a breeder alien laying an egg is higher than moving to another room or attacking a player. This situation changes, however, when there are many players in the room. In this case the probability of laying an egg decreases and the probabilities of moving to another room (fleeing) or attacking a player (defending the brood) increases. Similar rules are defined for all actions of the other alien types.

Furthermore, alien behavior also depends on their health condition. When badly hurt, they tend to act more defensively and try to reach a safe location (lair). When in good health and in bigger numbers, they act more aggressively putting pressure on the players to control alien spreading.

2.7 Alien Structures

In a way similar to players using their equipment, aliens can place immobile structures in rooms in order to assist their spreading, to harm players and to protect themselves. Most structures are constructed by workers, except traps, which are placed by crawlers. The construction process of structures is rather long (several minutes), which allows players a chance to stop it in time, e.g., by killing the worker. Finished structures can only be destroyed by a Technician with special equipment.

- *Hatchery* **–** Makes eggs hatch faster. Breeders only hatch in rooms with hatcheries.
- *Alien lair* **–** A place where aliens can retreat to heal. All aliens (except eggs) flee to the closest lair when seriously hurt. Aliens in a lair are more resistant to toxins.
- *PSI beacon* **–** A small beacon which gives false scanner readings to the players. Players can scan a room repeatedly in order to detect the random results or ask assistance from a technician with a scanner extension who can detect the beacon.
- *Cobwebs* – Traps which are placed by Crawlers. A player entering a room with a cobweb is ensnared and immobilized until freed by another player. While trapped, the player can still scan the room, but cannot operate tangible equipment.

3 Graphical User Interface

The graphical user interface on the players PDA is a central control entity of the game. It is used for presenting game status, for operating the virtual and tangible devices, to register the player at certain locations and to attack the aliens. The upper part of the screen presents the name and role of the player and provides means for leaving the game. In the bottom of the screen, control elements can be used to activate equipment, to check the budget, to scan for aliens and to monitor the health status. The main display area in the middle changes depending on the respective action during the game play. The device location is tracked (at room-level granularity) by scanning RFID tags placed on the door plates of rooms. Inside rooms the PDAs can be used to scan the tangible objects. In every case, the display will reflect the context change and present a corresponding interface (Fig. 5).

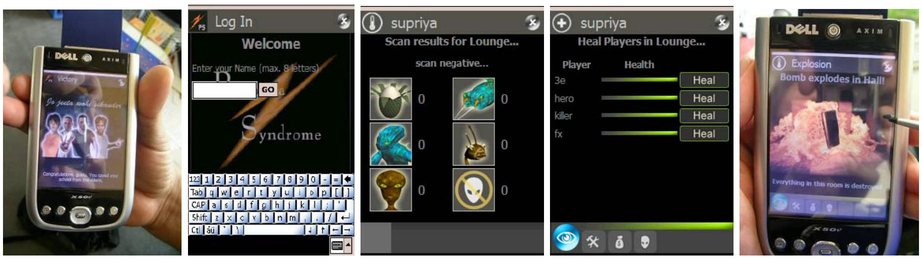


Fig. 4. Welcome Screen, Login, Scanner, Health Status, Bomb Explosion

The interface was constructed as web pages which incorporate various media items; like photos, computer graphics, sound, videos, etc. Several media production tools, like Adobe Photoshop©, Macromedia Flash©, Autodesk 3ds Max© and Combustion© have been used for content development.

4 Technical Infrastructure

Paranoia Syndrome's technical infrastructure of consists of five basic entities (Fig. 6):

- A MySQL database, maintaining the actual state of the game.
- The game simulation engine, which continuously monitors the game state, generates events and writes updates back into the database.
- The web server, which dynamically generates web pages (using PHP), that form the graphical user interface. These are transmitted wirelessly to the PDAs of the players. The pages can also influence the game state, by passing intended player actions as commands in form of HTML variables. The PHP code running on the server checks for these variables on execution and applies changes to the database.
- PDAs (Dell Axim x50v) equipped with RFID Readers in CompactFlash Slots.
- The Aladin platform [1] running on the PDAs. This ubiquitous computing framework is responsible for handling input events from the RFID reader. Detected RFID tag information is passed to the web server via URL parameters. Appropriate

web pages are then generated by the web server and displayed on the PDA by Aladin's integrated OpenNetCF web browser.

The first three entities typically run on a single machine. Via the remote interface of MySQL it is possible to distribute these entities, e.g., due to performance reasons.

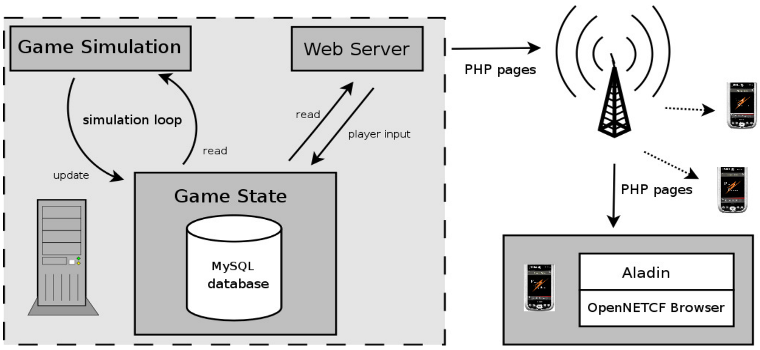


Figure 5: Technical Infrastructure of Paranoia Syndrome

Since HTML is a pull only protocol, a push service was implemented to support immediate information/event forwarding from the server, e.g., alerts, etc. This mechanism, running in JavaScript on the web browser, periodically checks a certain URL for state changes. The requested page is never cached, but is dynamically generated from the database each time it is called. When the game simulation has an event to send to a client, it places an entry in the game database, containing a URL. The JavaScript service checks for this URL and, if present, calls the related page.

Paranoia Syndrome utilizes the Aladin framework [1] for underlying application support. Aladin provides context-aware applications an open service model and flexible plug-in system, which enables framework extensions at runtime. Aladin employs a hybrid approach combining standard web presentation technologies with plug-in-based context detection and interpretation. The underlying software architecture provides two principle abstraction layers allowing an Aladin device to be highly customized. These abstraction layers include: (1) context detection and (2) context interpretation. This overall structure decouples the Aladin runtime from low-level dependencies and allows common functionality, such as plug-in management, state management, error recovery mechanisms and event handling, to be shared between devices.

As game state for Paranoia Syndrome resides outside of the Aladin framework, Aladin is used to provide low-level context information as well as a mechanism for game presentation. For Paranoia Syndrome, the Aladin RFID plug-in was used in conjunction with a specialized context interpretation plug-in which provides context information directly to the web presentation layer in the form of query parameters.

5 Experiences

The Paranoia Syndrome game was played on several occasions using different combinations of ISNM offices and labs as a playing field. As expected, game play involved a high amount of social interaction between players when coordinating their actions. While an emphasis of social interaction is typical for many pervasive games (compared to PC or console based games; cf. e.g., [7]), several aspects of the Paranoia Syndrome game design apparently contributed to particularly high coordination requirements: (1) Cooperation of players with different roles is the only viable strategy for winning the game. (2) A player can only observe the state of his or her alien opponents in one room at a time. Thus, players need to branch out into different locations and communicate their respective information about aliens in the various rooms in order to develop an optimal strategy for game play. And (3), certain actions of the players themselves might be (virtually) dangerous to other players, e.g., detonating a bomb in a room will hurt both aliens and humans in a room. Here again, communication between players becomes a crucial element of game play.

Feedback from players indicated that the overall game idea - fighting an alien invasion by physically moving from room to room while acquiring room information and activating weapons through RFID scans - was well understood by novice players. Some problems were reported concerning the inspection of the weapons' states for which scans of the physical objects' RFID labels are required. Future work could involve the addition of displays or speakers to the tangible objects which would provide players a faster understanding of the weapons' current state during game play; i.e. an evolution from more or less passive tangible objects to "smart toys" [7].

6 Conclusions and Future Work

Paranoia Syndrome is a multi-player, location-based pervasive game that uses PDAs for visualizing a virtual world of aliens who have invaded the physical space in a building environment. Players interact with the game by physically moving from room to room, influencing the game state via a virtual interface on their PDAs and tangible interactions with physical objects.

The relatively simple and inexpensive approach to location tracking and tangible interaction using RFID labels makes the Paranoia Syndrome game highly portable. Future automatic location tracking mechanisms could possibly improve the playing experience by freeing the player from the task of reporting his or her locations actively, leading to a more natural form of interaction. Also the granularity of the playing field could be improved from room-level to sub-sections of rooms, increasing realism and tactical possibilities.

Additional future work may also include strategies for recovering from gaps in wireless LAN coverage. Currently, whenever a player moves out of reach of one access point and into range of another, a delay of a few seconds occurs; disrupting the connection to the game server and factually halting game play for the player. A proactive strategy might be incorporated which establishes new connections in the background; providing seamless WLAN coverage and an improved gaming experience.

Paranoia Syndrome places an emphasis on the social interaction between players; as only a coordinated team effort can lead to a successful outcome of game play. The need for social interaction is increased through the inclusion of various player roles and elements from traditional real-time strategy games as well as players' general uncertainty about the artificially intelligent alien enemies whose actions can only be observed based on the current players' locations. In our opinion, the inclusion of role-playing and artificial intelligence elements represents a next step in the evolution of pervasive gaming; analogous to the advancement of PC and console games from simple instances like Pong and Pacman to today's highly complex gaming experiences.

REFERENCES

1. CARLSON, D.V., Aladin – An Extensible Ubiquitous Computing Infrastructure. Master Thesis, ISNM – International School of New Media, Lübeck, Germany, 2005.
2. CHEOK, A.D.; YANG, X.; YING, Z.Z.; BILLINGHURST, M.; KATO, H., Touch-Space: Mixed Reality Game Space based on Ubiquitous, Tangible, and Social Computing, in Personal and Ubiquitous Computing vol. 6, 2002, pp. 430-442.10.
3. FRUIT SALAD PROJECT, http://www.isnm.de/projects/FruitSalad.html (last visit February 15th, 2006).
4. GUARDIAN ANGEL PROJECT, http://www.isnm.de/ projects/GuardianAngel.html (last visit February 15th, 2006).
5. IPerG – Integrated Project of Pervasive Games. 2004. http://www.pervasive-gaming.org/ (last visit February 15th, 2006).
6. JUNG, B.; SCHRADER, A.; CALSON, D.V., Tangible Interfaces for Pervasive Gaming, in Proceedings of the 2nd International Conference of the Digital Games Research Association. Changing Views: Worlds in Play, Vancouver, British Columbia, Canada, June 16-20, 2005.
7. MAGERKURTH, C.; CHEOK, A.D.; MANDRY, R.L.; NILSEN, T., Pervasive Games: Bringing Computer Entertainment Back to the Real World, in ACM Computers in Entertainment*, vol. 3(3)*, July 2005.
8. MAGERKURTH, C.; MEMISOGLU, M.; ENGELKE, T. and STREITZ, N., Towards the next generation of tabletop gaming experiences, in: ACM International Conference Proceeding Series; Proceedings of the 2004 conference on Graphics interface; London, Ontario, Canada; Pages: 73 – 80.
9. NOKIA Xpress-on™ Fun Shells, http://www.nokia.com/nokia/0,4879,58227,00.html (last visit February 15th, 2006).
10. PERVASIVE'2004 – Workshop: Gaming Applications in Pervasive Computing Environments, Vienna, April 18-23, 2004. http://www.pervasive2004.org/workshops.php#W1 (last visit February 15th, 2006).
11. SONY EyeToy System, Sony Playstation, http://www.eyetoy.com/german/index.html (last visit February 15th, 2006).
12. ULBRICHT, C.; SCHMALSTIEG, D., Tangible Augmented Reality for Computer Games, in Proceedings of the Third IASTED International Conference on Visualization, Imaging and Image Processing 2003, pp. 950-954. See also http://www.cg.tuwien.ac.at/research/publications/2003/Ulbricht-2003-TanX/#BibTeX (last visit February 15th, 2006).
13. ULLMER, B.; ISHII, H., Emerging Frameworks for Tangible User Interfaces, in Human-Computer Interaction in the New Millenium, John M. Carroll (ed.), Addison-Wesley, August 2001, pp. 579-601.

Wanderer - Location Independent GPS-Game

Jonas Hielscher [1,2], Jiri Heitlager [2]

[1] Student at the Media Technology MSc Program, Leiden University, The Netherlands
http://mediatechnology.liacs.nl/
[2] Z25.org Foundation, Utrecht, The Netherlands
http://z25.org
jonas@pixelsix.org, jiri@z25.org

Abstract. Many pervasive game concepts using GPS-technology are developed for predefined locations; they are location based. In this study we present a game concept that uses GPS-technology in a location independent way, called Wanderer. The game uses the real world as a game space and inside this it transforms real objects to obstacles. Because it is not location based the player is free to choose his own game space and thus the difficulty of the game.

1 Introduction

New generations of mobile devices, such as mobile phones, PDA's and portable game consoles are increasingly integrating GPS-technology as an extra feature and making them available for the normal market. These technical developments enable new possible forms of pervasive gaming. With such devices, games can be played everywhere and the real world itself can be easily integrated into the game play or become an integral part of the game environment. Through this development digital games have the possibilities to leave one's private space and enter the public space. By using the real world as a game board, location-aware games [1] make physical objects and physical body movements important elements in digital games.

In this paper we present the GPS-game *Wanderer* to show how the real world can be used as a playground without being dependent on a specific predefined location. The concept is developed such that the game could easily be played with every mobile device equipped with GPS at any location.

2 The GPS-game Wanderer

The concept and partial prototype of *Wanderer* were developed and tested during the Cargo+Posse Mobile GPS GamingWorkshop 2005 [2]. The prototype setup consisted of an Apple iBook computer connected to a Garmin Etrex Legend GPS-device.

2.1 Project Background

During our first tests with the GPS device we recognized the following: while walking through the city with a GPS device we were more focused on the device's display giving us the GPS data then on the physical world surrounding us. Furthermore, the accuracy of the tested device was only about 20 meters corrected to 5 meters (within the city).

To minimize the possible distraction from the real world through visual feedback from the GPS device we decided to develop a game based only on auditory feedback and using the public space as its game space. Because of the limited accuracy of the used device in the city and the intention to build a location independent game, we decided to use only speed and direction as input parameters in our game. This limitation enabled us to develop an intriguing game concept, focusing only on the elements, that seemed relevant to us.

2.2 Related Work

The game concept *Wanderer* was inspired by the game *Dance Dance Revolution* [3] and the urban street sport *Le Parkour* [4].

Dance Dance Revolution is a physical dance game. The game is typically played on a dance pad with four arrow panels: left, down, up, and right. These panels are pressed using the player's feet, in response to arrows that appear on the screen in front of the player. To win the game the player must follow the given commands. The player's control over his body movement and his feeling of rhythm is essential to accomplish the commands. Experienced players often do not only follow the given commands, but combine this with creative dance moves.

Fig. 1. Dance Dance Revolution dance pad

Le Parkour (also called Parkour, PK, l'art du déplacement, free-running) is a physical discipline founded by David Belle. Practitioners of *Parkour* (called traceurs) try to get from one point in a city to another in a straight line. The goal of practicing *Le Parkour* is to be able to adapt one's movements to any given scenario so that any obstacle can be overcome with the human body's abilities (J. Lebret [4]).

Fig. 2. picture of traceurs jumping over a fence in order to follow his parkour

In the game *Wanderer* we combined the elements of both game activities. Like in the game *Dance Dance Revolution* the player gets commands for his movements. The commands must be followed by moving through the real space and overcoming possible obstacles like in *Le Parkour.*

2.3 The Game Concept

The GPS game *Wanderer* is played outdoor and can be played anywhere where a GPS signal is received. The objective of the game is to be in continuous motion. The player is not allowed to move slower or faster than a given speed range (about 3-4 km/h). The player receives auditory feedback on whether or not s/he is moving too fast/slow. Furthermore, the player must respond to auditory signals provided through a headphone connected to the game system. The auditory signals are commands such as “Go left!”, “Go right!” or “Turn around and go back!”. The commands are only triggered when the player’s speed is within the specified speed range. After an audio command, the player has a certain number of seconds to respond correctly to the command. In this reaction period the player could be confronted with physical objects that make it impossible for her/him to comply to the command (Fig. 3). The player is then challenged to search for a place in her/his surroundings where s/he can execute the command and gain a credit. If s/he fails to do so, a credit is lost. When the player has no more credits the game ends. Because the game is not mapped onto the physical space (it has no notion of where it is), it can be played in any location. Playing *Wanderer,* the player is continuously confronted with objects in public space, thus transforming physical objects in public space into objects that are part of the game space.

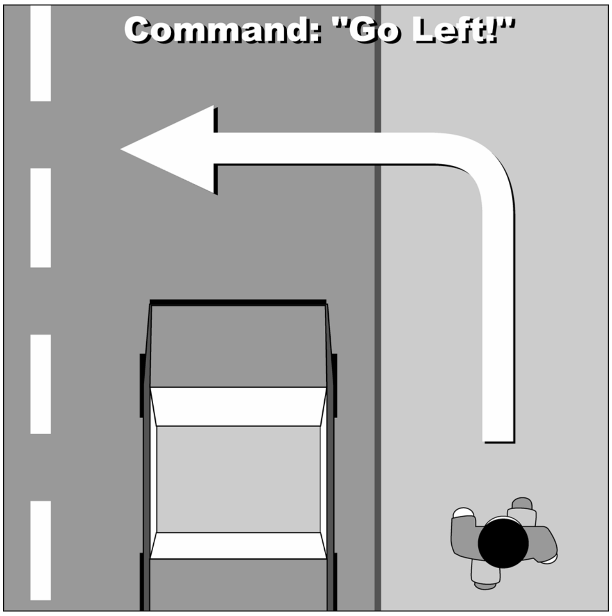


Fig. 3. The player gets the command “Go left!”. Because a parked car blocks his way, he first has to run forward and then to the left. If he fails to do this within the given time limitation one credit is lost. This example shows how real objects becomes obstacles in the game space

2.3 Initial Testing

For the first tests the developed prototype was suitable, but for further research a smaller hardware setup is preferable. Instead of using a GPS device with a laptop computer, a small GPS hand-held device would give more flexibility. Nevertheless during the tests with the first prototype some results could be concluded. Primarily, the game is pervasive. During the tests the players where highly motivated to follow the commands given by the game even when the environment was not allowing the player to perform the instructed movements. For example, players crossed streets, even with cars approaching that were forced to stop in order not to hit the player. During this example the players made it clear that they were not unaware of the environment, but were willing to force the environment in order to keep playing the game.

3 Discussion

Location-aware games such as *Wanderer*, played outdoor in public space, confront the player’s in-game desires with elements of the real world. The game space, the so called magic circle as defined by Dutch historian Johan Huizinga [5] is now interfered by real consequences. In location-aware games the game space is mixed with elements of the real world. The player has to consider not only the in-game consequences, but also the consequences of his/her actions in the real world.

The question arises, how far a player would go by playing a game in public space? Will players respect common norms and rules within public space in the same way as they respect them while not playing?

Playing in public touches also another interesting matter, namely the relationship between a player and the audience in public space. Does a player's game play change when his/her actions are being observed? Does the awareness of being watched change the player’s performance? All these questions arise through the phenomena of mixing the game world with the real and serious world in pervasive gaming. These matters of mixing realities are further discussed by Jane McGonigal [6], in her work about immersive and pervasive gaming:

“A good immersive game will show you game patterns in non-game places; these patterns reveal opportunities for interaction and intervention. The more a player chooses to believe, the more (and more interesting) opportunities are revealed. In conclusion, I choose not to see pervasive players’ performed belief as a kind of paranoia or dangerous credulity, but rather as a conscious decision to prolong the pleasures of the play experience and to apply the skills acquired in gaming to real life. [6]*”*

4 Conclusion

With the game Wanderer, we demonstrated a possible way to use GPS technology to create a game without being dependent on a specific predefined location. By concentrating on limited technical elements (only using speed and direction of the GPS output), we came up with a simple but intriguing game concept that could easily be played on most mobile devices with GPS and in nearly any urban environment. By discussing the first small test results, already some interesting questions were raised about the effects of playing pervasive games in public space.

5 Acknowledgements

Thanks to Maarten Lamers of Leiden University’s Institute of Advanced Computer Science (LIACS) for commenting on a draft version of this paper, and we would like to thank the initiators of the Cargo + Posse Workshop.

References

1. Magerkurth, C., Cheok, A.D, Mandryk, R.L., Nilsen, T., Pervasive Games: Bringing Computer Entertainment Back to the Real World, ACM Computers in Entertainment, 3(3), July 2005, Available at: http://pergames.de/PervasiveGames_CIE.pdf
2. Cargo + Posse Mobile GPS Gaming Workshop, September 2005, Oostende. http://posse.scout.becoming.be/
3. Konami of America – Dance Dance Revolution.
4. Lebret, J., Parkour: More than an art - a way of life!, Parkour.NET
5. Huizinga, J., Homo Ludens, The Beacon Press, Boston, 1955
6. McGonigal, J., A Real Little Game: The Performance of Belief in Pervasive Play, Digital Games Research Associaton (DiGRA) "Level Up" Conference, November 2003 Available at: http://www.avantgame.com/writings.htm

Pervasive GameFlow: Understanding Player enjoyment in Pervasive Gaming

Kalle Jegers

Dept of Informatics, Umeå University, 90751 Umeå, Sweden
kalle.jegers@informatik.umu.se

Abstract. Player enjoyment is perhaps the most important issue in successful game design, but is previously not addressed in the area of Pervasive games. Departing from the GameFlow model of player enjoyment in computer gaming, this paper presents an initial outline for a new model of Pervasive player enjoyment- the Pervasive GameFlow model. The suggested model is described and discussed in terms of additions and elaborations in relation to the GameFlow model, and is intended to serve as a departing point for further empirical studies of player enjoyment in Pervasive games.

1 Introduction

Understanding what makes the players enjoy a game is perhaps the most important issue in successful computer game design. The importance is specifically highlighted in the relatively new and evolving area of Pervasive games. In order to successfully survive and transform into a mass-market phenomenon, commercial Pervasive games needs to be designed on a solid foundation of knowledge considering what makes people enjoy this unique type of games. From a research perspective, an understanding of how to approach player enjoyment enriches evaluation in studies of experimental Pervasive game prototypes and concepts. Further, understanding player enjoyment in Pervasive games allows for understanding user experiences derived from use of Pervasive technology in general, which is of great importance as Pervasive computing eventually becomes an everyday phenomenon. In Pervasive gaming literature, we find related work on technological, software architectural and social/contextual dimensions of Pervasive gaming (e.g. [1], [2], [3], [7], [8], [9]) but none of the related studies addresses player enjoyment explicitly. We may therefore conclude that there is a need for studies establishing a model for understanding player enjoyment in Pervasive games. Recently, the GameFlow model [10] has been introduced for understanding player enjoyment in traditional computer gaming. In this paper, the GameFlow model is evaluated in relation to Pervasive games. The purposes of this paper is to conceptually and theoretically analyze and elaborate the GameFlow model in terms of applicability in the case of Pervasive gaming, and to present an initial model of Pervasive player enjoyment.

2 GameFlow

The concept of Playability, or the Usability of Computer games (c.f. [5], [6]) provides an approach to understand the factors of importance when designing and evaluating computer games. Within the concept, the three main aspects of interface, mechanics and gameplay are central, and are manifested in various kinds of heuristics and frameworks. These central aspects are of great importance for a successful game design, but seem to be somewhat focused towards the software system of the game and the overall player-game interaction performed in gaming sessions, and not specifically on aspects of player enjoyment. The GameFlow model [10], however, presents a framework that specifically addresses player enjoyment in computer gaming and therefore seems like a very promising approach to understand player enjoyment in Pervasive gaming as well. GameFlow [10] is based on two integrated cornerstones: the theory of Flow [4] and criteria from computer games usability and user-experience literature (for the complete list of sources, see [10]). In short, the Flow theory [4] describes the fundamentals of an optimal experience of enjoyment, which according to Csikszentmihalyi is general throughout contexts and cultures the world over and independent of particular tasks or activities. An experience of flow consists of eight elements: a task that can be completed, the ability to concentrate on the task, that concentration is possible because the task has clear goals, that concentration is possible because the task provides immediate feedback, the ability to exercise a sense of control over actions, a deep but effortless involvement that removes awareness of the frustrations of everyday life, concern for self disappears but sense of self emerges stronger afterwards, the sense of the duration of time is altered. The GameFlow model consists of eight core elements (derived from the computer games literature), which in turn consists of varying number of criteria that relate to the elements of flow. The core elements are: concentration, challenge, skills, control, clear goals, feedback, immersion and social. For a complete overview of GameFlow, see [10]. The foundation of the model (with suggested additions) could also be found in Table 1 in this paper.

3 Adding the Pervasive Dimension

In order to analyze the GameFlow model in relation to Pervasive games, we need to highlight some distinguishing characteristics and features of Pervasive games, previously not anticipated by the GameFlow model. Considering experimental prototypes and studies in related work (see for instance [1], [2], [3], [9]), we may notice three major characteristics that in various extents are present in Pervasive games. The characteristics are: mobile/place independent game play, social interaction between players and integration of the physical and the virtual world.

3.1 Mobile/place independent game play

The place independency of Pervasive games implies that computer gaming now may be pursued not only in relatively stable contexts of desktop computers, game consoles and arcade halls, but in potentially all possible contexts of everyday life. Drawing on integrated platforms of mobile and desktop computing technology, Pervasive games have the potential to implement game designs allowing the player to access the game in virtually all everyday contexts and environments, at all times. Instead of isolating game play to specific environments and limited sessions, as in the case with PC and console games, Pervasive games allows for greater degrees of freedom and new kinds of playing behaviour often characterized as anytime, anywhere gaming.

3.2 Social Interaction between players

Instead of providing challenges and experiences through various AI and pre-programmed scenarios, Pervasive games often make use of the players. Drawing on massively multiplayer solutions or small-scale interaction between few players, Pervasive games often puts the social interaction between players at the core of the game play. By presenting the player community with some kind of overall goal(s) and some tools for interaction and then leaving the field open, Pervasive games make use of driving forces related to social factors and the creativity of the player community, instead of presenting the players with fixed scenarios.

3.3 Integration of Physical and Virtual Worlds

A common feature of Pervasive games, previously not implemented in computer gaming, is to integrate the physical world with the virtual world when creating the game world. By placing virtual objects at physical locations or by enhancing physical locations with information presented in the virtual world, Pervasive games expands the use of both the physical and the virtual in game design. Traditional computer games have a clear focus on the virtual world, as they build their game worlds almost exclusively on the virtual dimension.

4. From GameFlow to Pervasive GameFlow

In this section, the GameFlow model is extended to include and counter for the specific aspects of modern computer gaming implied by Pervasive games. Emphasis will be on identifying parts, elements and criteria of the GameFlow model that may be problematic or needs to be elaborated. The discussions and elaborations will be presented in a structure following the elements of the GameFlow model (see [10] or Table 1, for an overview of the elements and criteria. Note that Table 1 also includes additional elements and proposed changes to the framework).

4.1 Concentration and Challenge

Instead of suggesting total elimination of surrounding factors in favour for the gaming task, a Pervasive game should support the player in the process of switching concentration between in-game tasks and surrounding factors of importance. Two of the GameFlow criteria, *players should not be distracted from tasks that they want or need to concentrate on* and *games should quickly grab the players' attention and maintain their focus throughout the game* could however be considered to be somewhat problematic in relation to the vision of anytime, anywhere gaming (place/time independent game play), which Pervasive gaming upholds. The GameFlow model implies that *"during play, distractions from major game tasks should be minimized by reducing nongame-related interactions and reducing the game interface to maximize the amount of screen taken up with game action"* (Johnson & Wiles, 2003 in [10]). This is valid for traditional gaming contexts, where the player is seated in front of a desktop computer or a console, but becomes rather problematic when the usage situation and context could be virtually any everyday life context as suggested by Pervasive games. Some of the everyday context distractions (e.g. alerts from surrounding traffic or obstructing everyday objects such as fences or icy sidewalks) are of much greater importance than any part of a gaming experience, and needs to be monitored by the player even when playing a Pervasive game. In the GameFlow model, two criteria for the challenge element need to be elaborated in order for the element to suit Pervasive gaming better. According to GameFlow, *the level of challenge should increase as the player progresses through the game…* and *the game should provide new challenges at an appropriate pace.* Further elaborated, *"games should present the players with an appropriate series of distinct and challenging situations (Smith, 1999) that are calculated from careful level and obstacle design (Pagulayan et al. 2003)"* [10]. These criteria becomes rather problematic considering how the Pervasive gaming vision implies social interaction between players as the most important driving force in the game play. When the development of a game and a game scenario becomes user driven, as intended in the Pervasive gaming vision, the community of players will be in charge of the game world. In this case, the role of the game designers will be to provide the players with appropriate support for developing and managing their own experiences of game play. In this situation, pre-programmed scenarios, levels, obstacles and pacing become rather subordinated in relation to the Pervasive gaming vision of social interaction between players. Instead of controlling the pace and level of challenge presented to the player, Pervasive games should stimulate and support the players in their own creation of game scenarios and pacing. Pervasive games should help the players in keeping a balance in the creation of paths and developments in the game world, but not put too much control or constraints on the pacing and challenge evolving.

4.3 Player Skills and Control

The player skills element seems unproblematic and relevant from a Pervasive gaming perspective. However, one criterion considering the development of player skills, *games should increase the players' skills at an appropriate pace as they progress* *through the game*, needs to be somewhat elaborated in line with the discussion performed around the Challenge element (see above). When the progress in the game is player driven, the game should be very flexible and enable the player skills to be developed in a pace set by the players, rather than presenting the players with a fixed and pre-programmed structure for skills development. The element of control presents some criteria that need to be adjusted in order to suit Pervasive games. The criterion *players should feel a sense of control over the game shell (starting, stopping, saving etc.)*, becomes rather problematic in respect to the Pervasive gaming vision of place/time independent game play and the constantly ongoing games this implies. The elaboration of the criterion gives that "[the players should be allowed to] *turn the game on and off (Desurvire et al. 2004) and save the game in different states. These capabilities give players control over the game shell and the freedom to explore the game at their own pace (Federoff, 2002)"* [10]. The features implied by these recommendations would be rather problematic to pursue in a Pervasive game that make use of the place/time independent game play part of the Pervasive gaming vision. Instead of offering the traditional shell control, Pervasive games should enable the players to easily pick up game play in a constantly ongoing game and quickly get a picture of the current status in the game world (in order to assess how the state of the game has evolved since the player last visited the game world).

4.5 Feedback and Clear Goals

The feedback element of the framework seems rather unproblematic from a Pervasive gaming perspective, and is currently not in need of further elaboration. The criterion *intermediate goals should be clear and presented at appropriate times* could be somewhat problematic, since it is depending on a preset and controlled structure for the game narrative. When the vision of social interaction as driving force is used in a Pervasive game, the role of the game changes into supporting the players in creation of their personal intermediate goals. These personal goals could also be shared among a group of players within the frames of social interaction, which the game then needs to support. Therefore, a Pervasive game should support the players in forming and communicating their own intermediate goals.

4.7 Immersion and Social Interaction

The criterion *players should become less aware of their surroundings* becomes rather interesting to discuss from a Pervasive gaming perspective. Elaborating the criteria, the GameFlow model states that "*games are often seen as a form of escape from the real world or social norms, or as a way to do things that people otherwise lack the skills, resources or social permission to do (Lazzaro, 2004)"* [10]. The immersion referred to in the criterion is mostly occurring in traditional HCI usage contexts, where a player sits in front of a desktop computer or a console in a private environment and context. In this case, the interface of the game is limited to the game screen and controls and the game world is upheld solely on the computer/console screen. The player must ideally focus completely on what happens on the screen, in order to be immersed in the game world. When the game world changes from being completely virtual to incorporate physical world settings, such as streets, parks, diners, town centres etc. the kind of immersion referred to by the GameFlow model becomes rather difficult to support. Since the player might be moving around physically to move in the virtual game world, the focus will constantly shift between the virtual and the physical, and when the surroundings actually becomes an important part of the game world, it becomes important that the player keep track of them. Second, the escape from real world social norms, which the lost awareness of the surroundings supports, becomes very different in the case of Pervasive gaming. The virtual world upheld by the computer or console is, in the traditional case of computer gaming, clearly separated from the everyday world and contexts, which makes the escape from social norms and other shortcomings possible and convincing. Considering a Pervasive game that mixes the physical and the virtual worlds in a composite way and enables anytime, anywhere game play, the everyday social norms and the game world in some cases becomes rather difficult to separate. The player of such a Pervasive game will have to move between different social contexts present in the everyday world in order to play the Pervasive game. By necessity, the player must therefore take into consideration and focus on not only the social world and norms upheld by the virtual parts of the game world, but also those present in the everyday world. An unexpected and incorrect action performed in a public space will always be violating the current norm system in that space, even if it is a product of following the norms of the Pervasive game. This mix of "real" everyday social norms and rules, and the rules produced by the game world needs to be in perfect fit in order to support the integration between physical and virtual worlds. Pervasive games should therefore support a seamless transition between different everyday contexts, and not imply or require player actions that might result in a violation of social norms in everyday contexts. Further, Pervasive games should enable the player to shift focus between the virtual and physical parts of the game world without losing too much of the feeling of immersion. The GameFlow criteria considering social interaction are all very general and are in some way or another applicable on most computer games. Considering the elaborations of the criteria, however, it becomes obvious that they are too limited to grasp the full complexity of using social interaction as the driving force in game play, which the Pervasive gaming vision implies. According to the GameFlow elaborations, games *"should create opportunities for player competition, cooperation and connection"* (Lazzaro 2004; Pagulayan et al. 2003, in [10]) and further that "*game should support social interactions through chat and online boards"* (Lazzaro, 2004 in [10]). To summarize the elaborations performed in the GameFlow model, we may conclude that the criteria are either too general to really say something about social interaction as the driving force in the game play (or something about what would constitute good quality of social interaction), or focused on aspects outside the actual game system. In order to better suit the vision of Pervasive games, the criteria should be refined and more focused on the quality and purpose of social interaction in the gaming context. A Pervasive game should support and enable possibilities for game oriented, meaningful and purposeful social interaction within the gaming system. The games should not only uphold features for communication between players, but should also incorporate triggers and structures (e.g. quests and events, factions, guilds or gangs) that motivate the players to communicate and interact socially.

5 Pervasive GameFlow

Below, the result from the discussions performed in the previous section is summarized in a table, describing the suggested outline for a model of player enjoyment in Pervasive games- Pervasive GameFlow. Some of the criteria formulated in the original GameFlow model have been excluded in the Pervasive GameFlow model as a result of the evaluation presented above. Other criteria have been reformulated and finally, some new criteria have been included as a result of the evaluation. The reformulated and additional criteria are presented in *italic* in the model below.

Table 1: The Pervasive player enjoyment model- Pervasive GameFlow

Element	Criteria
Concentration Games should require concentration and the player should be able to concentrate on the game	- Games should provide a lot of stimuli from different sources - Games must provide stimuli that are worth attending to - Games should quickly grab the players' attention and maintain their focus throughout the game - Players shouldn't be burdened with tasks that don't feel important - Games should have a high workload while still being appropriate for the players' perceptual, cognitive and memory limits -Players should not be distracted from tasks that they want or need to concentrate on *- Pervasive games should support the player in the process of switching concentration between in-game tasks and surrounding factors of importance*
Challenge Games should be sufficiently challenging and match the player's skill level	- Challenges in games must match the players' skill levels - Games should provide different levels of challenge for different players - The level of challenge should increase as the player progresses through the game and increases their skill level - Games should provide new challenges at an appropriate pace *- Pervasive games should stimulate and support the players in their own creation of game scenarios and pacing* *- Pervasive games should help the players in keeping a balance in the creation of paths and developments in the game world, but not put too much control or constraints on the pacing and challenge evolving*
Player skills Games must support player skill development and mastery	- Players should be able to start playing the game without reading the manual - Learning the game should not be boring, but be part of the fun - Games should include online help so players don't need to exit the game - Players should be taught to play the game through tutorials or initial levels that feel like playing the game - Games should increase the players' skills at an appropriate pace as they progress through the game - Players should be rewarded appropriately for their effort and skill development - Game interfaces and mechanics should be easy to learn and use *- Pervasive games should be very flexible and enable the players' skills to be developed in a pace set by the players*

Control Players should feel a sense of control over their actions in the game	- Players should feel a sense of control over their characters or units and their movements and interactions in the game world - Players should feel a sense of control over the game interface and input devices - Players should feel a sense of control over the game shell (starting, stopping, saving, etc.) - Players should not be able to make errors that are detrimental to the game and should be supported in recovering from errors - Players should feel a sense of control and impact onto the game world (like their actions matter and they are shaping the game world) - Players should feel a sense of control over the actions that they take and the strategies that they use and that they are free to play the game the way that they want (not simply discovering actions and strategies planned by the game developers) *- Pervasive games should enable the players to easily pick up game play in a constantly ongoing game and quickly get a picture of the current status in the game world (in order to assess how the state of the game has evolved since the player last visited the game world)*
Clear goals Games should provide the player with clear goals at appropriate times	- Overriding goals should be clear and presented early - Intermediate goals should be clear and presented at appropriate times *- Pervasive games should support the players in forming and communicating their own intermediate goals*
Feedback Players must receive appropriate feedback at appropriate times	- Players should receive feedback on progress toward their goals - Players should receive immediate feedback on their actions - Players should always know their status or score
Immersion Players should experience deep but effortless involvement in the game	- Players should become less aware of their surroundings - Players should become less self-aware and less worried about everyday life or self - Players should experience an altered sense of time - Players should feel emotionally involved in the game - Players should feel viscerally involved in the game *- Pervasive games should support a seamless transition between different everyday contexts, and not imply or require player actions that might result in a violation of social norms in everyday contexts* *- Pervasive games should enable the player to shift focus between the virtual and physical parts of the game world without losing too much of the feeling of immersion*
Social Interaction Games should support and create opportunities for social interaction	- Games should support competition and cooperation between players - Games should support social interaction between players (chat, etc.) - Games should support social communities inside and outside the game *- Pervasive games should support and enable possibilities for game oriented, meaningful and purposeful social interaction within the gaming system* *- Pervasive games should incorporate triggers and structures (e.g. quests and events, factions, guilds or gangs) that motivate the players to communicate and interact socially*

6 Conclusions and Future Work

From the theoretical/conceptual analysis of the GameFlow model, we may conclude that the model seems promising and suitable for understanding player enjoyment in Pervasive games. In order to better capture the specific implications from Pervasive games, some additions, changes and elaborations were suggested on basis of the Pervasive gaming vision, resulting in an outline for a new model for player enjoyment in pervasive games- the Pervasive GameFlow model. The suggested model now needs to be empirically validated. Future work may include user-centered evaluation of various Pervasive games using the Pervasive GameFlow model, in order to verify the model and identify further elaborations and extensions needed.

7 References

1. Benford, S., Magerkurth, C., Ljungstrand, P. (2005) Bridging the Physical and Digital in Pervasive Gaming. In Communications of the ACM, March 2005, vol. 48. No. 3.
2. Björk, S., Holopainen, J., Ljungstrand, P., Åkesson, K-P. (2002) Designing Ubiquitous Computer Games- A Report from a Workshop Exploring Ubiquitous Computing Entertainment. In Personal and Ubiquitous Computing (2002), 6:443-458.
3. Cheok, A. D., Yang, X., Ying, Z. Z., Billinghurst, M., Kato, H. (2002) Touch-Space: Mixed Reality Game Space Based on Ubiquitous, Tangible, and Social Computing. In Personal and Ubiquitous Computing (2002), 6: 430-442.
4. Csikszentmihalyi, M. (1990) Flow: The Psychology of Optimal Experience. Harper Perennial, New York.
5. Desuvire, H., Caplan, M., Toth, J., A., (2004) Using Heuristics to Evaluate the Playability of Games. Late breaking results paper, in Proceedings of ACM CHI 2004, Vienna, Austria.
6. Federoff, M. (2003) Improving Games with User Testing: Getting Better Data Earlier. In Game Developer's Magazine, June 2003.
7. Flintham, M., Anastasi, R., Benford, S., Drozd, A., Mathrick, J., Rowland, D., Oldroyd, A., Sutton, J., Tandavanitj, N., Adams, M., Row-Farr, J. (2003) Uncle Roy All Around You: Mixing Games and Theatre on the City Streets. In the Level Up conference proceedings, Utrecht, Nederlands, 2003.
8. Magerkurth, C., Engelke, T., Memisoglu, M. (2004) Augmenting the Virtual Domain with Physical and Social Elements: Towards a Paradigm Shift in Computer Entertainment Technology. In ACM Computers in Entertainment, Vol. 2, No. 4, October 2004.
9. Manninen, T. (2002) Contextual Virtual Interaction as Part of Ubiquitous Game Design and Development. In Personal and Ubiquitous Computing (2002), 6:390-406.
10. Sweetser, P., Wyeth, P. (2005) GameFlow: A Model for Evaluating Player Enjoyment in Games. In ACM Computers in Entertainment, vol. 3, No. 3, July 2005.

Systematically Exploring the Design Space of Location-based Games

Peter Kiefer, Sebastian Matyas and Christoph Schlieder[1]

[1] Laboratory for Semantic Information Technologies
Otto-Friedrich-University Bamberg
96045 Bamberg, Germany

{peter.kiefer, sebastian.matyas,
christoph.schlieder}@wiai.uni-bamberg.de

Abstract. With the rapid integration of mobile devices and localization technologies like GPS in our every day life, the interest for using combined technologies for entertainment is also growing. This is the idea of location-based games, which take use of localization technology and integrate the player's position into their game concept to generate a pervasive game experience. For this class of games we provide a systemization method not solely based on the technological dimension but also from the game conceptual and spatial-temporal dimension. The systematization is further used to derive a game design method which utilizes these three game design dimensions. By variation of the parameter values in these dimensions new location-based games can be designed. As an example our proposed method is illustrated with an existing location-based game, GeoTicTacToe.

1 Introduction

The integration of localization technology into mobile devices, like PDAs, cell phones or smartphones, is one of the current trends in the mobile market. Location-based services, especially navigation systems, have found their way into everyday life. Another area with increasing market share is mobile gaming, allowing people to play their favorite games on their mobile devices wherever and whenever they want.

The combination of these two areas – games played on mobile devices using localization technology – can generate true pervasive game experiences and is called *location-based gaming.* This kind of gaming is still in its infancy and its success has so far rather been a scientific than a commercial one. Location-based games were successfully used for research on the principles of pervasive computing and as use cases for upcoming technologies, like augmented reality (e.g. ARQuake, Thomas et al. 2000). Although technology was (and still is) the driving force for the emergence of such games, and although high-end devices can significantly enhance the pleasure of gaming, the commercial success of a game not only depends on how a game is played, but also on what the game is about.

In this paper we intend to show that location-based games are of interest not only from a technician's perspective, but also from a game designer's point of view. We provide a new systematization of location-based games, which is, in contrast to previous systematizations of pervasive games (e.g. Magerkurth et al., 2005), not exclusively technology oriented. We identify three orthogonal dimensions spanning the game design space for location-based games. Finally, we show how to use our systematization for the design of new location-based games by varying an existing one.
While plenty of work on game design for traditional computer games exists (e.g. Salen and Zimmermann 2003), and while even some authors consider game design for mobile games (e.g. Davidsson et al. 2004), the conceptual design of location-based games has not received much attention so far. The integration of position and movement into the game concept offers a variety of new possibilities which go by far beyond the typical conversion-from-computer-game type often found for mobile games. Until now most authors have designed their games by intuition with trial and error (Björk et al. 2002). Another approach is the use of metaphors, like the Geogames framework (Schlieder et al. 2005a) which builds on the idea of mapping classic board games to geographic space. On the one hand, design by metaphors is more systematic than design by intuition, but on the other hand it stays limited to a certain subset of location-based games. The Geogames framework, for example, describes only the class of location-based games which has common elements with classic board games.

The rest of this paper is structured as follows: Section 2 reviews seven typical location-based games found in literature or on the market. We introduce three design dimensions in section 3 and categorize those games along these dimensions. In section 4 the design by variation game design method is illustrated on an example game. In the last section we discuss related work on game design and give an insight on future research issues.

2 Examples of Location-based Games

In order to obtain the dimensions critical for the design of location-based games, we systematically explore the design space of an undoubtedly incomplete list of games. We will consider location-based games played in a research context as well as commercial games. Unfortunately, we lack the space to give a complete overview on all the location-based games we analyzed at this point. We therefore will pick some of the most prominent examples with the goal to illustrate the broad spectrum of different design ideas.

Geocaching, one of the oldest and probably the widest known location-based games, is played by single players who try to find treasures (usually boxes with little gimmicks in it) hidden at certain geographic positions in the real world, called "caches". A player may trade one gimmick from the box with one he or she has brought along. The coordinates of caches are provided by a large web-based community. Due to the inaccuracy of satellite navigation, the task of the game is not only GPS navigation, but also a detailed search in the surroundings of a coordinate.

In *Can You See Me Now (CYSMN)* (Flintham et al., 2003a) from Blast Theory Studios, online players are chased by street players. The former ones play CYSMN on a normal personal computer, while the latter ones are moving in the real world using PDAs and connected GPS receivers. The street runners play collaboratively to catch the online players. Their position is projected on the computer screen on which the online players experience and play the game. On the other hand, the street players can observe the state of the game on a map displayed on their PDA. When the position of a street player is identical to that of an online player, the street player has successfully caught his adversary.

Uncle Roy All Around You (Flintham et al., 2003b), also from Blast Theory, lets a street player work collaboratively with an online player to look for the office of Uncle Roy. To find this building in a real environment, the online player poses the street player different tasks (or puzzles) leading him or her step by step closer to Uncle Roy.

GeoTicTacToe and *CityPoker* (see Schlieder et al. 2005a, Schlieder 2005b) combine the strategic appeal of traditional board games with the physical effort found in sportive activity like a hundred meter sprint. The first game is a location-based variant of Tic Tac Toe, a game where two players try to set three markers, X or O, in a diagonal, horizontal or vertical line. *CityPoker* lets the players search and exchange their poker cards in the physical world competing for the best final poker hand.

Human Pacman, realised by Choek et al. (2004), is a straightforward port of the classical arcade game Pacman. Players either play the role of Pacman or that of the ghosts. The latter ones try to catch Pacman who in return struggles to collect all virtual cookies distributed on the real world game board. When Pacman eats special items at specific locations, he turns from hunted to hunting and may eat the ghosts as soon as he is at the same position – just like in the original arcade game.

Journey I and II, designed for a term paper by Jakl (2004), is a single player adventure game. To proceed in the classical storyline of three acts, players have to move in the physical world. They enter a new chapter of this crime thriller as soon as a certain position change has been detected.

3 Game Design Dimensions

In the following we will explain the dimensions we identified to classify location-based games. Each dimension is scaled nominally and the dimensions are orthogonal to each other, so in principle each combination of values is possible, although not for all combinations examples of games exist yet.

3.1 Dimension of game environmental embedding

This dimension deals with the way the game world is embedded in the player's environment. We distinguish the classes *pure location-based games (LBG)*, *mixed reality location-based games (MR)* and *augmented reality location-based games (AR)*. Although there more or less exists a common understanding in the community about the meaning of these three classes, it is hard to find precise definitions, especially for location-based games. For the extraction of common properties of location-based games, we found the following definition to be sensible:

Def.: A *location-based game* is a game which is supported by localization technology and integrates the position of (one or several) players as main game element into its rules.

This general definition of a location-based game is based upon the two criterions *technology* and *game rules*, whereas none of these criterions alone would suffice to constitute a location-based game. For instance, in soccer the players' positions obviously play an important role, but soccer is no location-based game, for it is not supported by localization technology. On the other hand, a mobile gambling game which adopts its availability or billing conditions to the legal context of the federal state (or country) where the player is currently located cannot be regarded as being location-based, because the gambling itself does not use the position in its rules. To clarify the second criterion, we can say that in location-based games the rules induce the necessity of moving to a certain location in a real world environment, which may be an absolute position (e.g. GPS coordinate) or a relative position (relative to the current location or relative to another player).

Def.: *Mixed reality location-based games* add a virtual game layer to the real world, which is embedded through cognitive reasoning.

The markers X or O a player drops in *GeoTicTacToe*, for example, are only virtual game objects and have no physical equivalent. The same is the case for Human Pacman, with the virtual cookie objects (the player does not physically eat cookies, although a variant with real bakery would probably be interesting, see Choek 2004), or for CYSMN where the online players' avatars have no physical counterparts in the game environment.

Most of nowadays' location-based games fall into the class of mixed reality location-based games, e.g. *CYSMN, Uncle Roy All Around You, GeoTicTacToe, CityPoker* and *Journey I/II*. *Geocaching* with the physical gimmicks, as a counter-example, is not a mixed-reality location-based game and would therefore be classified as a pure location-based game. The mapping of the virtual layer to the physical world in a mixed reality location-based game is achieved through reasoning and imagination. Cognitive assistance may be provided, e.g. by using a PDA screen like in *CYSMN*.

Def.: *Augmented-reality location-based games* are a real subset of mixed-reality location-based games, but here the game environmental embedding is experienced perceptually from a first-person perspective.

In other words, the mapping of the virtual layer to the physical world is not done by the player's imagination, but has to be solved by the mobile device. One typical issue arising in this context is the head tracking problem. From a technological point of view, augmented-reality games require high-level hardware support, e.g. head-mounted displays. A prominent example for an augmented-reality location-based game is *Human Pacman* (Choek, 2004).

3.2 Game Conceptual dimension

Game concepts in our perspective are more specific than the commonly used game genres established for pc or console games (e.g. adventure, first-person shooter) and more general than game design patterns (Björk, 2003; Davidsson, 2004). We describe a game concept by the abilities a player must have and the tasks he or she must solve for winning the game. From our collection of analyzed games, of which section 2 only shows the prominent representatives, we derive the following game concepts. A location-based game can be instance of one or several of these game concepts.

Chase game: A location-based game incorporating this game concept requires players to have superior physical abilities for winning. In *CYSMN*, for example, players win by being fast.

Item hunt game: This game concept embeds a search for items hidden in the natural surroundings on the game board, e.g. a box under some bushes. The most prominent example is certainly *Geocaching*.

Puzzle game: Instances of this game concept are won by solving puzzles. These puzzles range from simple knowledge questions ("Who is buried in the cathedral in front of you?") to complex story lines like found in adventure games. An example for a puzzle game is *Uncle Roy All Around You* or the *Journey series*.

Strategy game: This type of game is won by superior planning capabilities. In *CityPoker*, for example, a player needs to plan his own actions to reach a good poker hand, while at the same time trying to cross the other player's plans.

3.3 Spatial and temporal dimension

This dimension describes a game in terms of when and where the actions relevant for the game can take place.

An example for a *spatially and temporally discrete game (sdtd)* is the Journey Series: the actions relevant for the game do not happen anywhere on the game board, but at certain predefined locations. Additionally, the player may only move when the game allows him to do so, e.g. when a new chapter of the game needs to be started.

A *spatially discrete, but temporally continuous game (sdtc)* also restricts relevant actions to a limited amount of discrete locations, but the player may undertake the actions at those locations whenever he likes. In *CityPoker*, for example, poker cards can only be changed at five discrete locations, but the players are free to choose the time for visiting the locations. In other words: A temporally continuous game does not have the typical turn-taking of board games like chess.

Finally, in a *spatially and temporally continuous game (sctc)*, actions can take place anywhere on the game board and at any time. In *CYSMN*, for example, a player can be caught at any place and whenever an online and a street player meet.

To our knowledge, no game implements the fourth value for the spatial and temporal dimension, which would be a *spatially continuous, but temporally discrete (sctd)* game. In this type of game players would be restricted to take turns, but be allowed to move continuously. Example: In his first turn player A may move 100 meters in any direction, while player B has to wait. Afterwards, player B does his turn by moving 100 meters, while A keeps standing, before it will again be A's turn. A location-based game may also be a mixed form like *Human Pacman*, where some actions (eating a cookie) are restricted to discrete locations, while others (catching Pacman) may happen anywhere.

4 Design by variation

Table 1 illustrates how our selected location-based games are classified in regard to the three game design dimensions of our systematization method, game environmental embedding, game conceptual and spatial-temporal dimension.

	Embedding	**Game Concepts**	**Spatial-Temporal**
Geocaching	LBG	Item hunt	sdtc
CYSMN	MR	Chase	sctc
Journey I/II	MR	Puzzle	sdtd
Uncle Roy	MR	Item Hunt/Puzzle	sctc
GeoTicTacToe	MR	Strategy/Chase	sdtc
CityPoker	MR	Item Hunt/Strategy/ Chase/Puzzle	sdtc
Human Pacman	AR	Chase	(sc-sd)tc

Table 1: Classification of the selected location-based games

With these three orthogonal and nominally scaled dimensions we enable the game designer to build new games by simple picking one value for each of the dimensions. Furthermore, it supports the easy creation of new games out of an existing one by varying the parameter values in one or several dimensions. For example, it is possible to take a location-based game with the game concepts {chase game, strategy game} and create a new one by adding some item hunt elements. In the following we vary the Geogame *GeoTicTacToe*.

a) Location-based embedding (MR → LBG): For turning the original GeoTicTacToe into a pure location-based game, we replace the virtual markers with physical objects, i.e. players now carry Xs and Os with them which they have to drop at the locations. Additionally we remove the virtual layer from the mobile latter screen and do not show previously set markers.

b) Pure strategy game (Strategy/Chase → Strategy): Imagine we would like to play *GeoTicTacToe* with elderly or handicapped people by removing the chase aspects. This can easily be managed by forcing players to wait at a location until the other player has set his marker, i.e. we reintroduce strict turn-taking. The resulting waiting times should certainly be filled with entertaining content to keep players interested.

c) Multi conceptual game (Strategy/Chase → Item Hunt/Strategy/Chase/Puzzle): Introducing the additional game concepts item hunt and puzzle game, we now create a completely new game feeling. Before setting a marker, a player needs to search the surroundings of a location for a hidden RFID tag. After scanning this RFID, the mobile device poses the player a quiz that he has to solve (e.g. a simple multiple-choice question), before finally the virtual marker is dropped.

d) Spatial continuity (sdtc → (sc-sd)tc): Setting markers is still restricted to the nine locations, but events may happen on the way. Each player is equipped with a certain amount of (virtual) traps he can drop anywhere on his way. As soon as the adversary comes close to one of those virtual and hidden traps, he has to wait some minutes before moving on.

5 Related Work and Future Research Issues

Although game design is more and more recognized as an art form like film making, writing or painting, it still lacks proofed methods other art directions posses. Common methods like painting or cut techniques are not available for game designer. Although this is slowly changing for computer game design (for e.g. Rouse, 2005), it remains true in the field of location-based game design. In this paper design by variation was presented which enables the systematical design of location-based games along three game design dimensions. Varying a game along the dimensions of environmental embedding, game concepts or the spatial-temporal dimension, can create totally new game experiences.

Previous systematizations of location-based, pervasive or ubiquitous games (e.g. Magerkurth et al., 2005 or Rashid et al., 2006) have usually carried out classification solely by technological aspects. These systematizations were thought as overviews of existing games and technology, so no conclusions with respect to game design were proposed.

Davidsson et al. (2004) presented an enormous variety of game design patterns for mobile games by analyzing a huge collection of mobile games. But they considered location-based games only as one single pattern in their categorization, subsumed under the label pervasive games, and did not distinguish them any further. We think the specific characteristics of location-based games need a deeper analysis to utilize the full potential of these games.

Our future research is concerned to incorporate other properties of location-based games in our game design method. For concepts like cooperative versus competitive game play or multiplayer experiences game design by variation needs to be further extended.

References

Björk, S., Lundgren, S., Holopainen, J. (2003): Game Design Patterns. In: Level Up - 1st international Digital Games Research Conference 2003, University of Utrecht

Choek, D., A., Goh, H., K., Liu, W., Farbiz, F., Fong, W. S., Teo, S., L., Li, Y., Yung, X. (2004): Human Pacman: a mobile, wide-area entertainment system based on physical, social, and ubiquitous computing, In: Personal and Ubiquitous Computing, Volume 8, Issue 2, May 2004, pp. 71 – 81, ISSN: 1617-4909

Davidsson, O., Peitz, J., Björk, S., (2004): Game Design Patterns for Mobile Games. In: Project report to Nokia Research Center, Finland

Flintham, M., Anastasi, R., Benford, S. D., Hemmings, T., Crabtree, A., Greenhalgh, C. M., Rodden, T. A., Tandavanitj, N., Adams, M., and Row-Farr, J. (2003a): Where on-line meets on-the-streets: experiences with mobile mixed reality games. In: Proceedings of the CHI 2003 Conference on Human Factors in Computing Systems, ACM Press, New York

Flintham M, Anastasi R, Benford S, Drozd A, Mathrick J, Rowland D, Tandavanitj N, Adams M, Row-Farr J, Oldroyd A, Sutton J (2003b): Uncle Roy All Around You: mixing games and theatre on the city streets. In: Level Up - 1st international Digital Games Research Conference 2003, University of Utrecht

Jakl, A. (2004): The workflow of C++ game development, Symbian Developer Network, technical paper, http://www.symbian.com/developer/techlib/papers/ (accessed February 2006)

Magerkurth, C., Cheok, A.D., Mandryk, R.L., Nilsen, T. (2005): Pervasive Games: Bringing Computer Entertainment Back to the Real World. In: ACM Computers in Entertainment, Vol. 3, No. 3, 2005.

Rouse, R. III (2005): Game Design: Theory & Practice, Wordware Game Developer's Library, ISBN: 1556229127

Rashid, O., Mullins, I., Coulton, P., and Edwards, R. (2006): Extending cyberspace: location based games using cellular phones. In: Computers in Entertainment, 4, 1, 4.

Schlieder, C., Kiefer, P., Matyas, S. (2005a): Geogames: A Conceptual Framework and Tool for the Design of Location-Based Games from Classic Board Games. In: Intelligent Technologies for Interactive Entertainment, Springer (LNAI 3814) Berlin, pp. 164 - 173

Schlieder, C. (2005b). Representing the Meaning of Spatial Behavior by Spatially Grounded Intentional Systems, In: Geospatial Semantics, LNCS 3799, pp. 30 – 44, Berlin: Springer.

Salen, K., Zimmerman, E. (2003): Rules of Play: Game Design Fundamentals, MIT Press, ISBN 0262240459

Thomas, B., Close, B., Donoghue, J., Squires, J., De Bondi, P., Morris, M., Piekarski, W. (2000): ARQuake: An outdoor/indoor augmented reality first person application. In: International Symposium on Wearable Computers (ISWC'00), Atlanta, Georgia

An RFID-based game to encourage social interaction

Lillian Kittredge[1] Gaetano Borriello[1]

University of Washington, Seattle WA 98105, USA

Abstract. Radio Frequency IDentification (RFID) is an emerging and increasingly popular technology. Though the majority of applications deployed thus far have been utilitarian ones, in this work, we present an RFID-based game that encourages social interaction. Throughout the design process we have paid close attention to issues of privacy and the logistics of deploying a building-scale RFID system.

1 Introduction

Radio Frequency IDentification (RFID) is an emerging and increasingly popular technology with many applications. The majority of applications deployed thus far have been utilitarian ones, mainly in supply-chain management [11]. In this work, we present an RFID-based game.

This application differs in that people and objects are tagged, in a space where people work. By bringing RFID explicitly into the public sphere, it may help create a dialog with the audience for this technology and its many possible users. We hope that an easy-to-understand game will provide future users with more of a background on which to base their understanding of RFID and kick-start their imagination about future applications. Our goal is to encourage RFID-applications research and to view the issues of RFID deployment and use from different perspectives.

The major goals of the design of our game were:

- To encourage social interaction in the community of students, faculty, and staff that make up our department - approximately 1000 individuals,
- To start gaining an understanding of the privacy mechanisms that will be needed in any consumer-scale deployment of RFID, and
- To spur use of the extensive system of RFID readers being deployed in our building (the Allen Center at the University of Washington).

We based our work on a building-scale RFID reader deployment, called the *RFID ecosystem*, described in Section 3.1. We are installing readers at key intersections of hallways in a 7-story 8,000 square meter facility. Of course, one of the design considerations in building our game is that it not depend on 100% accuracy (tags near readers will occasionally not be read) or on 100% coverage (the readers will be installed only at key intersections, open areas, and hallways in our building).

We use the RFID ecosystem to track users' movements (while keeping their privacy in mind) and determine interactions between players. The more interactions with other players a user has, and the more meaningful the interactions, the more points that user scores in the game. As this is a continuously running long-lived game, we use a global interface to keep players aware of the game state and keep them motivated to interact with other players while considering their current position in terms of total score.

In Section 2, we discuss the game as it applies to the players, and the privacy issues involved in the game. Section 3 describes the RFID system on which our game is based, and as the game architecture. We discuss related work in Section 4 and future work in Section 5.

2 The Game

A strong sense of community is important to the culture of our department. Because of this, the main purpose of this game is to encourage new and continued social interaction among the regular denizens of our CSE building. Scoring is based on meaningful interactions with other players, as well as casual or less frequent interactions. Since the game brings a constant reminder of the RFID system developed by the department, it also encourages attention to and pride in departmental projects. Moreover, it causes a larger group of people to think about the issues, in terms of privacy and utility, of creating RFID-based applications for consumers.

The game is to be played over a long period of time, and simultaneously with everyday activities. Individual interactions are cooperative, though players accumulate scores and will be able to see their ranking versus other players.

2.1 Game basics

Figure 1 shows the game board and basic moves (described in the next section). The game board is entirely virtual. It consists of a unit circle, with a rainbow of colors around the edge, blending in to each other and fading to white in the center. (The colors are to make the display more engaging, and to make it easier to name locations on the board.) Players' avatars start out at a random point on the edge of the circle, and drift towards the center at a constant rate. The primary goal is to stay out of the center, with sub-goals associated with bonus areas of the board, and other bonuses discussed in Section 2.5.

Basic move The basic move is accomplished by being seen interacting with another player. An interaction consists of the tags associated with each player being seen by an RFID reader within a short window of time (short enough that the users can be considered to have been in the same location – within sight of each other). Any interaction pulls both players outwards from the center of the circle, and pulls them angularly towards each other, that is, not in a straight line, but along the arc between them. Such an interaction is illustrated in Figure

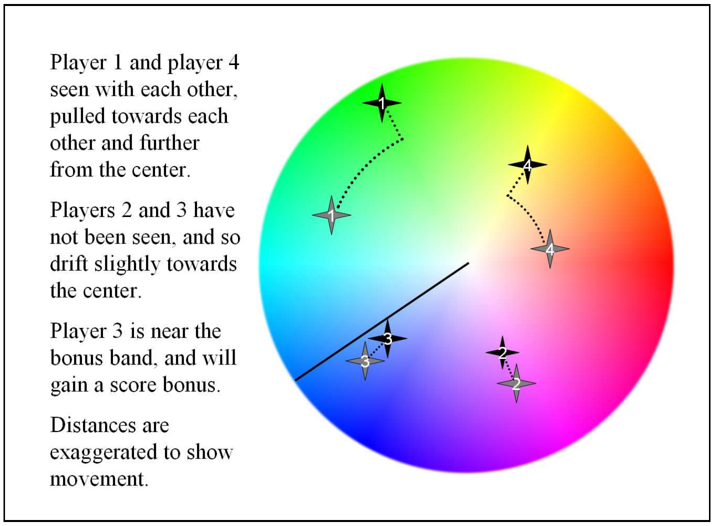


Fig. 1. The game board, with a sample interaction between players. The board is colored with red at the right, sweeping to blue in the lower left and green at the top left. The dotted lines indicate the path of movement on the game board by players 1 and 4, who have just been seen interacting with each other in the real world. Players 2 and 3 have not been seen, so they drift towards the center, but player 3 is close to the bonus band, and so will be receiving a score bonus.

1. The strength of the attraction in the board depends on the literal *length* and metaphorical *depth* of the interaction. An interaction that lasts longer causes a stronger pull, but so does one that *means* more. Walking down the hall together is a more meaningful interaction than happening to be in the same conference room during a colloquium, for instance, and so it pulls players in the field more strongly. We can detect a walk by a sequence of co-locations at topologically-close RFID readers, e.g., two users' tags seen by one reader at one end of a hallway and a short time later by another reader at the other end implying that the two individuals are walking together. Spending substantial time with another player one is not normally seen with should also be considered more meaningful, because it indicates the user is making new connections. There are many variations of interactions and we have only just begun to explore this space.

Due to the constant drift towards the center, when a player is not seen interacting with others frequently enough, that player drifts towards the center.

A player's score is dependent primarily on their distance from the center of the board, taking into account the distance at the moment, as well as the distances in the past month or two. Since the installation is ongoing and the game continues indefinitely, scores are computed as a weighted average of the points accumulated during each day that the user has been playing, with more recent days weighted more heavily. This way, a new player will be able to eventually catch up to someone who's been playing a long time.

The other major effect on the players' score is their proximity to bonus locations on the board. Without this factor, players would only be motivated to be seen with any arbitrary other player, and so could just stick to their cliques and habits. If they want to get to a particular place on the board, though, they need to figure out who to interact with, to pull them both towards the bonus. This encourages interaction with others with whom the player may not normally interact without the incentive provided by the game.

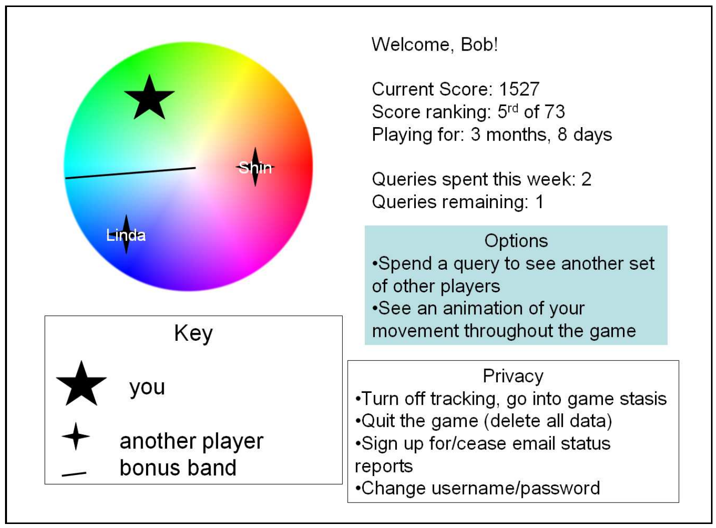


Fig. 2. Mock-up of the game interface as seen by a sample user "Bob", through the on-line interface. He sees his location, score and rank, and is offered the options to leave the game temporarily or permanently. He sees two other players with whom he can decide to interact. Though there are many other players, to help enforce privacy, only a small subset is presented at any time to a given player. Bob must choose to "spend" some of his queries for the week if he wishes to see the game locations of more other players.

2.2 Game play and interface

It is possible for users to "play" this game just by going about their daily activities, and interacting with others as they would normally, allowing the system to see them and update their game location in whatever uncontrolled way it happens to. (Indeed, it was an intentional design goal that players should be able to participate in the game at a basic level with a minimum of effort.)

However, players can also keep themselves up to date on their score and ranking, using the individual on-line interface as seen in the mock-up shown in Figure 2. This interface is accessed through a secure website using a user name and password of the player's choosing. In order to help players reach a specific location on the board (whether just to stay out of the center, or to reach a bonus location), the interface will offer to show them a small number of other players with whom it would be in their interest to interact (the selection of which players to show is discussed in Section 2.3.1).

Since this game is meant to be played in the department, players will all know each other, or be able to find out easily enough who other players are. By suggesting interactions that wouldn't happen on their own, we hope that the game will foster greater interaction and with it an even stronger sense of community.

In addition to the individual interface, we intend to have a global interface visible on the web or on a public kiosk. A mock-up of the global interface is shown in Figure 3. We hope that the global interface will encourage discussion and awareness of the game, and collaboration between players.

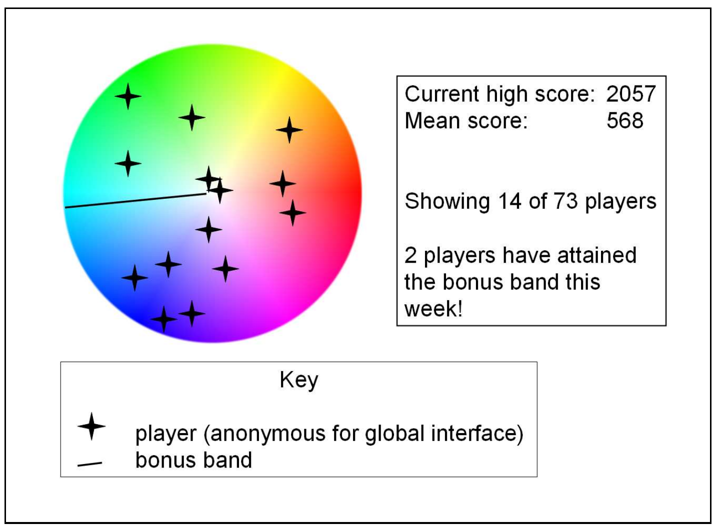


Fig. 3. Mock-up of the global game interface to be shown on a public kiosk or web page, updating at regular intervals. To protect the privacy of the players, only a random subset of the players are shown, with no names. To give players an idea of their rank or the competition they face, it shows global score statistics. To keep players up to date on the potential bonuses to be had, it shows the bonus bands.

2.3 Privacy in the game

Users may have different privacy expectations in a game than they would in other aspects of their daily life. Here it is understood that they are playing for fun, and that if they decide not to continue playing, it will have no adverse affect on them. However, privacy is an important issue to address head-on with any technology that tracks people's movements. In this application, we protect not only the location information itself, but also the game information generated from that location information. In other words, we also consider how a player could be tracked *indirectly* (or have other information about their interactions inferred) by other players observing their avatar's movement on the game board. In this section, we discuss the threats to privacy in the game, and the steps we take to alleviate them.

Control of information It would be a clear violation of privacy to make any user's physical location data available to other users. More subtly, though, *disclosing a player's game location* too much of the time is also a threat to privacy. If a malicious party were to track the game location of one or multiple players at all times, it might be possible to determine what the players' physical location had been at particular times, or to tell who each player tends to interact with. For example, say that Cindy knows where Bob and Alice both are on the game board. If she can watch them move on the board towards each other, she can tell that they've interacted in real life.

We alleviate this problem by selecting only a small subset of the other players to show on a player's individual interface. The system ensures that no single player shows up on another player's interface for too long. To both limit the amount of information and allow players some amount of control over how much information about other players they get, players have an allotment of requests for other players' information which they can "spend" during a week. In Figure 2, Bob has used up two of his queries this week, the most recent of which showed him Shin and Linda. (This idea of protecting privacy by limiting the number of queries a user can make is an emerging privacy technique in databases research [6].)

In order to help players reach bonus bands (and in order to nudge them towards interacting with people they don't normally interact with) the game chooses with somewhat higher probability to show users who are in game locations that will help the user requesting the information.

Similarly to the individual interface, if the global interface (Figure 3) showed all of the players at once, even anonymized, it would be possible to infer, for instance by consulting an individual interface, which player was which, and gather all of their game data that way. We solve this by only showing a small random subset of the players at a time. The players in the global interface are anonymized so that non-players will not be able to know who players are.

On both the global and individual interfaces, we only show updates to players' locations at random intervals, rather than continuously. This helps prevent users from getting real-time knowledge of other users' actions.

In addition to privacy safeguards within the RFID ecosystem itself (discussed in Section 3.1, users can simply decide not to carry their ID tag with them. In a pinch, they can also hide tags under metallic or water-heavy objects when they wish to avoid the tag being seen by a particular reader.

2.4 Strategy

Interestingly, the limited information about other players and the small allotment of requests for information allocated to each player introduce an element of strategy to the game: should I spend my requests for information now, or save them for later in the week when they might matter more? Should I go ahead and go chat and walk with my friend, not knowing where he is on the board, since at least it will pull us both out from the center?

Other elements of strategy are unrelated to the limited information about other players. For instance, I need to get to the printer – should I go the long way around to get the bonus for the long path, even though the long way takes me by a location that will pull me a different direction than I want to go? Of course, the longer path may increase socialization with people in another hallway that the player traverses more rarely. And so on.

We expect that players may develop their own coordinated strategies to cooperate in the game, being seen together at the same location for mutual benefit. In variations of the game with more complicated rules and tagged game objects (as discussed in the next section), scheming may develop. If rules only apply under particular circumstances (particular users at a particular read) and if they benefit one player more than others, that player may exert effort to bring about those circumstances. In some configurations, an adversarial element may even emerge.

2.5 Game extensions

An immediate concern about the basic game rules is this: if players are attracted to each other in the game space, how do we prevent them from becoming clumped together all at one point in the space? To vary mobility in the game field, we add special non-ID tags, here called *tokens*. To facilitate a player's movement around the circle, there may be a selection of tokens which cause an attraction in the game similar to that of another player, but which do not themselves move in the game board. Along these lines, being seen at a particular location could exert a constant force on the player, such as pulling them towards the red part of the board, or exerting a constant clockwise force, etc. Tokens or locations, or combinations thereof, might also influence the ease and speed with which players move on the board - generally increasing mobility would make interactions to other players have greater effect, but would also mean drifting towards the center faster.

Scoring can be made more complex by providing more opportunities for bonus points. These bonus locations may be the bonus bands already discussed, or may be particular spots in the board, (a harder goal, since the player has to control their radial distance from the center). To encourage physical activity, players receive a bonus for being seen taking the stairs, or walking all the way around the floor in a short amount of time.

Combinations of the tokens and meaningful locations can be arbitrarily complex. For instance, a token might be defined to only have an effect when there are three or more players present, or a particular other token present, or when in a particular location. In a different kind of complexity, a "transfer" token could cause a delayed player-interaction when it's seen first with one player and later with a different one. The transfer of the object implying that the two players exchanged the object in a place not covered by and RFID reader.

Adjusting the game All of the rules discussed so far (the basic rules, and all of the rules involving bonuses, tokens and special locations) have multiple parameters associated with them. For the basic rules, which kinds of interaction are more meaningful than which others? How quickly should players move on the board? At a higher level, which rules should even be included? More rules make the game more interesting, but too many may make it frustratingly complex.

We are designing the game to be easily modifiable, both so that parameters to rules, and the set of rules themselves, can be easily changed. To test the changes to these parameters, we will use simulated data about player and token movements. We will collect and generate this based on observations of people around the department (with their permission). Later runs may use real data from the ecosystem, recorded, anonymized, and replayed, for similar tweaking of parameters.

3 Game Implementation

3.1 RFID Ecosystem

We are taking advantage of the *RFID ecosystem* which is being deployed in the Allen Center, (home of our Computer Science and Engineering department). This system is a collection of stationary long-range RFID readers, small mobile tags, and a database and information management system which records data and filters it for applications. It also includes an API by which applications receive more abstract events of interest than just simple tag read (tag seen at a specific reader antenna at a specific time), e.g., two tags seen by a reader at nearly the same time. The game will eventually be one of several applications using the system. Users of the RFID ecosystem specify which applications should be allowed to see their data.

Between the RFID ecosystem and the player interface is the game engine. This engine stores all of the game state and the rules of interaction between players and objects. It receives *events* from the ecosystem layer which alert it to what is happening in the world. Using these, it builds up its own higher-level understanding of the world state (such as is needed to detect when a token has changed hands from one player to another) and applies the rules as appropriate to the players locations, scores, and meta-data.

Practical issues with tags In the implementation of the game, players will receive individual ID badges, which will be small enough (about the size of a credit card) that they can be carried a number of ways, whether in a pocket, on a lanyard, or pinned to clothing. Since we want to encourage players to keep the game in mind and remind each other, we will provide customizable lanyards or pins, which keep the tags visible.

Tokens can be attached to colorful objects of shape and style depending on their purpose and meaning. For instance, a token that attracts players universally towards red might have a red case. If tokens were to go missing, game administrators would be able to locate them or view their last known location and the last player they were seen with.

Privacy in the RFID ecosystem The RFID ecosystem is explicitly built with privacy controls. Its features include

- Tag IDs are never transmitted in the clear
- Data is stored on secure servers
- Users specify which applications are allowed to see their data.
- Users can at any time instruct the system to stop tracking them (ignore reads of their tags), or erase all of their stored data.

When the user asks not to be tracked by the RFID ecosystem, it alerts the game engine, which will take the player out of the game.

4 Related Work

There is a large body of work on RFID-based games, location-based games and other pervasive gaming. Though much of it is relevant to our work, here we point out what we hope is a representative subset.

There has been other work in RFID-based games which puts tags in small game objects and readers in the game table. Examples are the smart jigsaw puzzle assistant [3], and smart playing cards [10], both of which track the identities and locations of the playing pieces, and offer advice and scorekeeping.

Using wearable tags and fast readers that provide feedback when tags are scanned, fast-paced sports games are possible. Tagaboo [8] is one example of such a game - tagged objects which are associated with points or behaviors are worn in a vest by one child, while the other wears a glove containing a reader and processor.

Location-based games have also been explored, mostly on a city level rather than in buildings. Can You See Me Now [2] and Spacerace [5] are two examples, both using GPS. The first users wireless internet (802.11b) and GPS readers on separate devices, while the second uses GPS enhanced mobile phones. In location aware computing, the distinction between the physical world and the game board becomes blurred. Though we have drawn a distinction between them, other work has tied the two together. Pirates! [1] is such a game, where players carry handheld wireless devices, and their physical location triggers game events.

As we have designed our game with the awareness that reader coverage will be less than 100%, the “seamful games” work in [4] explicitly make use of these gaps in coverage. In that work, the ubiquitous technology in question is wireless 802.11.

5 Future work

Though we will undoubtedly learn substantially more between now and the end of our actual deployment, we are aware of further expansions we could apply to this game. Many of the changes and extensions discussed in Section 2.5 will effectively be future work. Additionally, the parameters to the basic rules can be changed and their effect observed. We can also make the game arbitrarily intelligent, with more sophisticated ways of deciding which other players to show.

Our RFID system uses writable tags. In future work we may make use of this feature, for example by causing certain locations to write information on tokens, which will become meaningful upon visiting that location again.

Further in the future, we can consider incorporating more information about what the players are doing. There is ongoing research in our department using multiple sensors in a single board to identify social interactions [7, 9]. In expanding the RFID technology, we can also make use of motion-sensitive RFID tags, for example to tell if a user is moving a token or other tagged game object. Taking the same problem from an entirely different perspective, we could potentially do the same game with a completely disparate technology underneath, such as WiFi localization or other techniques in activity recognition.

Lastly, we can also look into expanding to larger populations and areas. Though privacy issues will have to be addressed, offering game tags to users could be an engaging way to make new or visiting members of the department feel at home and part of the community. We hope that our system design will prove to be extensible enough to be applicable to other departments and workplaces elsewhere.

References

1. Björk, S., Falk, J., Hansson, R., Ljungstrand, P.: Pirates! - Using the physical world as a game board. In Proceedings of Interact 2001, IFIP TC. 13 Conference on Human-Computer Interaction (Tokyo) (2001).
2. Benford, S., Fraser, M., Reynard, G., Koleva, B.: Staging and evaluating public performances as an approach to CVE research. Proceedings of the 4th international conference on Collaborative virtual environments Bonn (2002).
3. Bohn, J., The smart jigsaw puzzle assistant: Using RFID technology for building augmented real-world games, In Workshop on Gaming Applications in Pervasive Computing Environments at Pervasive 2004 (Vienna), http://www.pergames.de, 2004.
4. Chalmers, M., Barkhuus, L., Bell, M., Brown, B., Hall, M., Sherwood, S., Tennent, P.: Gaming on the edge: Using seams in pervasive games. In The Second International Workshop on Gaming Applications in Pervasive Computing Environmnets at Pervasive 2005 (Munich), http://www.pergames.de (2005)
5. Drab, S., Binder, G.: Spacerace - A Location Based game for mobile phones using Assisted GPS. In The Second International Workshop on Gaming Applications in Pervasive Computing Environmnets at Pervasive 2005 (Munich), http://www.pergames.de, (2005)

6. Blum, A., Dwork, C., Mcsherry, F., Nissim, K.: Practical privacy: the SuLQ framework. Proceedings of the twenty-fourth ACM SIGMOD-SIGACT-SIGART symposium on Principles of database systems (Baltimore) (2005)
7. Kautz, H.: Sensing and Modeling Dynamic Social Networks, http://www.cs.washington.edu/ai/socialnetworks/
8. Konkel, M., Leung, V., Ulmer, B.: Tagaboo: a collaborative children's game based upon wearable RFID technology. Personal and Ubiquitous Computing (September 2004).
9. Pentland, A., Choudhury, T., Eagle, N., Singh, P.: Human Dynamics: Computation for Organization, in: Pattern Recognition Letters, Volume 26, Issue 4, Pages 503-511, (March 2005)
10. Römer, K., Domnitcheva, S.: Smart Playing Cards: A Ubiquitous Computing Game, in: Personal and Ubiquitous Computing. (December 2002)
11. Want, R.: RFID: A key to automating everything. Scientific American (January 2004) 56–65

Mobile Device based Interaction Patterns in Augmented Toy Environments

Matthias Lampe, Steve Hinske, Sandra Brockmann

Institute for Pervasive Computing, ETH Zurich, Clausiusstrasse 59, IFW, CH-8092 Zurich, Switzerland
{lampe, hinske}@inf.ethz.ch, brockmann@student.ethz.ch

Abstract. In our paper, we present the Augmented Knight's Castle, a pervasive playset, which enriches the child's pretend play by using background music, sound effects and verbal commentary of toys that react to the child's play. Radio frequency identification (RFID) technology is used to automatically and unobtrusively identify toys in the playset. Mobile devices equipped with RFID readers are introduced into the playset to provoke further interaction and to enhance the play (e.g., through the integration of interactive learning experiences). We describe two approaches of mobile device integration (mobile phones and mobile devices embedded into toys) with a preliminary analysis of their advantages and disadvantages. One objective of our presented augmented playset is to conduct a user study whose results will help us and others to improve the integration of mobile devices into augmented toys and playsets.

1 Introduction

Playing with toys is an essential part of the childhood. Besides being a recreational amusement and pure fun, playing also serves as an important function for the psychological, physiological and social development of a child [1, 2]. To further support creativity and inspire the fantasy of children, traditional toys can be enriched by adding multimedia content to them. The ideal entertainment experience then comes from the combination of physical experience, virtual content, storytelling and the imagination of the user [3].

By adding audio components to the award winning Playmobil Knights Empire Castle[1], we present an entertaining and exciting multimedia playground that foster the children's pretend play (see Fig. 1). Based on the actual game situations and settings, sound effects, background music and verbal commentaries are played. Radio frequency identification (RFID) technology is used to automatically and unobtrusively identify toys in the playset.

To provoke further interaction, mobile devices that implement the touch-me paradigm [4] through RFID are added to the play. That means, a child can use the mobile device to touch pieces of the playset and images or videos can be displayed. We pursue two approaches to add mobile devices to the playset: first, mobile phones

[1] www.playmobil.com

that are enabled as touch-me devices, and second, mobile devices which are embedded into toys to enable them as touch-me devices. To better evaluate the two different approaches, we are planning to conduct a user study with children of different age groups. The results of the user study will help us and others to improve the integration of mobile devices into augmented toys and playsets and therefore enhancing the children's fun and play.

Fig. 1. The Augmented Knight's Castle Playset

The remainder paper is organized as follows: in section 2, we describe the basic setting of the Augmented Knight's Castle playset. Section 3 introduces the mobile device based interactions in our augmented playset including a preliminary analysis of the two presented approaches. In section 4, we point out the differences of our approach to related work. The paper concludes with a summary of our contribution and a brief description of the planned user study in section 5.

2 The Basic Setting of the Augmented Knight's Castle

Designing a truly pervasive game, we required that the augmentation does not interfere, block or compromise the traditional play in any ways but that it seamlessly integrates with the toy playset (i.e. toys are handled in the way children are used to). Furthermore, we did not want the children to wear any special equipment (e.g., head-mounted displays). According to [5], our playset can therefore be categorized as an augmented toy.

RFID technology represents a suitable means to bridge the physical and virtual world in an invisible or at least unobtrusive manner [6] and is our choice to detect the position of objects in the playset. We use high frequency (HF) RFID technology that operates at 13.56 MHz and complies with the ISO 15693 standard. The RFID hardware from Feig[2] consists of one ID ISC.MR100 reader, one ID ISC.ANT.MUX multiplexer, which performs time multiplexing to query the tags in each antenna field, and 8 antennas in different sizes. Fig. 2 shows the playset and gives an idea on how the RFID technology is integrated into the playset.

Fig. 2. Playset with technology hidden (l.) and RFID antennas to observe the active zones (r.)

The RFID tags in the form of flexible RFID labels of different sizes are attached to or incorporated into the pieces of the playset to uniquely identify them. To tackle the problem with orientation of tags in antenna fields [7] we tagged objects with several tags of different orientation (e.g., back and bottom side of figures) to have at least one of the tags read in an antenna field. The 64-bit ID that is stored on the RFID tag is used as the key to map the pieces to their virtual information such as name, images, stories, or sounds. The RFID antennas are either attached to buildings or to different types of floor elements to detect the presence of game pieces in their proximity. The RFID readers are connected to the base station, on which the tag observations are filtered (i.e., to remove false-negative reads) and aggregated by our RFID middleware [8]. The middleware also provides an abstract interface to the RFID hardware to easily exchange the hardware from different vendors without changing the software.

Fig. 3. Enchanted tree with mobile RFID reader

In order to be able to observe the close proximity of larger objects that move in the course of play, we incorporated mobile RFID readers into these objects. The reader

[2] www.feig.de

module consists of a BTnode[3] that communicates with the base station via Bluetooth and that operates a Skyetek M1-mini[4] RFID reader with an external antenna integrated into the surface of an object. Fig. 3 shows, for example, the enchanted tree with the mobile reader module at the back. The reader is covered with brown plastic tape to hide it during the play.

The advantage of HF RFID technology for our application is the limited read range that allows clearly specifying a zone which will be observed by a RFID antenna. Our playset defines the following static active zones: the courtyard, drawbridge, prison, and living quarters of the king's castle, the plain in front of the castle, the dark forest and the dragon tower. In addition, there are two mobile active zones that can move around and still observe their close environment: the carriage and the enchanted tree. The seamless integration of the RFID antennas in different modules of the playset (i.e. buildings, floor elements, and landscape parts) and the mobile RFID readers implicate that the setup of the playset is not predefined but allows changing it to a certain degree according to the desires of the children.

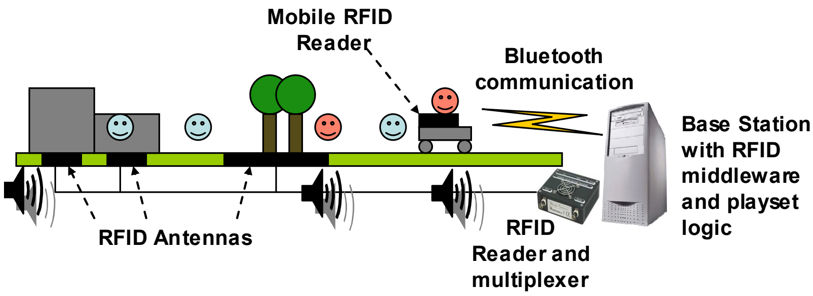


Fig. 4. Technical architecture of the playset

Based on the actual game situations and settings, sound effects, background music and verbal commentaries are played either as a response to an action (e.g., the fanfare is played when the king comes out of his quarters) or randomly (e.g., a dog barks or birds chirp). The kind of reaction is preconfigured using a state machine based software architecture in the playset logic that runs on the base station. Event-action-rules can be defined to generate events from the raw RFID tag observations using comparison and aggregation operations. For example, an event could be triggered when the red dragon is leaving the dragon tower or the background music changes from idyllic to battle sound when at least three dragon knight figures are placed on the plain in front of the king's castle. These events then trigger the transitions of the state machines with which more complex reactions can be modeled than solely events would allow. A state can perform certain audio play actions (e.g., playing a roaring in reaction to moving the red dragon). Fig. 4 summarizes the technical architecture of the playset.

So far, the augmentation of the toys is on an acoustical level only. But it is possible to even further enhance the playing experience by adding light, scent, vibration, or other actuators.

---

[3] www.btnode.ethz.ch
[4] www.skyetek.com

3 Adding Mobile Devices to the Playset

The benefits of adding mobile devices such as mobile phones to the Augmented Knight's Castle playset are a more interesting and interactive play. Mobile phones can be used for displaying images and videos, for playing sounds and music, and they can become pointing and touching devices bringing new forms of interactions and possibilities into the play. We pursue two approaches of integrating mobile devices to the playset: first, mobile phones that are enabled as touch-me devices, and second, mobile devices which are embedded into toys to enable them as touch-me devices.

3.1 Integrating Mobile Phones into the Playset

To enable the mobile phone as a touch-me device, we equipped a Nokia 6830 with our custom built BTnode RFID reader module (see previous section) similar to the approach of [4]. As shown in Fig. 5, the external antenna is attached to the top part of the mobile phone to allow the point-and-touch interaction with pieces of the playset. The application on the mobile phone is implemented in C++ for Symbian OS and communicates with the BTnode and the base station via two Bluetooth connections.

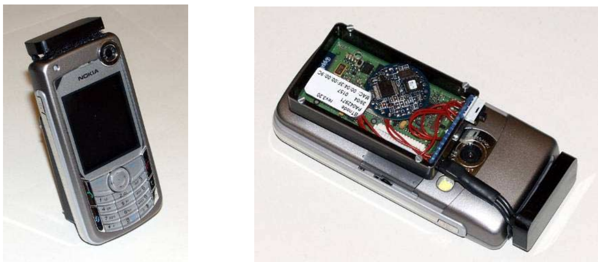


Fig. 5. Nokia 6830 with BTnode-RFID-reader and external antenna (front and back view)

The mobile phone has several advantages that support its integration into the playset: no extra device has to be provided since there is already a high deployment of mobile phones in the population of western countries even among children, who can just use their phones with the playset. Moreover, mobile phones can easily be exchanged if they break or malfunction. In the future, mobile phones with near field communication[5] (NFC) will become more widespread, which have already an integrated RFID reader and can act as touch-me device. For now, we have to first equip the mobile phone with a RFID reader. On top, the playset software has to be installed prior to play.

To enrich the play, the mobile phone has the capabilities to play audio and videos and display images and text. Enabled as a touch-me device, pieces of the playset that the child touches can be identified (see Fig. 6). This allows mobile phone to embody many roles during a course of play: it can act as an information device displaying multimedia content related to the piece of the playset that is touched. This role can

[5] www.nfc-forum.org

also be the interface to integrate learning into the play (see section 3.3). Another role is that of a weapon: The children can touch each other's mobile phones and figures on the playset to initiate a fight between the figures. It can also embody a virtual bottle containing a magic potion, which might have been found at the enchanted tree. The potion can then be administered to a wounded knight to heal him by touching the figure (see Fig. 6). Many other different roles (e.g. flowers, food, or gifts) are conceivable whose embodiment can even be further enhanced by one haptic capability of a mobile phone: the vibration alarm. In our playset implementation, the consequences of the application of such virtual objects are mere enhancement of the child's pretend play. A typical reaction is an affirmative verbal commentary of a figure or a sound effect played. In a playset that is oriented more towards role playing or tabletop games, a virtual game state could keep track of application of virtual objects (e.g., a knight can fight stronger if he has been drinking a magic potion before).

Fig. 6. Point-me, touch-me interaction between mobile phone and figure (left) and a mobile phone that takes on the role of a magic potion (right)

3.2 Mobile Devices embedded into Toys

Despite all its multimedia and haptic functionality to embody a role, the mobile phone cannot change its look-and-feel of a technical device, which hinders a seamless integration into the playset. In addition, the touch-me paradigm of using a mobile phone is not very intuitive which might change if more people are used to NFC-enabled phones. These drawbacks led us to the approach of embedding mobile devices into toys for a more seamless and intuitive integration of the previously described interactions into the play.

Once more, we apply the BTnode platform with a connected Skyetek M1-mini RFID reader and embed it into different toys to enable them as touch-me devices (see Fig. 7 and Fig. 8). The external antenna is adjusted to the form factor of the toy to specify the sensible area to touch objects with (e.g., the opening of the bottle or the blade of the sword). The BTnode controls the RFID reader and sends the IDs of the RFID tags to the base station via a Bluetooth L2CAP connection. After activating, the toy with the embedded device is ready to use and no additional setup or installation is needed.

Fig. 7. BTnode with mobile RFID reader embedded into a toy sword

In the embedded solution the toy itself is the embodiment of one or several roles in the playset (see Fig. 8) depending on its role in real life: for example, a sword is used for fighting but can also be used to poke around examining objects. Therefore, the toys have to be carefully chosen since the role can only be communicated by the look-and-feel of the toy which also supports the intuitive usage of the touch-me paradigm. This has, of course, the downside that only few roles can be embodied by one toy and that several toys have to be equipped with a mobile device in order to enrich the child's play. At least one toy that can get information or selecting a figure should be included in the playset. In our case we chose the sword to also act as selection device but other toys (e.g. magic wand) are also possible.

Fig. 8. Touch-me paradigm of different toys with embedded BTnode and RFID reader

To take advantage of the embedded BTnode platform and to allow another form of interaction, we attached a sensor board to the BTnode that includes, among others, light and 3d-acceleration sensors and a microphone. These sensors bring context into the play which can be added to the point-and-touch interaction to make the play more engaging: the 3d-acceleration sensors measure if a child shakes the magic potion well before it administers it to a figure and the sword fight is enriched by requiring movement of the swords. The data of the sensors will be transferred to the base station, analyzed according to certain parameters and influences the results of the interaction. In the future, we plan to also embed haptics and other unobtrusive output into the toys (e.g. vibration or LEDs to let the bottle glow when it is active).

3.3 Interactive Learning Experiences

Integrating interactive learning experiences is one of the new possibilities offered by the integration of mobile devices into the playset: children can learn songs or poems from the troubadour of the king's castle by simply pointing at the figure of the troubadour with their mobile phone. Another possibility is a mobile phone mode where playset pieces that are touched tell their names in a foreign language promoting the learning of foreign language vocabulary. In addition, the children can access facts about certain themes of the Middle Ages by touching pieces of the playset using the toy sword with the embedded mobile device (e.g., accessing historical facts about chivalry by touching a knight), or they could play simple learning games using the mobile devices (e.g., pointing to figures on the playset in the correct hierarchical order of the feudal system in the Middle Ages). Different learning modules can be added or downloaded dynamically according to the age and knowledge level of the children. Third parties could easily develop their own themes and learning modules or games and incorporate them into the augmented playset.

4 Related Work

The idea of equipping toys with electronic or virtual components is not new and there have been several approaches and ideas in this field with similar aspects. A good overview and classification of pervasive games can be found in [5]. These games or toys that combine the real and the virtual world are usually called pervasive games, hybrid games, smart toys, or augmented toys, depending on their exact purpose and design.

Zowie playsets (i.e., Redbeard's Pirate Quest and Ellie's Enchanted Garden) are tangible toys with integrated sensors for transmitting the state of movable playing pieces to a computer application [2]. Based on this setting, several computer-like games are implemented that integrate the real-world playset into their virtual world. The playing pieces function as a facilitator: the output comes from a computer screen, and the pieces are used as a kind of tangible user interface to perform the actions demanded from the storyline or play mode. The focus on the computer as output device differs from our approach of integrating mobile phones into the playset: A lot of the attention of the child's play is focused on the computer. This would happen only for very short times on when using mobile phones. Using mobile devices embedded into toys keeps the attention always on the playset.

StoryToy is a toy animal farm with an integrated storytelling environment consisting of an audio replay engine and a tactile user interface based on a sensor network [9]. It does not require a computer and has the objective to tell stories or play sounds based on the child's interaction with the animals of the farm. The story toy has several similarities to our basic playset (detection of game figures that trigger audio output), but does not integrate mobile phones into the toy probably due to the younger age of the target group. Besides sound effects, we also play background music that adapts to the actual play situation. This atmospheric but often overlooked [10] music triggers real immersion into the game.

Another category of pervasive games that are related to augmented playsets are augmented tabletop games (e.g., KnightMage [11], or False Prophets [12]). These games also have physical playsets that are enhanced with different pervasive computing technologies to keep track of the player's action, sense the location of game pieces, support the game with effects, or bring virtual parts of the game into the physical realm. However, the games are often not playable without technology any more. Moreover, they enforce rules and a flow of events due to their game nature in contrast to our enhanced free child's pretend play. The idea of adding a mobile device is applied in KnightMage, where a PDA equipped with an RFID reader supports the touch-me paradigm to get virtual information about game pieces.

RFID technology has been used also by other researchers for identifying game pieces such as cards or figures. Examples are the smart jigsaw puzzle assistant [13], the smart playing cards [14], and the STARS platform to develop augmented tabletop games [15].

5 Conclusion & Future work

We presented the Augmented Knight's Castle, which enriches the child's pretend play by using background music, sound effects and verbal commentary in reaction to the child's play. Tests and previous experiences using RFID in smart objects allowed us to successfully and reliably adopt RFID as an automatic and unobtrusive identification technology in the playset. Mobile devices were added to the playset to provoke further interaction applying the touch-me paradigm and enrich the child's play.

Critically analyzing the two approaches to integrate mobile devices into the playset (mobile phones and mobile devices embedded into toys), we can say that both approaches have their advantages and disadvantages: a mobile phone has strong functional capabilities and can be applied very generally, but lacks the usability as a toy. The strength of an embedded mobile device in a toy is its seamless integration and intuitive usage, but all functions have to be custom built and implemented. To better weigh the advantages and disadvantages and make recommendations on the integration of mobile devices into the playset, we plan to conduct a user study with the presented playset. We intend to compare the acceptance of the mobile device integration into the playset and are planning to perform the user study with three groups of children: (a) children playing the basic playset without mobile devices at all, (b) children playing with the playset where mobile phones are added, and (c) children playing with the playset and toys with embedded mobile devices. This research setting will allow us to evaluate the acceptance of the two approaches compared with each other and mobile device usage in general compared to the basic augmented play without mobile devices. Ideally, the user study will also be performed with children of different age groups for the three different playset groups to examine the effect of age towards the acceptance of mobile devices in the playset. The results will help us and others to improve the integration of mobile devices into augmented toys and playsets and therefore enhancing the children's fun, play and learning.

Bibliography

[1] G. Butterworth and M. Harris, *Principles of Developmental Psychology*. Hillsdale, NJ: Lawrence Erlbaum, 1994.

[2] H. Shwe, "Smarter Play for Smart Toys: The benefits of Technology-EnhancedPlay," *Zowie Intertainment White Paper 3208*, 1999.

[3] C. B. Stapleton, C. E. Hughes, and J. M. Moshell, "Mixed reality and the interactive imagination," presented at First Swedish-American Workshop on modelling and simulation (SAWMAS 02), 2002.

[4] L. Pohjanheimo, H. Keränen, and H. Ailisto, "Implementing TouchMe Paradigm with a Mobile Phone," presented at Joint sOc-EUSAI conference, Grenoble, 2005.

[5] C. Magerkurth, A. D. Cheok, R. L. Mandryk, and T. Nilsen, "Pervasive Games: Bringing Computer Entertainment Back to the Real World," *ACM Computers in Entertainment*, vol. 3, 2005.

[6] R. Want, K. P. Fishkin, A. Gujar, and B. L. Harrison, "Bridging Physical and Virtual Worlds with Electronic Tags," 1999.

[7] C. Floerkemeier and M. Lampe, "Issues with RFID usage in ubiquitous computing applications.," presented at Pervasive Computing: Second International Conference, PERVASIVE 2004, Vienna, 2004.

[8] C. Floerkemeier and M. Lampe, "RFID middleware design - addressing application requirements and RFID constraints," presented at Joint sOc-EUSAI conference, Grenoble, 2005.

[9] W. Fontijn and P. Mendels, "StoryToy the Interactive Storytelling Toy," presented at The Second International Workshop on Gaming Applications in Pervasive Computing Environments at Pervasive 2005, Munich, 2005.

[10] C. Magerkurth, M. Memisoglu, and T. Engelke, "Towards the next generation of tabletop gaming experiences," presented at Conference on Graphics Interface 2004, 2004.

[11] C. Magerkurth, R. Stenzel, N. Streitz, and E. Neuhold., "A multimodal interaction framework for pervasive game applications," presented at Workshop at Artificial Intelligence in Mobile System (AIMS), Fraunhofer IPSI, 2003

[12] R. L. Mandryk and D. S. Maranan., "False prophets: exploring hybrid board/video games," *CHI '02 extended abstracts on Human factors in computing systems*, pp. 640–641, 2002.

[13] J. Bohn, "The Smart Jigsaw Puzzle Assistant: Using RFID Technology for Building Augmented Real-World Games," presented at International Workshop on Gaming Applications in Pervasive Computing Environments at Pervasive 2004, 2004.

[14] K. Römer and S. Domnitcheva, "Smart Playing Cards: A Ubiquitous Computing Game," *Personal and Ubiquitous Computing*, vol. 6, pp. 371–377, 2002.

[15] C. Magerkurth, R. Stenzel, and T. Prante, "STARS - A Ubiquitous Computing Platform for Computer Augmented Tabletop Games," presented at Video Track and Adjunct Proceedings of the Fifth International Conference on Ubiquitous Computing (UBICOMP'03), Seattle, WA, USA, 2003.

Participant Roles in Socially Expanded Games

Markus Montola[1], and Annika Waern[2]

[1] Hypermedia Laboratory, 33014 University of Tampere
markus.montola@uta.fi
[2] Swedish Institute of Computer Science, Box 1263, SE-164 9 Kista, Sweden
annika@sics.se

Abstract. One common feature in pervasive games is the way they obfuscate the social boundary of play by involving non-players in the game in various ways. We discuss how several earlier pervasive games have invited bystanders into participation, mapping design alternatives for future game development.

1 Introduction

Games are often considered to happen inside a defined social boundary – a *magic circle* – which serves as a protective frame defining playful events as happening outside the players' ordinary lives [2, 11]. We have earlier [6, 7, 8] presented a three-dimensional design space for pervasive games, suggesting that pervasive games expand spatially, temporally and socially beyond the limits of regular games. Pervasive games are typically played in places and times that are not defined in advance, and the activity of playing is ambiguous, often blurred with player's ordinary life.

Social expansion implies that the game expands socially over the boundary of game, most often inviting non-players to participate in a way or another. The social boundary of game is redefined, and thus the protective frame is compromised. This is clearly an ethically challenging style of game design, but also a very promising one due to the fact that it can be used to create very engaging experiences. In this paper, we will take a closer look at the design options and potential risks that arise from social expansion, by inspecting a group of pervasive games[1].

For pervasive games, it is extremely important to investigate social expansion in depth, as it is almost a necessary consequence of expanding a game widely in space and time. Take for example the simple game *Botfighters*[2] [11]; when players come close to each other, their 'bots' engage in battle, calling the player to action. Although the game is purely a player vs. player experience and does not depend on bystander presence, the gaming activities of the players influence the everyday lives of outsid-

[1] Many of the games referred here have been described in further detail in [8].

[2] *Botfighters* is a location-aware mobile game, where players near each other can initiate player-vs.-player fights. When escaping a battle or chasing an opponent, the player must physically move in order to change the cellphone cell where he stands. The game mechanics strongly encourage keeping the game active 24 hours a day..

ers. The bystander might bump into a running player, or wake up to his girlfriend's phone as she gets attacked by another player.

2 Shifting Roles

How, then, do people get involved in pervasive games? One way to approach this is to analyse the roles that games offer to players and non-players. There are multiple roles available even in classical games. The archetypical *player* is a person who is at the same time aware of the ongoing game and able to perform actions to influence its current state, and who has a particular personal objective in the game (often a winning condition). Players can be differentiated from the other active *non-player participant* roles. Non-players are differentiated by their lack of a personal game goal; the (sports) referee role is an archetypical example.

A borderline role is that of the *spectator*. Spectators are aware of the game and can even be actively involved in it (e.g., through cheering or providing players with information). The difference between spectators and players is that spectators have no direct influence over the game; their involvement in the game is restricted to their ability to influence the behaviour of the participants.

The final role worth that merits discussion in this paper is the *bystander*; whether unaware or aware of an ongoing game, bystanders have no intention or opportunity to participate in it. Socially unexpanded games are typically completely insulated from bystanders: they are not affected by the game (even if aware of it) and they have no influence over the game.

In socially expanded games, these roles are not fully separated from each other. The simple case is when a socially expanded game offers opportunities for *role shifts*. Our major example of this will be the *rabbit hole invitation mechanism* employed in alternate reality gaming, discussed in detail below. A non-ambiguous example of role shifts is offered by *Anthills*[3] concept. This board game supports moving between all four roles. Bystanders are (peripherally) aware of the ongoing game but not affected by it. As the game features a large, public board, it also supports a spectatorship. There is also an active spectator role, where a spectator can join the game on either side, or alter the current state of the game board (by kicking the anthill or triggering locust waves etc.). Finally, the game supports role-shifts at any moment during the game. Players can join and leave after any move.

The most spectacular feature for socially expanded games is that the roles also can become blurred. One feature that has been utilised in several games is that players might not know who else is involved in the game. For example in *Killer: The Game of Assassination*[4] [3], the players typically do not know who the other players are.

---

[3] A concept-level prototype developed within IPerG project. *Anthills* is a light party game. The game is a technology-enhanced board game where two ant hills battle each other for territory. Players do simple turn-based moves and can go in and out of the teams as they please.

[4] *Killer* is an example of the larger *circle of death* game genre, where players seek to assassinate each other in their everyday life, typically using propped bombs or water pistols. The

Uncle Roy All Around You[5] [1] and *Prosopopeia*[6] designers made use of design elements that made the players continuously suspect that people around them were other players.

3 Contextual Awareness

Several game designs offer ambiguous roles for players and spectators through a deliberately ambiguous game context. When a person first makes contact with the game, it does not make itself fully known. It will be noticeable that something is taking place, but not exactly what is happening. The typical pattern is that people become aware of the game through passing through three broad stages of awareness.

- **Unaware state:** The game experiences go unnoticed or are interpreted as 'everyday' phenomena.
- **Ambiguous state:** The experiences produced by the game are too obvious or too closely related to each other to be ignored; still there is no frame of reference that would reveal and confirm the fact that it is a game, which we will refer to as the *gameness* of the experience.
- **Conscious state:** The game context is accessible to the person.

The critical stage is that of ambiguity, as this is when it is possible to misinterpret the experience as reality. As discussed further on in this section, the game experience in this state is that of a *reality game*, a piece of fabricated reality that is a game but does not reveal itself as such. A particular problem is that the audience will form their own interpretation of the context. Unless the ambiguous experience is carefully designed, these interpretations can very well be much more dangerous and worrying than the true explanation (that it was a game).

It should be noted that the ambiguous state can still support a playful, *ludic*, interpretation. An example of this was observed with the reality game *Vem gråter*[7], where at least one of the informants reported a ludic experience in the ambiguous state. This participant had read some of the background material for the game on-line, and then

---

game typically lasts for less than a week, and involves various creative strategies of assassination, sometimes involving help from unaware outsiders.

[5] *Uncle Roy All Around You* was developed by Blast Theory as an experiment in game-based performance arts. The game mixed online and on-street participation. The game theme focuses on making contact with people you do not know beforehand, both players and bystanders. Players interacted with instructed actors as well as with complete outsiders.

[6] *Prosopopeia* was a pervasive larp mixing character-immersive role-playing in cityscape with the players' ordinary lives. The aim was to create as seamless experience as possible, which was created by a minimalistic rule set and encouraging players to do things for real instead of simulating them in any way. This game was developed within IPerG.

[7] *Vem gråter* was a prototypical reality game, a series of mysterious poltergeist phenomena staged at Gotland University College. By observing the clues hidden in the events – witch hunters skulking about, text written on walls – a bystander could understand that a ludic structure was present and possibly solve the haunting puzzle.

went, with a group of friends late at night, to visit one of the places where the background story was set.

Interestingly enough, it is actually possible to create game experiences that take the opposite direction. In *Uncle Roy All Around You* players were initially very clearly invited to a game. They were explicitly told that it was a game and they were given a clear game objective to find Uncle Roy. A time limit was set, which made it possible to also fail the quest. However, as the game went on the original goal became subsequently blurred, the focus shifting towards much less goal-oriented objectives with a strong focus on social expansion. Eventually, the players were confronted with several tasks which involved confronting strangers, with no clear knowledge about who were in the game and who were not. A similar design strategy was employed in *Majestic*[8], where the game was first publicly announced and bought as a game. Once the game was started, it was suddenly 'cancelled' for unclear reasons. A couple of days later, the gamer received a second, much more ambiguous invitation to the real game.

3.1 Reality Games

Reality games are not games in the typical sense of the word; they are games that do not reveal their gameness to the participant. As the player does not know that he is playing a game, it's easy to question whether he actually is or not. A typical reality game is based on fabricating reality; staging events that are interesting from the target audience's point of view. *Vem gråter* was a reality game, intending to present a poltergeist mystery to university staff.

In reality games, the critical function is to entertain the participant or to provide him with an artistic experience. This way they differ from *candid camera*, which is intended to entertain an external audience, and from *scam-baiting*[9], which is intended to entertain the scam-baiters (and to steal some of the scammer's time). In the unaware and ambiguous states, socially expanded games appear as fabricated reality. This becomes particularly problematic when the game is unbalanced in a way that there exists a group of players that are aware of the ongoing game, and a group of outsiders who are affected by the game but unaware of its context. In *Prosopopeia* the players talked on several occasions with strangers about the game content. *The A.I. Game* fabricated a false movie credit, a 'sentient machine therapist', in the end credits of a commercial. All such designs should be considered and designed also from the outsider perspective.

Vem gråter illustrates the importance of the thematic choices of socially expanded games. As this game used a scary themes, it elicited negative interpretations – even though nobody actually was made to believe in ghosts. The pleasurable intensity of a

---

[8] *Majestic* was Electronic Arts attempt to launch alternate reality games as a retail affair. The game had to be bought in stores as a normal computer game, but once initialised it ran as an alternate reality game utilising multiple channels of communication. The game was discontinued in the fall of 2001.

[9] Playing along with internet scammers, often documenting the funny results in websites like www.419eater.com.

scary movie is generated by the combination of safeness of the fictional situation and scariness of the portrayed events.

Prosopopeia risked a similar problem. In this pervasive larp the players were supposed to look for a disappeared woman from Stockholm. As a thematic decision, the woman was an old hippie, so the players decided to track her down by speaking to junkies and drunks on the streets. While this is not inherently problematic, it could have been perceived as scary or dangerous by some participants.

4 Role Offers

In all games featuring social expansion, the transition between the contextual states should be deliberately planned. The designer should understand what kinds of people are likely to associate with the game and how they should arrive at the planned state in the progression.

When the game makes itself known, be it ambiguously or unambiguously, it should enable different types of role-taking. A person who becomes aware that something is going on might want to join the game (or the mysterious activity), but he or she might also be satisfied just to watch or to take on some other non-player role. In line with the previous discussion of possible roles, a game could offer any of the following roles.

- **Invitation to play:** The game offers active participation as a player.
- **Invitation to participate:** The game offers active participation, but not in a direct player role.
- **Invitation to the spectatorship:** The game offers spectator opportunities.
- **Invitation to refuse:** The game offers the option to ignore the game.

An interesting aspect of offers is that whenever roles of an active participant or a spectator are available, these offers also implicitly imply an invitation to refuse the game. This will typically be a redeeming factor in itself: if you do not like what you see you can choose to ignore it. However, in the ambiguous state the invitation to refuse is less complete than in the conscious state. The refusing person will be left with an interpretation without the ludic context (fabricated reality never exposed as non-ordinary), or alternatively that he or she is missing something interesting and fun. Quite often such an ambiguous experience is interpreted as ‘some prank’.

4.1 Invitation to Play

Invitation to play can be done in various ways. The seamless transition from bystander to player can be done in a fashion widely used and discussed in alternate reality games – through a *rabbit hole invitation*. A metaphorical rabbit hole is a clue hidden somewhere in ordinary life, leading the interested person towards a mystery hunt which is a clear ludic experience. (The fact that it is a preconstructed game, the *gameness* of the experience, will however often remain hidden.) Many examples exist, *The A.I. Game*[10] being the pioneer of the technique [4, 5] (see [12] for detailed analysis).

In the *The A.I. Game,* the first players picked up a clue from watching a movie trailer on TV. At that point, the players were in the unaware state. When they started to investigate this clue, they found mysterious web sites. As it became clear that something strange was going on and reality fabrication had taken place, the players shifted to ambiguous state. Some obvious hints lead players towards ludic interpretations, especially the fact that all the game websites were dated in the future. However, only later it became clear to the players that they were actually solving an intricate pre-planned fictional mystery.

Vem gråter was intended to keep the participants in the ambiguous state as long as possible, confirming the gameness of the events only after the final scene. As previously discussed, this enabled both a non-ludic and a ludic interpretation of the events and the on-line content.

Another interesting model of invitation to play is *viral invitation*, where core players are trusted to bring more players into the game as it goes on.

4.2 Invitation to Non-Player Participation

Apart from invitation to play, a game can also offer *non-player participatory roles* for bystanders. We have already discussed *Killer* where the non-player finding a prop can contact the game master and have the player penalized.

Pervasive games may offer roles for participants and spectators who are in an ambiguous context: a participant or a spectator knows that something is going on, without knowing any details of the game or who are playing, or even that it is a game. One example of this was the *Whirling Dervishes*[11] performance/game, in which a flash mob reclaimed a street. Bystanders were invited to join the on-street dance session. Unknown to the participants, the players had a playful goal in the event of attracting as many participants as possible.

It should be noted that it is possible to design a game which offers participatory non-player roles while these participants are unaware of the ongoing game. In [9] we present possible game designs having these features, such as *Yum Yum Sheep*[12].

On the other hand, offering roles of a non-player participant when they become aware of the game is often perceived as fun and engaging. In the *Yum Yum Sheep*

[10] *The A.I. Game*, also known as *The Beast*, has been thoroughly detailed elsewhere [3, 4, 1]. Basically it was a web-based puzzle game with a very intricate rabbit hole structure. One of the main points was that the game tried to deny its gameness – even claiming that it was not a game, allowing immersive gameplay experiences.

[11] *Whirling Dervishes* was a flash mob performance in San Francisco involving ludic elements. The players flooded a street for a moment, performing a dervish dance. One of the participants' aims (or ludic goals) was to involve as many outsiders in the performance as possible.

[12] *Yum Yum Sheep* is a Bluetooth-based mobile phone game concept where the objective is to run around in an area, trying to spot as many other Bluetooth IDs as possible. Each ID is depicted as a sheep, fed to the player's monster that grows stronger from this. When two players meet, their monsters battle each other.

study, some of the informants invented such roles for themselves. For example, one of the informants said that if he knew he was being stalked as part of a game, he might start to play along, in a way hiding or running to make it more difficult to follow him.

One entertaining structure is the one where non-player participants to assign sanctions to the players. The options might include refereeing the player activity, possibly in a fashion similar to the voting done in reality TV shows. The design may also allow non-players to express their opinions on the whole game very tangibly and quickly, by allowing them to retaliate if they feel upset by the game. In *Yum Yum Sheep*, the non-players could choose to gather around a player in order to have many sheep overpowering the monster instead. The informants commonly perceived this as a fun option.

4.3. Invitation to Spectatorship

The easiest and least controversial form of social expansion is to offer outsiders the possibility to watch the show. The spectator role is particularly redeeming in the ambiguous state, since an activity that invites people to watch is typically interpreted as less dangerous or subversive than one that is performed in secrecy. Spectator roles can also be offered through Internet and other mass media, and depending on the nature of spectator position, even after the game has concluded.

In socially expanded games, spectators can have a role in the game design. In *Killer,* the explicit purpose of the players is to conduct their murders without witnesses. This makes *Killer* an interesting spectator game, for it tries to avoid spectators.

4.4. Invitation to Refuse

As previously mentioned, if the game offers some opportunity for an active or spectator role, it also implicitly offers the option to refuse the game. However, unless the game provides some way for the refusing person to also leave the influence of the game, the offer to refuse becomes vacuous. This was perhaps the most serious design flaw of *Vem gråter*. As the game was staged in an area where people had to spend time working or studying, they were not able to completely leave the influence of the game. From this perspective, *Prosopopeia* was much less problematic as the players were constantly on the move, or else in prepared and isolated game locations.

The most straightforward approach to this problem is to avoid the unconscious and ambiguous states altogether, striving for full awareness about the gameness of the experience of the game for both participants and non-participants. A perfectly viable alternative is to hide the game. Many alternate reality games (such as *The A.I. Game*) are predominantly played through web sites that only the players can find, and through email and phone calls that only reach the actual players.

The significance of providing an invitation to refuse is demonstrated especially in the reality games. As the conscious state of contextual awareness is deliberately avoided, the participants might not realize that the experience is fictional – and thus it is not. It is impossible for a person who is not playing to quit playing.

5. Conclusions

We have investigated the subject of social expansion in pervasive games based on a host of game examples, and seen how social expansion offers numerous interesting alternatives for pervasive game design. The core issue is to provide interesting role offers both to players and bystanders; and our examples show that such role offers can be constructed even when the full game context is not known.

As the wider genre of pervasive gaming develops further, the various roles of non-player participants need to be investigated further as well. Some variations can be seen already; in *Yum Yum Sheep* they form the objectives of the game, in *Killer* they represent obstacles. In *Prosopopeia* the non-players provided a detailed landscape concealing many elements the game was built upon; players had to spot the fabricated parts of reality in order to succeed in the game.

The use of social expansion has proven an effective and enjoyable strategy to deeply engaging game play, and the transition between roles often form an intriguing part of the gameplay. The potentially most interesting design alternatives are the ones that make the game feel more tangible, real and immersive by compromising the magic circle the most. However, these are also the potentially most problematic designs. We intend to address this by further exploring the ethical challenges of social expansion, in particular from the non-player perspective.

References

1. Benford, S., Crabtree A., Reeves, S., Sheridan, J., and Dix. A. *Designing for the Opportunities and Risks of Staging Digital Experiences in Public Settings*. Proceedings of CHI 2006, forthcoming.
2. Huizinga, J. *Homo Ludens - A Study of Play Element in Culture*. Boston, Beacon Press, 1938/1955.
3. Jackson, S. *Killer. The Game of Assassination*. Steve Jackson Games. 1998, first edition in 1981.
4. McGonigal, J. *'This Is Not a Game': Immersive Aesthetics & Collective Play*, in: DAC 2003 Conference Proceedings. Melbourne, Australia, May 2003.
5. McGonigal, J. *A Real Little Game: The Performance of Belief in Pervasive Play*, in: Level Up. Proceedings of DiGRA conference. Utrecht, Netherlands, November 2003.
6. Montola, M., *Exploring the Edge of the Magic Circle*, in: Proceedings of the 6th DAC conference CD. Copenhagen, Denmark, December 2005.
7. Montola, M., Jäppinen, A., Lahti, J., Lankoski, P., Waern, A., and Holopainen, J. *Pervasive Game Design and Evaluation Guidelines for IPerG Phase Two*. Deliverable D5.4 of IPerG Project. Forthcoming in www.pervasive-gaming.org, 2006.
8. Montola, M. and Waern, A., and Nieuwdorp, E. *Domain of Pervasive Gaming*. Deliverable D5.3B of IPerG project. Available in www.pervasive-gaming.org. 2006.
9. Niemi, J., Sawano, S. and Waern, A. *Involving Non-Players in Pervasive Games*. Conference on Critical Computing, Aarhus, August 2005.

10. Salen, K., and Zimmerman, E. *Rules of Play. Game Design Fundamentals*. Massachusetts, MIT Press, 2004.
11. Sotamaa, O., *All The World's a Botfighter Stage: Notes on Location-based Multi-User Gaming*, in proceedings of Computer Games and Digital Cultures Conference. June 2002.
12. Szulborski, D., This Is Not A Game. A Guide to Alternate Reality Gaming. Exe Active Media Group, 2005.

Airhockey Over a Distance – Connecting People Through Physical Casual Game Play

Florian 'Floyd' Mueller, Luke Cole, Shannon O'Brien, Wouter Walmink

Connecting People Group
CSIRO – Commonwealth Scientific and Industrial Research Organisation
ICT Centre
Canberra, ACT 2601
Australia
{floyd.mueller, luke.cole, shannon.obrien, wouter.walmink}@csiro.au

Abstract. In modern society, people increasingly lack social interaction, although beneficial to work and personal life. Airhockey Over a Distance aims to work against this trend by recreating the social experience and rapport facilitated by physical, casual game play in a distributed environment. We networked two airhockey tables and augmented them with a videoconference. Mechanics on each table allow for a physical puck to be shot back and forth between the two locations, creating a perceived "shared space" between the participants. Supporting the hitting of a fast-moving, tangible puck between the two players creates a compelling social game experience, which can support social interactions and contribute to an increased connectedness between people who are physically apart.

1 Introduction

Fig. 1. Airhockey Over a Distance

Social interaction is an essential part of what it means to be human. The "social intelligence hypothesis" even suggests that primate intelligence originally evolved to solve social problems [cited in 3]. Our daily interactions with others are crucial for a fulfilling work and social life, and add meaning to our existence. However, today's lifestyle with its associated physical distribution of personal contacts and work arrangements decreases the chances of engaging in social interactions with family, friends and colleagues [9]. Furthermore, it has been noted that commercial success can depend on the existence of social interactions in the work environment [5].

We believe casual physical games such as airhockey, pool or table-tennis, which are known to be social facilitators and 'ice-breakers' in community places, can work against the trend of social decline by supporting networked game-play between participants that are geographically apart. Our approach focuses on two components: providing distributed players with the ability to engage in a conversation at any time and supporting a physical (in contrast to virtual), playful game experience.

Previous work has shown the use of physical interaction in networked entertainment applications [6][8][10]. These games aim to create an illusion of a shared physical object across the network to create a compelling game experience. Our approach supports not just sharing, but passing a physical object back and forth between two physically dispersed locations.

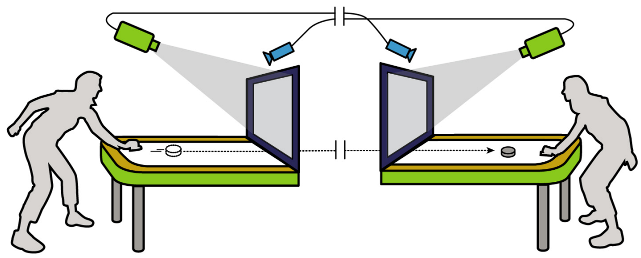


Fig. 2. Conceptual diagram

2 Airhockey Over a Distance

Airhockey Over a Distance is played like a conventional airhockey game: two competing players are trying to score points in the opposing player's goal by hitting a real, physical puck back and forth with a small round bat [Fig 1]. In our implementation, the table is figuratively split in half and the two ends are connected via a network [Fig 2]. Each player is recorded by a camera and the video is displayed on the screen of the opposing player, creating the illusion of playing together on one table [Fig 3]. Once the puck passes the midway-line, it is detected, and a corresponding physical puck is shot out at the other table via four rotating puck cannons (the position is not replicated at this stage). These cannons hold enough pucks for several games, and a lever pushes the bottom puck of the array towards a spinning disc which shoots the puck out at very high speeds [Fig 4]. For the players, it feels like they are passing a real, physical puck back and forward between each other, through the network. A game usually lasts for 2-10 minutes, supporting quick, casual game play.

Fig. 3. Setup including table and projector frame

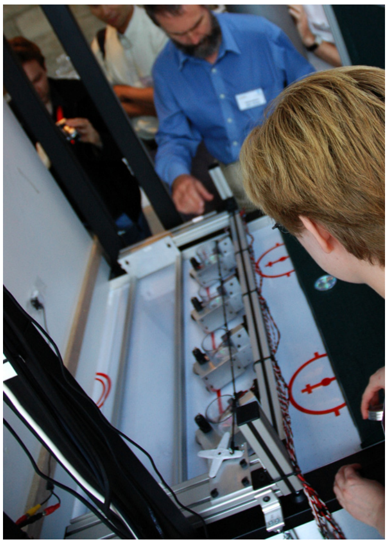


Fig. 4. Puck cannons behind the videoconference screen

3 Pervasive Connectedness

We are aiming for an increased connectedness between remote participants through the inclusion of a videoconference and network component into games that are familiar to players from a co-located setting. Connectedness is enforced by activities like thinking about each other, knowing what the other is doing and feeling, and sharing experiences. We intend to transfer the bonding experience that can occur during co-located game-play to a distributed networked setting in which the players are physically apart. We believe that if users have an enjoyable experience which can create an associated bond between them, recreating this experience between players that are in geographically different locations can be beneficial.

We believe the following recommendations can contribute towards our aim:

1. The game should be familiar to users.

By modifying an existing game, the inhibition to join is much lower for the user than by introducing a new game. Furthermore, if the rules are already known to the players, it is easier to engage in play. However, due to the fact that recreating the same game in a networked environment is not always practical or technologically feasible, modifications to the rules or type of play might be necessary. However, the core interaction (such as hitting a puck, kicking a ball) should be kept as familiar as possible, to encourage a rapid take-up by the participants.

2. The videoconferencing system should be high-quality.

High-quality for audio and video is necessary for supporting social interactions, in which facial expressions, gestures and vocal changes play an important role.

3. Physical interaction

We believe the physically of the game contributes to the bonding experience and can hence create a stronger connectedness than, for example, a mouse and keyboard interaction. Hitting a puck back and forth, as in our example Airhockey Over a Distance, requires fast hand-eye coordination, and missing a puck often elicits amusement and laughter by players. Being able to check how hard (and therefore how fast) a player can hit a puck is also something participants are eager to test. The strong force-feedback of the puck being hit, as well as the resulting characteristic sound further adds to the compelling game experience that made airhockey an arcade hit worldwide for so many years [1].

4. Pervasive Connectivity

We envision networked social games to be accessible in the home but also in social spaces, such as arcades, pubs, social clubs etc. Wherever people want to play, they should be able to. For the user it should not matter if she or he plays against a local player or remote player. Wherever she or he chooses to "have some fun" by a game, it should be possible with a co-located or remote player. The presence of a videoconference should not affect the interaction with the other player significantly. We see Airhockey Over a Distance as an example of a pervasive networked game that is part of a distributed set of tools within our environment through which we facilitate, maintain and establish our social bonds with remote others. This is a subset of the concept described by [4] on pervasive computing. Physical networked games can be a valuable addition to the pervasive game genre [2], which includes augmented board games and mobile games already, explicitly supporting remote social interactions.

4 User Scenarios

We envision Airhockey Over a Distance to be played in places which afford a socializing opportunity. Setting up a table in canteens of two different branches of a distributed corporation could enable employees to play with colleagues they would otherwise never meet. If they are located in different time-zones, such a system would allow employees to check the availability of their remote counterparts and make them aware of their work culture, supporting social interactions on a serendipitous and casual basis.

Airhockey Over a Distance does not require any special skills nor does it have complex rules or a steep learning curve, hence it is very accessible. Players might not even need to speak the same language in order to have an enjoyable experience together; hence Airhockey Over a Distance has the potential to be played internationally.

Arcade parlors are another possible venue for Airhockey Over a Distance, in which co-located airhockey tables are installed already. Networked versions would allow friends from different cities to play and socialize together. Smaller versions could be available as add-ons for personal console game systems, which already include a network component, making them suitable for the mass-market.

Placing connected airhockey tables into youth clubs could enable teenagers to get in contact with young adults from different countries in order to learn in a playful way about other cultures and languages. Installing setups in hospitals could give inpatient children the opportunity to play with peers in other hospitals or to play with friends from their home in order to work against isolation and loneliness.

5 Virtual Airhockey

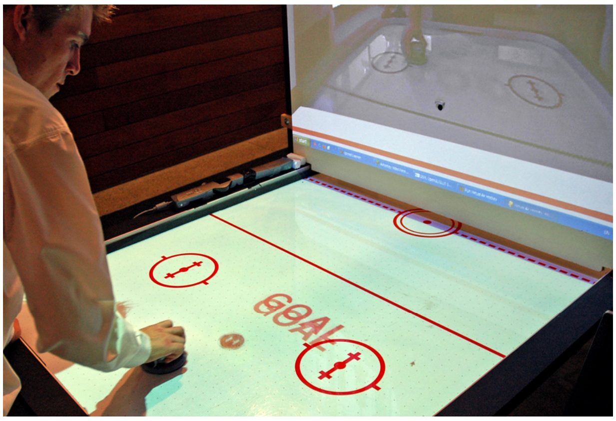


Fig. 5. Virtual Airhockey is played on the same table

We are aiming to measure the connectedness a physical game of Airhockey Over a Distance can create between remote players. In order to do that, we have also built a vision-based version of the networked airhockey table [Figure 5]. It uses the same videoconferencing technology and is played on the same physical table; however, the puck is virtual, projected from above. The players use a modified bat which includes a tracking system to hit the virtual puck back and forth.

In order to keep confounding factors to a minimum, the rules of the virtual and physical game are the same, as are the size of the table and the videoconference screen. The main difference is the physicality of the puck; however, the projected puck looks similar to a physical puck, since a physical puck is flat and only a few millimeters high. The player is able to hit the virtual puck, and even sound effects are included, however, the player does not receive the force feedback from the impact when hitting the puck.

We are planning a comparative experiment between the physical and the virtual game. Our main focus is the interaction between the participants and the connectedness the game creates. We aim to investigate if the physicality and hence the physical feedback of the hits influence the interaction levels and if it can contribute to a perceived "shared space" between the remote players. We hypothesize that the physicality better replicates the experience of sharing a table with a game partner, and therefore the two players have an increased sense of connectedness with each other, contributing towards social interactions and hence resulting in a stronger interpersonal bond. The results will allow us to better understand the significance of distributed physical interfaces on interactions between geographically separated participants.

6 Conclusions

We believe the physicality of Airhockey Over a Distance creates a compelling game experience different than most current networked computer games. We are currently conducting experiments to compare the effect on connectedness between a virtual and a physical game of airhockey. We believe from preliminary feedback we gained at an internal event [7] that this physical distributed game can facilitate an increased bond through social interaction between geographically separated participants. We aim to gather further evidence by exposing Airhockey Over a Distance to a wider audience.

7 Acknowledgments

We thank CeNTIE (Centre for Networking Technologies for the Information Economy), which is supported by the Australian Government through the Advanced Networks Program (ANP) of the Department of Communications, Information Technology and the Arts and the CSIRO ICT Centre. Thanks to the following people who contributed extensively to this project: Roy Featherstone, Ken Taylor, Chris Gunn, Duncan Stevenson, Matthew Hutchins, Doug Palmer, Matt Adcock and Jocelyn Smith.

References

1. Air Hockey. http://en.wikipedia.org/wiki/Air_hockey
2. C. Magerkurth, A. D. Cheok, R. L. Mandryk, T. Nilsen. Pervasive games: bringing computer entertainment back to the real world. In: *Computers in Entertainment (CIE)*, ACM Press, Vol. 3 July, 2005. pp. 11-29.
3. Dautenhahn, K. Trying to Imitate - a Step towards Releasing Robots from Social Isolation. Proceedings of Perception to Action, IEEE Computer Society Press, Lausanne Switzerland (1994) pp. 290-301
4. Dillon, T. Pervasive and ubiquitous computing. http://www.nestafuturelab.org/viewpoint/art71.htm
5. Lechler, T. Social Interaction: A determinant of Entrepreneurial Team Venture Success, Small Business Economics 16(4):263–278, 2001
6. Mueller, F., Agamanolis, S., and Picard, R. Exertion Interfaces: Sports over a Distance for Social Bonding and Fun. In Proc. CHI 2003, ACM Press.
7. Mueller, F., Cole, L., O'Brien, S., Walmink, W. Airhockey Over A Distance. In Proc. CHI 2006, ACM Press.
8. New York Hall of Science. Press room. 2005. http://nyhallsci.org/nyhs-pressroom/nyhs-pressreleases/pr-tug_of_war.html
9. Putnam, R. Bowling Alone. Touchstone, Simon & Schuster, New York, USA, 2000.
10. White, T., Back, D. Telephonic Arm Wrestling. http://www.normill.ca/artpage.html

Report about the Crossmedia Game Epidemic Menace

Jan Ohlenburg[1], Irma Lindt[1], and Uta Pankoke-Babatz[1]

Fraunhofer FIT, Schloss Birlinghoven, 53754 Sankt Augustin, Germany,
jan.ohlenburg@fit.fraunhofer.de,
WWW home page: http://www.fraunhofer.fit.de

Abstract. Crossmedia games employ a wide variety of gaming interfaces including stationary and mobile devices to facilitate different game experiences within a single game.
This paper presents the Crossmedia game Epidemic Menace, introduces the game concept and describes the first Epidemic Menace game event. Furthermore, we are explaining the technical realization of Epidemic Menace, the employed evaluation methodologies and initial results of the evaluation.

1 Introduction

Pervasive games employ emergent pervasive technology to enhance computer games with physical and social aspects of the real world [5]. In contrast to traditional computer games typically taking place in rather limited and well-defined settings, pervasive games are blurring traditional boundaries of games with respect to their spatial, temporal, and social expansion [6].

Crossmedia games are a genre of pervasive gaming that is played with a variety of gaming devices and gaming interfaces to support different forms of participation and to deliver different game experiences [4]. Crossmedia games offer different gaming interfaces: stationary gaming interfaces available at different locations and mobile gaming interfaces carried by the players. The different gaming interfaces offer different functionality, allowing for a more active or a more passive involvement in the game and for different combinations of the physical environment and the virtual game world.

In this paper we are presenting the Crossmedia game Epidemic Menace - a game developed within the IPerG project [2]. The paper is structured as follows: Section 2 describes the game concept of Epidemic Menace including the storyline and the game rules. Section 3 describes the first Epidemic Menace game event that took place in August 2005. Section 4 explains the technical realization of Epidemic Menace. Section 5 explains the evaluation methodologies and our initial findings. Section 6 concludes the paper.

2 Game Concept

In Epidemic Menace players become medical experts and need to save mankind from threatening virus mutations. A villain scientist, craving for power, creates a lethal virus mutation and contaminates campus Birlinghoven. From there the viruses shall spread and infect all humans. To master this threat, expert teams - the players - are appointed. They have the task to destroy the viruses before they manage to escape the campus and to uncover how this could have happened.

Epidemic Menace is a collaborative game played in teams. Each team has a team game room equipped with stationary gaming devices allowing players to observe and to analyse the virus and to communicate with their team members. Additionally to the stationary devices in the team game room, each team receives a set of gaming devices that can be used outdoors to capture and destroy the virus. Players are tasked to clear the campus from the threatening viruses. At the same time, they have the goal to uncover a conspiracy story. To do so, players are capturing and disinfecting viruses distributed on the campus and they are trying to find video messages explaining the conspiracy.

At the beginning of the game, players select a gaming device that can be exchanged during the game play. Depending on the gaming device a player can either be in the mobile play mode (player is outdoors and her position is tracked) or in the stationary play mode (player is in the team game room). In the mobile play mode, each player is equipped with a mobile positioning device to track her position. To exchange a gaming device, a player goes to the technical support station, hands back her current gaming device, and chooses a new gaming device from the gaming devices available for her team. (Gaming devices cannot be exchanged between players directly.)

The gaming interfaces in Epidemic Menace running for example on mobile phones, stationary displays, mobile Augmented Reality etc. offer different functionality and deliver different game experiences. For the design and realization of the Crossmedia game we tried to meet different technical, design, commercial and ethical requirements, described in Lindt et al. [4]. In particular we pursued the following design goals [3]: Firstly, the functionality offered by a gaming interface should fit to the device, e.g. should be intuitively afforded by the device [7] to reduce training times, secondly, the experiences and functionality different devices offer should be balanced and thirdly, we wanted to integrate the social quality of traditional non-computer games into the game play by providing for collaboration and social interaction among players.

The viruses players are seeking are virtual and appear differently on different gaming interfaces. Viruses are closely interlinked with the real world: Their movement and replication properties depend strongly on real-world weather conditions.

A virus consists of different cell types that determine its behaviour in detail: growth, damage, stealth, and/or spread-by-wind cells. Growth cells influence the virus growth speed. The more growth cells a virus has, the quicker it grows. The growth of a virus is also influenced by the current temperature. The warmer it is the quicker a virus grows. If a virus reaches a certain size, it automatically splits up into two smaller viruses. Damage cells determine the probability of a player being infected if he is in close proximity of the virus. If a player gets infected, the gaming interface of the player starts to malfunction. Stealth cells determine how quickly it becomes visible that a player is infected. Spread-by-wind cells determine the movement of a virus. A virus with spread-by-wind cells moves according to the current wind direction and its movement speed is influenced by the current wind strength.

With the elaborated virus behaviour that is closely interlinked with the physical world, we tried to create an interesting player-virus interaction. Each virus behaves differently. Players need to observe the physical surrounding and the viruses in order to determine the intrinsic behaviour and the possible threats of viruses.

Epidemic Menace is primarily designed for undergraduate students of arts, media, media informatics and related subjects. Although the players might not be acquainted with pervasive games, we assume that they rather quickly learn the rules of the game and the functionality of the different gaming devices and that they experiment and come up with new rules and emergent behaviour during the game play. We also assume that the feedback we get from this user group is rather extensive and constructive. This is the reason why we chose this user group as target group for the Epidemic Menace game.

3 The Game Event

The game event was staged in August 2005 at the campus Birlinghoven in Sankt Augustin, Germany. The campus has a size of approximately 80.000 m^2 with a lot of different areas, such as a park, meadows, parking lots, trees and bushes, a rose garden, a remise and a castle (Fig. 1). Approximately half of the campus had been selected as the playing area and was equipped with five WiFi routers in order to cover most of the playing area with internet access. The event lasted for two days.

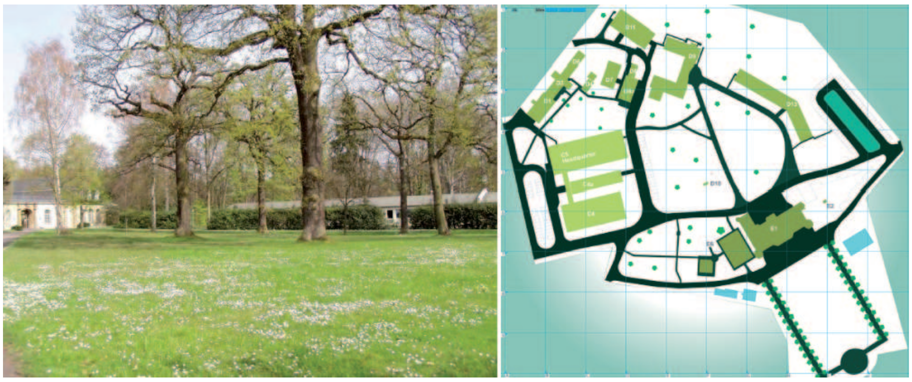


Fig. 1. Picture and map of the game area

The two team game rooms were located in a building adjacent to the playing area, allowing the players to switch easily between mobile and stationary play mode. Each team game room provided facilities for the stationary players to observe and to monitor the outdoor gaming area as well as communication facilities to coordinate the team members. The stationary game board (Fig. 2) – a large touch display – showed the whole gaming area and the location of each mobile player and the location and the size of all viruses. Using the touch screen the stationary players were able to get more information about each player and both teams by information dialogs showing the current devices, the infection status and the team points. Additionally, both team game rooms were equipped with a media wall (Fig. 2). The media wall consisted of three screens showing vital information and provided important functionalities, one of the screens showed the life stream of an observation camera monitoring the playing field, also allowing the players to rotate the view and to zoom in through an interface on the screen. Another screen provided a virus analysis tool, where the caught viruses could be analysed and broke apart in their different substances. The third screen was a communication centre allowing the stationary players to call the mobile players on their smart phones.

Fig. 2. Player using the stationary game board (left) and player in front of the media wall (right).

In a central position of the gaming area a technical support station was set up, where the devices for the outdoor play were handed out, charged and configured.

The game event started by an introduction for all players, describing them the situation that a scientist has released deadly viruses on the campus. The introduction was disrupted by a crew member telling the players that they had just received a video about an interrogation of one of the scientist working on the campus, which might bring more light into the situation at hand. The players were lead into a different room where they watched the introduction movie. Afterwards, the teams were formed and brought to their team game rooms. Each team was equipped with matching T-shirts to be easily identified as a team member. Separately, the different interfaces of the team game room were introduced to the teams before the game started.

Mobile players could choose from different gaming devices with quite different interfaces for the virus hunt. While each player was equipped with a PDA and a GPS device to track her position, they were additionally equipped with either a mobile AR system, a smart phone or a headphone. Since the mobile AR system was the most powerful (and most expensive) of the devices, only one was available per team (Fig. 3). The mobile AR system consists of a laptop strapped onto a backpack with a monocular head-mounted display allowing the player to see the animated 3D viruses in his proximity overlaid on top of the real world. By using a spraying can, the player could attack the virus if it was close enough, also risking of getting infected by the virus. The smart phone could either be used to communicate with the team game room, to send text messages to other players, or to set traps and catch viruses in the players proximity (Fig. 3). The display of the smart phone showed a fragment of the map of the game area where the player was currently located, the display automatically updated the fragment

Fig. 3. Player with mobile AR system (left), player with headphones (middle), smart phone (right).

while the player was moving. Additionally to the map the player could see viruses in his surroundings and try to catch them. In case a virus was successfully caught, it could be analysed later using the virus analysis tool. The headphones could be used in conjunction with the PDA forming the malleable music device (Fig. 3). Depending on the player's position, the sound, which was streamed to the PDA, was a mix of all viruses in the proximity depending on their mutation and their distance. Each of the mutations produced a very specific sound, the volume of this sound depended on the size of the mutation, letting a player figure out how the viruses in his proximity where composed.

The event was divided into different playing sessions for evaluating the two play modes. Also ensuring that each player would play at least once in the stationary play mode and once in the mobile play mode. During the first session all players where in the mobile play mode in order to get introduced the different gaming devices and their interfaces. During the second session we evaluated how the communication between the team game room and the mobile players worked. Two team members were in the team game room, one monitoring the game area, the other one communicating with the outdoor players. The mobile players were supposed to locate and catch or destroy the virus and also communicate with the team game room. In the third session the mobile players were moving in groups of two, one was advised to handle the communication and the other should fight the viruses.

Between the different sessions the teams would receive video messages from the game masters and interact with a robot dog (Sony AIBO) to inspect rooms, which were contaminated so that the players could not enter the room by themselves (Fig. 4). The robot dog played also an important role since it found – led by the players – an unconscious scientist. After waking up, she could give the teams the final clue, who was responsible for this situation.

Finally, both teams were debriefed in the castle, watched a last video message, and got the notice that the evil scientist has been caught thanks to their support.

Fig. 4. Players inspecting a room by using the remote interface of the robot dog.

4 Technical Realization

The Epidemic Menace game is set up using a classical client/server network layout. The game server receives all data from each of the devices and interfaces and distributes the current game state to all connected interfaces. The game state consists mainly of the current location of all players, their currently assigned devices, the location and the composition of the viruses as well as the current weather information. This game state is sent to each of the different gaming interfaces at different frequencies, depending on their real-time capabilities, e.g. the smart phone receives game state updates at a lower frequency as the stationary game board. Each gaming interface displays the current game state in its own way, since each device should provide a different level of presence and capabilities. While the mobile AR system displays a high resolution model of the virus, the mobile malleable music streams the sounds of the viruses to the players and the smart phone only shows a 2D map.

In order to provide the location of all mobile players, each of them was equipped with a PDA and a Bluetooth GPS receiver. Every few seconds, the PDA sends the current GPS location via a WiFi connection to the game server. Although the game area had a very good WiFi coverage, there were a lot of spot where the PDAs had no or very bad connectivity. Since the game server would not receive position updates in such areas and the interaction with the viruses is limited, the players get an audio feedback about the signal quality.

The game server takes care of the virus behaviour like movement, growth and infection of players and connects to a weather engine to adapt the behaviour of the viruses to the current weather situation, e.g. the viruses move with the wind.

The stationary game board receives the changed game states and displays all the information on the screen, i.e. the locations of the mobile players and viruses are updated. A special kind of the stationary game board, which is used by the game administrators also allows to create new viruses and change the location and the size of the viruses. Additionally, this orchestration game board is used by the technical staff to assign devices to the outdoor players. These updates are fed back into the game server.

The virus analysis tool is informed by the game server each time the team has caught a virus, which is displayed in a list and which can be selected by a player in the stationary play mode in order to analyse it.

The mobile AR system displays the viruses as high resolution 3D models (see Fig. 3), which morph from one type to the other, at the correct location on the campus, allowing the user to walk around the virus and look at it from different perspectives. A hidden virtual model of the campus and its buildings is used to obscure viruses behind buildings which cannot be seen by the players. The mobile AR system also receives the game state updates at a high frequency. The locations of the viruses are updated and the viewpoint of the user is adapted according to the current GPS location. An inertia tracker is used to track the orientation of the head of the user. The spraying can of the mobile AR system sends the action *spray* to the game server as long as the mouse button is pressed. The game server will evaluate the action, update the size of the viruses and the ammunition of the spray, the result of the action is not returned directly, but through the next game state update.

Contrary to the mobile AR system, the smart phone receives updated game states at a much lower frequency, since it is connected via 3G to the game server making game state updates a limited resource. According to the new location of the player the map is centred around the player and the virus in the proximity are shown. Using a small crosshair and the keys of the phone, the players can try to catch the virus. The action catch is send to the game server, where the result is evaluated depending on the crosshair and the distance between the player and the virus. In case the catch is successful, the virus is removed from the map and is send to the virus analysis tool. The result - success or failure - of the *catch* action is send directly back to the smart phone and a dialogue with the information is shown to the user. All devices notice the removal of the virus by a new game state update.

The mobile malleable music developed by Tanaka [8] is a streaming server, which streams an individual audio stream to each player depending on his location and the location and composition of the viruses in her surroundings. Therefore it is also depends on the game state updates of the game engine. Each cell type, i.e. growth, stealth, damage and wind, has a unique sound. The sound of a virus is mixed together by the individual sounds of each of the cell types. The amount of cells of a type influences the volume of that sound. Therefore each virus has a quite unique audio footprint. For each mobile player, which uses the mobile malleable music, the sounds of each virus in the proximity are mixed in real-time and streamed to the PDA of that player. While the player walks around the campus and while the viruses move themselves and mutate, the sound stream for the player will change, giving the player a hint whether viruses are near or whether a very threatening virus is coming closer.

5 Evaluation methodologies and initial results

The Epidemic Menace game was evaluated to improve the understanding of the game and the game dynamics and to provide a basis for future development of the game.

In particular, we wanted to evaluate the game concept and story, the game play across media, and the role of the devices.

The evaluation was mainly based on detailed field observations. Four observers were constantly following the players, writing down their observations with respect to player-environment, player-devices, player-to-player and player-gamemaster interaction. Observers indicated time and location for each notice. Observations were combined with player feedback discussions and questionnaires. During the play test we got results with respects to the game story and game concept, the social play, the suitability of devices, and the technical aspects and game orchestration experiences. In the following we will briefly outline some of the results.

Players liked the story and how it unfolded in the course of the game through video clips. To them, the story and the location campus Birlinghoven fit the game play. The intermediate video material interlinked the different play sessions during the two days and contributed to the players feeling of being part of the story. Players liked the two play-modes: stationary play in the team room and mobile play outdoors on the campus. We observed that collaboration across media and play modes worked well. Surprisingly, the speed of movement was rather high in both play modes. The speed of movement was suitable as a means to indicate high player immersion. Players easily understood the meaning and use of devices. However, it turned out that players preferred to play in pairs of two in both play modes, and that device specific roles emerged. The players liked communication and collaboration within their team and competition with the opposite team.

Overall, the concept of the game was approved by the players. They found it was ”a new kind of game” as one player put it. They liked the mixture of story, movie, bodily action, collaboration, strategy, adventure, the diversity of devices and techniques to be used.

The play test disclosed that players missed all those parts from the full game concept which were not implemented for the first prototype. It also gave a large number of details how the game could be improved for the second iteration. In particular, the player's engagement was sometimes rather low, e.g. during the explanations of the gaming devices and during breaks caused by technical problems. For the next iteration of Epidemic Menace we would like to achieve a more constant immersion of the players, by introducing gaming interfaces successively and by reducing breaks caused by technical problems.

6 Conclusions and next steps

This paper describes the game concept and the technical realization of the Crossmedia game Epidemic Menace. A first version of Epidemic Menace has been staged for two days on campus Birlinghoven in August 2005. The paper summarizes main aspects of the game event, explains employed evaluation methods and presents initial results.

For the next version of Epidemic Menace we are improving the configurability of the game, such that different combinations of gaming devices can be employed for play tests. We would like to investigate the effect of different gaming devices on the game experience in more detail. How do team members collaborate if each of them receives an equal set of gaming devices? How do a wide variety and a limited set of gaming devices influence the game experience? How do teams compete if they receive different sets of gaming devices? We are also realizing further alternative gaming interfaces for the next version including low cost Augmented Reality interfaces based on Tablet PCs and PDAs and we are investigating augmented video streamed to mobile devices.

7 Acknowledgements

The design, implementation and staging of Epidemic Menace have been done by several partners of the IPerG project. We would like to thank Sabiha Ghellal, Christof Danzl and Christian Wenninger from Sony NetServices, Leif Oppermann from the University of Nottingham, Matt Adams from Blast Theory, Tom Soderlund, and Wolfgang Prinz, Sabine Kolvenbach, Joel Fischer and Karl-Heinz Klein from Fraunhofer FIT for their contributions. We would also like to thank Atau Tanaka from Sony CSL Paris for allowing us to use the mobile malleable music. IPerG is partially funded by the European Commission as part of the IST program.

References

1. Epidemic Menace Website, http://www.epidemic-menace.de.
2. IPerG Website, http://iperg.sics.se.
3. Lindt, I., Ohlenburg, J., Pankoke-Babatz, U., Prinz, W., Ghellal, S.: Combining Multiple Gaming Interfaces in Epidemic Menace. Experience Report. In Proc. of CHI 2006, Montreal, Quebec, Canada (to be published)
4. Lindt, I., Ohlenburg, J., Pankoke-Babatz, U., Ghellal, S., Oppermann, L., Adams, M.: Designing Cross Media Games. In Proc. PerGames Workshop at Pervasive 2005, Munich, Germany.
5. Magerkurth, C., Cheok, A. D., Mandryk, R. L., Nilsen, T.: Pervasive games: bringing computer entertainment back to the real world. In Computers in Entertainment (CIE), Volume 3, Issue 3, July 2005.
6. Montola, M.: Exploring the Edge of the Magic Circle. Defining Pervasive Games. In Proc. of DAC 2005, Copenhagen, Denmark.
7. Norman, D.: The Design of Everyday Things. New York, Doubleday, 1988.
8. Tanaka, A.: Malleable Mobile Music. In Proc. Ubicomp 2004. Springer-Verlag, 2004.

Exploring the Usability of Video Game Heuristics for Pervasive Game Development in Smart Home Environments

Carsten Röcker[1], Maral Haar[2]

[1] Fraunhofer IPSI, AMBIENTE
Dolivostrasse 15, 64293 Darmstadt, Germany
roecker@ipsi.fraunhofer.de
[2] Experience Park
Rahlstedter Strasse 108b, 22149 Hamburg, Germany
maral@experience-park.com

Abstract. Over the last years, a variety of pervasive games was developed. Although some of these applications were quite successful in bringing digital games back to the real world, very little is known about their successful integration into smart environments. When developing video games, developers can make use of a broad variety of heuristics. Using these heuristics to guide the development process of applications for intelligent environments could significantly increase their functional quality. This paper addresses the question, whether existing heuristics can be used by pervasive game developers, or if specific design guidelines for smart home environments are required. In order to give an answer, the transferability of video game heuristics was evaluated in a two-step process. In a first step, a set of validated heuristics was analyzed to identify platform-dependent elements. In a second step, the transferability of those elements was assessed in a focus group study.

1 Introduction

While early ubiquitous computing applications were mostly restricted to the business context, the concept of Ambient Intelligence gets slowly adapted to the home domain. Within the last years, several applications emerged [1, 9], that aimed at integrating information, communication and sensing technologies into everyday objects and environments. By creating so-called 'Smart Home Environments' a vision of future living spaces is propagated, where people are supported and assisted in their everyday activities by information technology [13]. In parallel to the development of smart home applications, there is vigorous research in the area of pervasive gaming. Aiming to bring digital games back into the real world, a variety of concepts and prototypes emerged within the last years. A detailed overview of existing systems as well as a classification of current game genres can be found in [10]. The trend towards novel interaction concepts and physical interfaces is also visible in commercial products. New game consoles like, e.g., Nintendo DS, use touch pads and microphones as alternative interface technologies. By offering additional entertainment opportunities, novel controlling devices will play an increasing role when designing pervasive games [8]. Commercially available products include, for example, dance pads or car steering wheel with additional foot pedals. More recent examples, like Sony's EyeToy [6], allow players to control games by gestures and body movements. In order to make use of such new interaction technologies, new interaction metaphors and game elements have to be developed, posing new challenges to games designers.

The recent developments in interface and game design allow enhancing digital games with social interaction concepts, which attracts new groups of users. A recent survey by the Entertainment Software Association showed, that 35% of American parents play computer and video games. Among these, 80% play video games with their children, and two thirds (66%) feel "that playing games has brought their families closer together". Following this trend, it seems only natural to integrate new game concepts in the development process of ambient intelligence environments. One of the first projects, that considers pervasive gaming as an integral part of smart home environments is the Amigo project [5]. In addition, also commercial applications become available, that help developers to extend gaming experience into real-life environments. Philips' AmBX [12] technology allows game developers to control real-world artefacts using a special scripting language. Compatible hardware such as lights, fans or heaters, can be controlled according to the digital game setting and by that foster a pervasive gaming experience.

2 Using Heuristics for Game Development

When developing new games, the use of heuristics proofed to be very successful in order to achieve major design goals [11]. Today, a variety of different design heuristics for video games exist (see [3] for a literature overview). Nevertheless, choosing the appropriate heuristic is still a problem, as most heuristics are isolated, repetitive and sometimes even contradictory [14]. Desurvire et al. [2] addressed this problem by aggregating existing guidelines and defining a comprehensive set of heuristics for playability. The so-called 'Heuristics for Evaluating Playability' (HEP) consist of four categories:

- *Game Play* (a set of problems and challenges a user must face to win a game),
- *Game Story* (collection of all plots and characters),
- *Game Mechanics* (structure by which units interact with the environment), and
- *Game Usability* (interface and interaction elements, e.g., mouse, keyboard).

Each heuristic was tested on an evolving game design in order to assess its face validity and evaluation effectiveness. The results validated the set of aggregated heuristics and proofed their usefulness for creating usable and playable game design.

3 Goal and Approach

Although novel input and output devices are available, very little is known about the successful integration of pervasive gaming applications into smart home environments. Using heuristics to guide the development process would be an easy and promising approach. But even if validated heuristics exist, it is questionable, whether heuristics originally defined for video games, can also be employed when designing pervasive games for smart home environments.

Comparing PC and console games, Grassioulet [4] found, that the platform in general has great impact in game design. Looking at the results, there is reasonable doubt, that existing heuristics can be transferred to other application domains. The impact of the platform should be even stronger for more immersive and involving platforms like smart environments, where the border between game and reality is additionally blurred by the integration of everyday objects into the game.

The goal of this paper is to explore, whether existing heuristics can be used by pervasive game developers, or if specific design guidelines for smart home environments are required. In order to answer this question, the usability of HEP for pervasive game development in smart home environments was evaluated in a two-step process. In a first step, the HEP were analyzed to identify elements, that are independent from the platform and those which are not. In a second step, a focus group evaluation was conducted, in order to assess whether the platform-dependent elements are transferable to the smart home domain.

4 Analysis of HEP

As mentioned above, the HEP consist of four types of heuristics. The heuristics of the 'game play' and 'games story' category refer only to aspects, which are not related to the game platform. Therefore, the elements of both categories are considered to be also valid for entertainment systems in smart home environments. All other elements were individually analyzed and it was assessed if they can be directly applied to pervasive games, or if adaptation is necessary. The following table shows the results for the elements of the 'game mechanics' category.

Table 1: Heuristics of the 'game mechanics' category and the assessment of their transferability to the home domain.

Game Mechanics		Assessment of Transferability
M1	Game should react in a consistent, challenging, and exciting way to the player's actions (e.g., appropriate music with the action).	Considered to be independent from the platform.
M2	Make effects of the Artificial Intelligence (AI) clearly visible to the player by ensuring they are consistent with the player's reasonable expectations of the AI actor.	As the effects of AI can be much more intrusive in pervasive games, specific heuristics on appropriate behavior might be necessary.
M3	A player should always be able to identify their score/status and goal in the game.	As pervasive games are generally more involving, score and status information might not be appropriate.
M4	Mechanics/controller actions have consistently mapped and learnable responses.	Pervasive gaming applications in smart home environments are likely to include everyday objects as controller. Transferring this heuristic without validation is not possible.
M5	Shorten the learning curve by following the trends set by the gaming industry to meet user's expectations.	Considered to be independent from the platform. (but: problems might occur, as industry trends do not yet exist)
M6	Controls should be intuitive, and mapped in a natural way; they should be customizable and default to industry standard settings.	As games in smart home environments are likely to be controlled using smart artefacts, this heuristic is of particular importance in the design process.
M7	Player should be given controls that are basic enough to learn quickly yet expandable for advanced options.	The integration of multiple devices is an important characteristic of pervasive games. Therefore, this heuristic is of similar importance as M6.

The elements of the ‘game usability’ category were analyzed in the same way. The results are shown in Table 2.

Table 2: Heuristics of the ‘game usability’ category and the assessment of their transferability to the home domain.

Game Usability		Assessment of Transferability
U1	Provide immediate feedback for user actions.	Considered to be independent from the platform.
U2	The player can easily turn the game off and on, and be able to save games in different states.	Earlier evaluations [13] showed, that this is a general requirement when designing smart home environments.
U3	The player experiences the user interface as consistent (in control, color, typography, and dialog design) but the game play is varied.	As the interfaces of smart environments are designed to be unobtrusive and therefore not necessarily perceived as game interfaces by the user, the heuristic might require adaptation.
U4	The player should experience the menu as a part of the game.	Considered to be independent from the platform. (but: menus are usually rare in smart environments)
U5	Upon initially turning the game on the player has enough information to get started to play.	Considered to be independent from the platform.
U6	Players should be given context sensitive help while playing so that they do not get stuck or have to rely on a manual.	Considered to be independent from the platform.
U7	Sounds from the game provide meaningful feedback or stir a particular emotion.	Considered to be independent from the platform.
U8	Players do not need to use a manual to play game.	Considered to be independent from the platform.
U9	The interface should be as non-intrusive to the player as possible.	Considered to be independent from the platform. (but: is a general requirement of the development smart environments)
U10	Make the menu layers well-organized and minimalist to the extent the menu options are intuitive.	Considered to be independent from the platform. (but: menus are usually rare in smart environments)
U11	Get the player involved quickly and easily with tutorials and/or progressive or adjustable difficulty levels.	Considered to be independent from the platform.
U12	Art should be recognizable to player, and speak to its function.	As the interfaces and interactions used in smart environments differ significantly from the ones used in video games, this heuristic might not be applicable when designing pervasive games.

5 Focus Group Study

In order to validate the heuristics that were considered to be platform-dependent, a focus group study was conducted. To avoid any influences, the heuristics were not presented to the participants during the study. Instead, the goal of the focus group discussion was to define the requirements of future entertainment systems from a user’s perspective. The results were later compared with the heuristics to check, whether they could be confirmed or have to be adapted.

The study was conducted with N=10 participants of two age groups. The first group consisted of 3 men and 2 women aged between 16 and 25, the second group consisted of 2 men and 3 women aged between 32 and 38. Both groups included singles and attached persons as well as persons with and without a permanent occupation. The group with the older participants also included persons with and without children.

The study was structured into two parts. In the first part, a scenario describing an intelligent home environment was presented verbally to the participants. Instead of exclusively focusing on entertainment, the general idea of ambient intelligence was introduced and the technical possibilities of smart home environments were outlined. This was followed by a group discussion on future entertainment system. The participants started to talk about their current entertainment activities at home and discussed the possibilities to improve the entertainment experience in the future. To understand the context and structure of the various statements, the key ideas were documented on cards. After the discussion, the participants clustered the cards and rated the importance of each cluster using a metaplan technique.

The second part started with the presentation of several scenarios in a gallery-like setting. Each scenario was illustrated with pictures and subtitles, and displayed on a large whiteboard. The participants had 30 minutes to go through all scenarios without any comments from the test conductor. Each scenario focused on a different aspect of smart home environments, ranging from entertainment over information and communication applications to household automation. The fact, that the scenarios were not restricted to entertainment should help the participants to understand design alternatives, and to identify general problems of Ambient Intelligence in home environments.

The presentation of the scenarios was followed by a second focus group discussion, where the participants had to discuss the general idea of Ambient Intelligence. Based on the ideas presented in the scenarios, they were first asked to discuss potential risks and benefits, and then derive requirements for such systems. Similar to the first part, the general ideas were collected and rated by the participants after the discussion.

6 Results

The most important requirement named by participants of both groups is, that all effects and features, like for example the adaptation of the environment to the game, are controllable by the user. Most participants emphasized, that the interaction must be easy, quick and intuitive. Several people suggested interfaces with speech input and output. These requirements refer to the following heuristics:

- M4: Mechanics/controller actions have consistently mapped and learnable responses (‘easy and intuitive interaction’),
- M6: Intuitive controls mapped in a natural way (‘speech input and output to achieve intuitive and easy interaction), as well as
- U5, U6 and U8: Upon initially turning the game on, the player has enough information to get started to play; context sensitive help; no manual needed to play (‘easy, quick and intuitive interaction’).

Not covered by the heuristics is the requirement, that users have always to be in control of the system. As all participants liked traditional board games, they were initially rather reserved regarding the need for new entertainment systems. This is also supported by the fact, that both groups mentioned traditional board games as the benchmark for future entertainment systems.

There was agreement among the participants, that future entertainment systems should provide the opportunity to play with real game pieces and game boards. If possible, the participants want to play together with friends, like they are used to do. Nevertheless, the entertainment system should be able to replace human players if required. In general, the system should support community interactions between players, but stay in the background unless required. Special effects (like holographic artworks and sound) were regarded as good ways to increase the involvement, but still have to be controllable by the user. In addition, it is expected, that future entertainment systems provide better graphics and more realistic game worlds. According to the participants, the gaming experience would be enhanced by adapting the environment to the current game situation. These requirements refer to the heuristics:

- M1: Consistent, challenging and exciting way of reaction to player's actions ('optional special effects'),
- M2: Effects of AI clearly visible to player and consistent with his expectations ('replace human players without changing the gaming experience'),
- M5: Short learning curve by following trends ('adding value to existing games instead of something completely new'),
- M6: Intuitive controls, mapped to natural standard ('play with real game pieces like used to'),
- U2: Turn on and off the game easily ('turn special effect on and off'), and to
- U7: Sounds provide meaningful feedback or stir a particular emotion ('special effects to increase involvement').

Only the requirement to foster community between players, is not covered by the existing heuristics.

While the requirements mentioned so far, referred only to functional aspects of future entertainment systems, the participants had also specific requirements regarding the hardware. Both groups addressed several issues regarding compatibility, extensibility and usefulness of the system. All participants want a flexible system with upgrade options. In addition, the systems should be portable, so that the participants can take the systems with them, if they move into another house. These requirements refer to the heuristic

- M7: Basic controls to learn quickly, but expandable for advanced options ('extendable, flexible system with upgrade options').

Not covered by heuristics is the demand for compatibility and usefulness. Generally, the participants want a useful combination of features realized in independent components, which should be integrated in one system. This refers to

- U3: Consistent user interface with varied game play ('integration of different components into one system').

Both groups also mentioned requirements, which are not restricted to the entertainment domain, but apply to all smart home systems. One of the major issues was usability. The system should be useful, timesaving, as well as easy to use and learn, and it should not need any maintenance after it is installed. The group with the older participants also remarked, that the system should save power. They asked for low power consumption in general and an automatic change-over in stand-by mode, if the system is not used for a certain period of time. Further topics, addressed by many participants, were security and safety issues. The participants were concerned about (software) attacks from the outside, as well as about potential accidents caused by malfunctions of the system. They also feared surveillance, if systems use cameras to identify and track people within the home.

Several participants asked for entertainment systems that combine various functions. Like modern game consoles, which offer possibilities to watch DVDs and listen to music, future entertainment systems should combine a range of functions related to entertainment.

Most of the requirements mentioned by the participants could be directly linked to certain elements of the HEP. Nevertheless, some heuristics were not addressed during the focus group discussions. There were no statements from the participants regarding the following heuristics:

- M3: A player should always be able to identify their score/status and goal in the game.
- U1: Provide immediate feedback for user actions
- U4: The player should experience the menu as a part of the game.
- U9: The interface should be as non-intrusive to the player as possible.
- U10: Make the menu layers well-organized and minimalist to the extent the menu options are intuitive.
- U11: Get the player involved quickly and easily with tutorials and/or progressive or adjustable difficulty levels.
- U12: Art should be recognizable to player, and speak to its function.

The fact, that certain topics were not mentioned during the discussions does not necessarily mean, that they were not regarded as important by the participants. Instead, they might have been considered to be so elementary, that the participants did not think of them or found them worthwhile mentioning. Another explanation might be, that the heuristics were too specific to be mentioned in a discussion with potential users. This is especially likely for the usability heuristics listed above. Besides this, all of the formally non-validated heuristics were at least indirectly addressed by the participants, as they asked for entertainment systems, which are “easy to use” and “easy to learn”.

7 Conclusion

Generally, the heuristics seem to be transferable to pervasive gaming applications in smart home environments. It seems as if the requirements regarding the game mechanics are the same for all application domains.

With Sony’s EyeToy [6] and SingStar [7] first commercial products become available, which aim to foster social interactions between players. As the need for human-centered interaction was also mentioned in both focus groups, design guidelines for pervasive gaming applications should be extended with a heuristic addressing this topic. Therefore, it is suggested to complement the HEP with a heuristic like, “pervasive gaming application should support direct interaction between human players and use game elements which require direct interaction between players”.

The results also showed, that usability is an important requirement of potential users. As usability heuristics are based on human perception, learning and memory, they are likely to be similar for different applications domains. Nevertheless, it might be helpful to collect and extend existing usability guidelines, as they are also related to interface elements, which might be fundamentally different in smart home environments. Especially speech control, gesture recognition, or integrated and ambient interface elements might require adapted design guidelines.

References

1. Brumitt, B., Meyers, B., Krumm, J., Kern, A. Shafer, S. (2000) EasyLiving: Technologies for Intelligent Environments. In: *Proceedings of the International Conference on Handheld and Ubiquitous Computing,* pp. 12 – 27.
2. Desurvire, H., Caplan, M., Toth, J. A. (2004). Using Heuristics to Evaluate the Playability of Games. In: *Proceedings of the Conference on Human Factors in Computing Systems* (CHI'04), ACM Press, New York, NY, USA, pp. 1509 - 1512.
3. Federoff, M. A. (2002) *Heuristics and Usability Guidelines for the Creation and Evaluation of Fun in Video Games.* Master Thesis, Department of Telecommunications, Indiana Univserity,
4. Grassioulet, Y. (2002). *A Cognitive Ergonomics Approach to the Process of Game Design and Development.* Master Thesis, Psychology and Educational Sciences Department, University of Geneva, Geneva, Switzerland.
5. http://www.amigo-project.org
6. http://www.eyetoy.com
8. http://www.singstargame.com
8. Kane, B. (2005). *SIGGRAPH 2005: Beyond the Gamepad.* Gamasutra, CMP Media Inc.
9. Kidd, C. D., Orr, R. J., Abowd, G. D., Atkeson, C. G., Essa, I. A., MacIntyre, B., Mynatt, E., Starner, T. E., Newstetter, W. (1999) The Aware Home: A Living Laboratory for Ubiquitous Computing Research. In: N.A. Streitz, J. Siegel, V. Hartkopf, S. Konomi (Eds.) *Proceedings of the Second International Workshop on Cooperative Buildings* (CoBuild'99), pp. 191 – 198.
10. Magerkurth, C., Cheok, A. D., Mandryk, R. L., Nilsen, T. (2005) Pervasive Games: Bringing Computer Entertainment Back to the Real World. *Computers in Entertainment* (CIE), 3(3), pp. 11-29.
11. Nielson, J., Molich, R. (1994) *Heuristic Evaluation. Usability Inspection Methods.* Wiley and Sons Ltd., Indianapolis.
12. Orry, J. (2005). Philips amBX Introduces an Ambient Gaming Experience. *PRO.* 2006.
13. Röcker, C., Janse, M., Portolan, N., Streitz, N.A. (2005) User Requirements for Intelligent Home Environments: A Scenario-Driven Approach and Empirical Cross-Cultural Study. In: *Proceedings of the Smart Objects & Ambient Intelligence Conference* (SOC-EUSAI'05), Grenoble, France, October 12-14, 2005. pp. 111-116.
14. Sweetser, P., Wyeth, P. (2005). GameFlow: A Model for Evaluating Player Enjoyment in Games. *Computers in Entertainment*, 3(3), pp. 3 - 3.

Marker-Based Embodied Interaction for Handheld Augmented Reality Games

Michael Rohs

Deutsche Telekom Laboratories and TU Berlin
Ernst-Reuter-Platz 7, 10587 Berlin, Germany
michael.rohs@telekom.de

Abstract This paper proposes embodied and manipulative interaction for handheld augmented reality games. We use camera-equipped mobile devices and marker-based interaction as a means for gesture-based control of games that incorporate physical and virtual aspects. In addition to being a controller that recognizes multiple game-dependent gestures, the mobile device displays the camera image and augments it with graphical overlays. The overlays are registered with objects and areas in the camera image. We have developed marker-based interaction techniques that capture the posture and movement of a device relative to a marker and thus enable manipulative control. We describe game prototypes that use ubiquitous product packaging and other passive media as backgrounds for handheld augmented reality games.

1 Introduction

With advances in hardware capabilities, camera-equipped handheld devices gain more and more interest as a platform for augmented reality (AR) [5,8]. Handheld AR systems use displays and integrated cameras to provide video see-through augmentations. The handheld device acts as a window into the real world. Head-mounted displays are still cumbersome to wear and it is difficult to imagine that they will be used on a day-to-day basis outside the laboratory or special workplace settings. In contrast, handheld devices are well suited for certain applications of AR. Camera phones in particular are small and unobtrusive and a constant everyday companion for many people.

A central basic problem of AR is tracking the position and orientation of physical objects in order to accurately align the computer-generated overlay graphics to objects in the real-world view. We solve this problem with the aid of visual codes [6] and use marker-based interaction techniques with well-defined interaction primitives [7].

We propose to use ubiquitous passive media, such as product packages, tickets, and flyers as background media for handheld AR games. Such media provide visual surfaces and stable reference frames on which AR games can operate. We show three prototypical games that use handheld devices and also incorporate physical components.

2 Marker-Based Embodied Interaction for Games

The goal of this work is to augment physical games with information technology in a way that imposes minimal hardware and infrastructure requirements. We use marker recognition on camera phones to link physical and virtual game components. The markers provide a number of orientation parameters (see Figure 1), which enables *manipulative* or *embodied user interfaces*. We have developed manipulative interaction techniques for marker-based interaction. Moreover, the markers provide a reference coordinate system for producing graphical overlays over the physical game components.

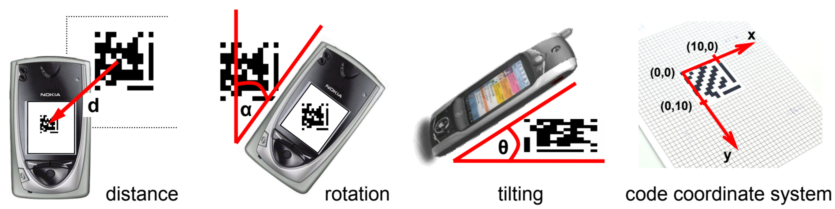


Figure 1. The orientation parameters $(x, y, d, \alpha, \theta_x, \theta_y)$ of visual code system.

Manipulative or *embodied user interfaces* [2] treat physical manipulations on the body of a handheld device as an integral part of its user interface. Embodied user interfaces try to extend the input language of handheld devices and artifacts by incorporating a variety of sensors into them. Example sensors are accelerometers, tilt sensors, capacitive coupling, and infrared range finders. Users can interact with such a device by tilting, translating, rotating, or squeezing it. The physical manipulation and the virtual representation are integrated and tightly coupled within the same device. Whereas in traditional GUIs virtual objects can be *directly manipulated*, embodied user interfaces allow for the direct manipulation of physical artifacts that embody the user interface. Embodied user interfaces mediate – i.e. sense and interpret – the actions of the user in an unobtrusive way. They take advantage of everyday spatial skills and make the interaction more similar to physical manipulations of ordinary non-computational physical objects.

Camera phones are very well suited for manipulative interaction, since they are small and lightweight and can be operated with a single hand. In our marker-based interaction paradigm we use the camera as a single sensor to implement physical hyperlinking and manipulative interaction. The semantics of the interaction is a function of the object and of one or more dynamic gestures or static postures. The camera phone embodies a "symbolic magnifying glass" that enables similar manipulations like an optical magnifying glass. Examples are the choice of focus point and distance. This will not show a magnified version of the physical object, but control some aspect of the game, as well as the graphical output. The camera phone becomes a *spatially aware display* [3], which acts like a window into a 3D workspace of virtual game components.

AR research mainly focuses on visual augmentation of physical spaces through head-worn or hand-held displays. An example of work in *handheld* AR is the "Invisible Train"[1], a game in which a virtual train is overlaid onto physical toy rail tracks. The course of the train can be controlled by altering the track switches. The game is controlled using touch screen input.

The following example games show how marker-based interaction can be employed to realize various kinds of computer-augmented physical games.

3 Handheld AR Packaging Game: Penalty Kick

Product packages are an interesting category of real-world objects for linking with pervasive games. Product packages are ubiquitously available in our everyday life. Simple games and quizzes on packaging have been around for a long time, for example as part of marketing campaigns. Especially larger packages, like cereal boxes, often contain games on the back side. Even though these games have been very simple and appeal only to a very limited proportion of the population, like children and teenagers, such games did not disappear.

To improve this state, and hence the communication channel between the customer and the manufacturer, we propose to realize marketing-related games on product packages as handheld AR games: Packages provide the background for AR games in the form of a playing field and a visual code. The playing field containing the visual code is captured by the camera. The games are controlled by applying embodied interaction gestures to the handheld device. It is likely that such games would appeal to a larger proportion of consumers and increase participation rates in the marketing campaigns they are part of.

Packaging games are targeted at a broad audience, basically any person who is a potential customer of the product. Interaction techniques thus have to be quickly learnable and must allow for serendipitous use, i.e. they have to be designed for walk-up-and-use without a significant setup procedure. Product package interactions are often executed in public space, for example in a store, in which the player cannot fully concentrate on the interaction, but is distracted by other events in the environment.

In the following, we generalize the discussion to include not only product packages, but also other kinds of background media, such as magazines, flyers, tickets, comic books, CD covers, and situated displays. This highlights the general applicability of the proposed concept to a large range of media.

The prototype is a simple penalty kick game that consists of a printed playing surface on a cereal box and virtual overlays generated by a camera phone. The playing surface shows a visual code in the center of the scene, a soccer field, a goal, the penalty spot, and spectators in the background. The display of the camera phone shows the virtual goal keeper, initially standing on the goal line,

[1] www.studierstube.org/invisible_train

Figure 2. "Penalty Kick" handheld AR game on a cereal package.

a virtual ball, initially positioned on the penalty spot, and textual overlays (see Figure 2). The code coordinate system of the central visual code is used to register the generated graphical overlays (the goal keeper and the ball) with elements in the camera image (the goal line and the penalty spot). For large game boards, multiple visual codes would be required to ensure that a visual code is visible in the camera image at all times, or other image features would have to be used.

The value of the visual code is a key to the game description. The game description is loaded via Bluetooth and then activated on the phone. In contrast to other handheld AR games, such as the "Invisible Train," the user is not confined to control the game by extensive use of the keypad or touch screen. Instead, the game was designed for embodied interaction. It applies visual code interaction primitives, such as rotation and tilting, that the player performs on the device. The necessary actions to interact with the game are simple and intuitive spatial mappings. Aiming at the goal requires rotation and tilting. The amount of device rotation relative to the goal controls the horizontal shot direction. The amount of tilting of the device controls the vertical shot direction (high or flat shot). The user kicks the ball by pressing the joystick key. Upon pressing the key, the ball quickly moves towards the goal (or misses it if the user did not aim right) and the goal keeper jumps to one of four possible positions to either catch or miss the ball with a fixed probability.[2]

The game instructions require just a few words, they can even be explored by users in a few trials without any instructions. Extremely short learning time and intuitive spatial mappings are crucial to reach a large target audience. Few

[2] Video: www.vs.inf.ethz.ch/res/show.html?what=visualcodes-packaging

people would be willing to read long instructions before playing a game like this. In a real deployment, the game would be associated with a lottery, e.g., to win another box of cereal. The proposed concept allows for the design of exciting single player games on product packages. The computer assumes the role of the second player. Most conventional games on product packages are only playable and enjoyable with two players.

4 Handheld Augmented Board Game: Impera Visco

"Impera Visco" is a turn-based strategy game for 2 to 4 players. 36 tiles are arranged in a 6×6 array on the table (see Figure 3). There are 6 different tile types that represent resources and operations on these resources. Each tile is made up of four quadrants, as shown on the right side of Figure 3. Quadrant 1 contains a unique visual code, the others show a type-specific image. The game also requires a dice and four pieces. The hardware of the prototype implementation includes a Symbian camera phone and a PC with Bluetooth. The game realizes the mechanics [4] *complex commodities*, *modular board*, *ubiquitous information*, and *informative board*.

Figure 3. Physical components of the augmented board game "Impera Visco."

The mission is to achieve wealth on the island of "Visco" by mining, trading, fighting, and cultivating land. First, the game board is scanned to capture the arrangement of the game tiles. Each turn is structured as follows: First, the player dices and moves his or her piece accordingly in horizontal and vertical direction. If other players are located on the target field, these players fight against each other. Players can train to have higher chances of winning fights. Since a user always has to perform an operation on the target field, the system knows the new position from the unique code value. In the prototype application, a single mobile phone is passed from one player to the next after each turn. This could easily be extended to multiple devices.

Some of the tile types are shown in Figure 3. Aiming the phone at quadrant 1 (the visual code itself) has a fixed semantics: It shows the score of each player, detailed statistics for the current player, the phone's current information about the position of all players, as well as help information about the possible operations on the tile. There are the following tile types:

- "Land" tiles are for growing cattle, corn, and vegetables on quadrants 2, 3, and 4, respectively. Animals grow slowest, vegetables fastest. Cattle is more valuable than corn and vegetables. Opponents can loot land tiles. However, players can place invisible guards on fields.
- "Water" tiles cannot be crossed if two or more of them are adjacent. A player may not be positioned on a water card. Water cards have a positive effect on adjacent land fields; they accelerate growth.
- "Mining" tiles produce gold, ore, and oil. Mining gold is slowest, ore fastest. Mining tiles can also be looted.
- "City" tiles allow for trading. Prices change over time. Cities have three layers: in the lowest layer things are cheap, but the chances of fraud are high; the higher the layer, the lower the risk.
- "Bank" tiles allow to convert collected goods to money, yet prices change frequently, thus it is worthwhile to check prices often.

a) field information b) player statistics c) player training f) choosing where to buy (risk vs. price)

Figure 4. Virtual components of the augmented board game "Impera Visco."

The game uses the interaction cues that are described in detail in [7]. These composable iconic cues tell the user, which embodied interaction postures are possible on a specific tile. A game operation is selected by focusing a quadrant, rotating the phone, or changing the distance. Operations are triggered by pressing a specific button. Figure 4 shows a number of game states and operations.

The visualization of the game state and the interpretation of embodied interaction postures is implemented in the visual code image maps framework [7] on Symbian phones. For ease of prototyping, the actual game logic runs on a PC and is implemented in Java and the Jess rule-engine. Jess allows to concisely describe the game components and current state as facts and rules in a knowledge base. Moving pieces on the board and triggering actions results in new facts.

These facts potentially activate rules, which in turn produce new facts. The Jess source code consists of about 1000 lines of code.

The initial goal in developing the game was to evaluate the use of fine-grained embodied interaction within the framework described in [7]. Less emphasis was put on producing an actually playable and enjoyable game [1]. This remains an area of future research.

5 Handheld Augmented Card Game: Smart Memory

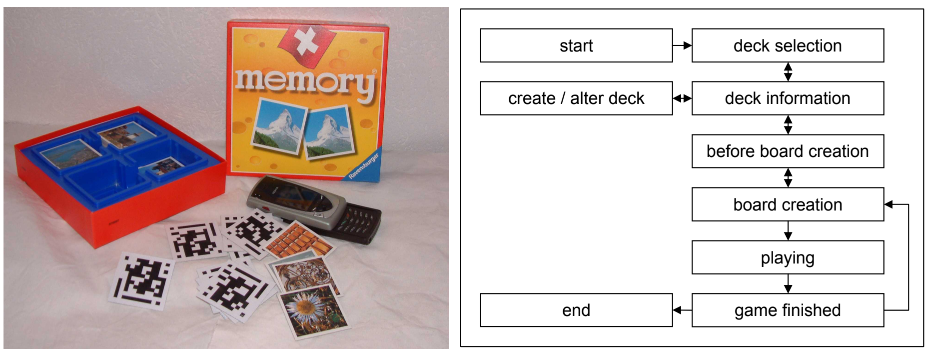


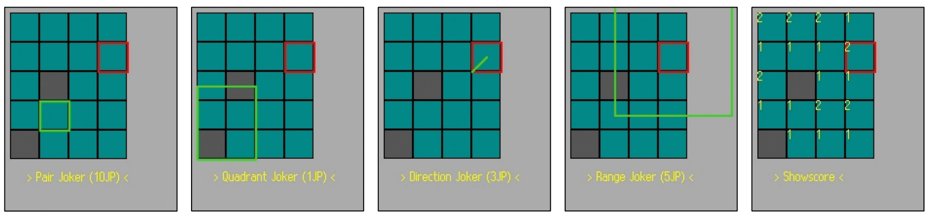
Figure 5. Physical components and flow diagram of the smart memory game.

“Smart memory” is a computer-augmented version of the classic “memory” game (see Figure 5), in which pairs of identical pictures have to be found among a number of cards that are laid out upside down on a table. One card side shows a picture, the other side a visual code. In each turn, a player reverses two cards. If their pictures match, the player gets the pair an continues, otherwise it is the next player’s turn. The design goal was to augment the game and enable new functionality, yet to retain its simplicity. The additional time spent interacting with the computer, as well as the setup time, was tried to be kept at a minimum. The game realizes the mechanics [4] *computerized clues* and *keeping track*.

The main enhancement is the introduction of “virtual jokers.” A joker provides additional information about the game, like the general direction in which the matching card of a given card can be found. At the start of the game, each player gets an account with joker points. The use of each joker costs some amount of joker points, depending on the usefulness of the joker.

A flow diagram of the game is depicted in Figure 5. To create a deck, the pairs are placed next to each other in a row, reversed, and then scanned. This way, the phone learns the visual code values that belong to each pair. The values for a pair are different. Otherwise players could try to match visual similarities in code patterns. After arranging the cards on the table, the board is scanned to build up an internal representation of its layout.

During play, the phone is normally placed upside down on the table, such that the camera faces upwards. Each card that the user reverses is shortly held over the phone, which recognizes the card and updates its internal representation of the board. Thus, during normal play, handling the phone is not required. The technology unobtrusively stays in the background. Since the phone counts points, it is no longer necessary to pile up collected cards. They can placed back on the board, which enables the *replay joker* (see below).



a) pair joker b) quadrant joker c) direction joker d) range joker e) statistics joker

Figure 6. Virtual jokers of the smart memory game.

If a player wants to use a virtual joker, he or she picks up the phone and chooses the joker. The cost of the joker is then deduced from the user's account and the visual cue displayed on the screen. The following jokers are implemented (see Figure 6):

- The *quadrant joker* shows in which quadrant the pair corresponding to a given card is located.
- The *pair joker* shows the exact location of the corresponding card. It is more expensive than the other jokers.
- The *direction joker* points in one of eight directions to indicate the rough direction of the corresponding card.
- The *range joker* shows the range in which the pair can be found.
- The *statistics joker* shows the number of times that the cards of the board have been flipped during a game.
- The *replay joker* allows to restart the whole game with the same board. It costs all of the initial joker points. This is useful if a player has memorized the positions of pairs during a game.

During test games it was discovered that some players were very reluctant to use their joker points, since they considered this as cheating, having the original memory game in mind. It might therefore be better to create new games than to try to enhance existing ones, because players have strong well-learned expectations about known games. Another complaint was that the phone still distracts too much from the game. If one player uses a joker, others tended to forget about the locations of cards. For a game in which concentration is very important, it is crucial that technology stays in the background and requires as little attention and interaction time as possible.

6 Conclusions and Future Work

We demonstrated the feasibility of handheld AR games, which are controlled using marker-based embodied interaction. Even though the general concept is promising, much work remains to be done. On the technical side, we are trying to include additional sensors beyond cameras for further interaction possibilities. We are also working on a description language for handheld AR games that takes sensor input into account and allows to specify graphical output as well as to formulate game rules. On the gaming side, it is still an open question, which types of games benefit most from a virtual component and what factors are important to make a game actually enjoyable and fun to use [1]. Usability testing of entertainment applications like the presented prototype games is another area that needs special attention.

Acknowledgments

Thanks to Jean-Daniel Merkli for designing and implementing the penalty kick game as part of his Diploma thesis, to Nicolas Born for designing and implementing "Impera Visco" in a semester project, and to Erich Laube for designing and implementing the smart memory game in a semester project.

References

1. H. Desurvire, M. Caplan, and J. A. Toth. Using heuristics to evaluate the playability of games. In *CHI '04: CHI '04 extended abstracts on Human factors in computing systems*, pages 1509–1512, New York, NY, USA, 2004. ACM Press.
2. K. P. Fishkin, A. Gujar, B. L. Harrison, T. P. Moran, and R. Want. Embodied user interfaces for really direct manipulation. *Commun. ACM*, 43(9):74–80, 2000.
3. G. Fitzmaurice and W. Buxton. The Chameleon: Spatially aware palmtop computers. In *CHI '94: Conference companion on Human factors in computing systems*, pages 451–452. ACM Press, 1994.
4. S. Lundgren and S. Björk. Game mechanics: Describing computer-augmented games in terms of interaction. In *Proceedings of the 1st International Conference on Technologies for Interactive Digital Storytelling and Entertainment (TIDSE 2003)*, 2003.
5. M. Moehring, C. Lessig, and O. Bimber. Video see-through ar on consumer cell phones. In *IEEE/ACM International Symposium on Augmented and Mixed Reality (ISMAR'04)*, pages 252–253, 2004.
6. M. Rohs. Real-world interaction with camera phones. In H. Murakami, H. Nakashima, H. Tokuda, and M. Yasumura, editors, *Second International Symposium on Ubiquitous Computing Systems (UCS 2004), Revised Selected Papers*, pages 74–89, Tokyo, Japan, July 2005. LNCS 3598, Springer.
7. M. Rohs and P. Zweifel. A conceptual framework for camera phone-based interaction techniques. In H. W. Gellersen, R. Want, and A. Schmidt, editors, *Pervasive Computing: Third International Conference, PERVASIVE 2005*, pages 171–189, Munich, Germany, May 2005. LNCS 3468, Springer.
8. D. Wagner and D. Schmalstieg. First steps towards handheld augmented reality. In *Seventh IEEE International Symposium on Wearable Computers*, pages 127–135, Washington, DC, USA, Oct. 2003. IEEE Computer Society.

MULTIMODAL MULTIPLAYER TABLETOP GAMING

Edward Tse[1,2], Saul Greenberg[2], Chia Shen[1], Clifton Forlines[1]

Abstract

There is a large disparity between the rich physical interfaces of co-located arcade games and the generic input devices seen in most home console systems. In this paper we argue that a digital table is a conducive form factor for general co-located home gaming as it affords: (a) seating in collaboratively relevant positions that give all equal opportunity to reach into the surface and share a common view, (b) rich whole handed gesture input normally only seen when handling physical objects, (c) the ability to monitor how others use space and access objects on the surface, and (d) the ability to communicate to each other and interact atop the surface via gestures and verbal utterances. Our thesis is that multimodal gesture and speech input benefits collaborative interaction over such a digital table. To investigate this thesis, we designed a multimodal, multiplayer gaming environment that allows players to interact directly atop a digital table via speech and rich whole hand gestures. We transform two commercial single player computer games, representing a strategy and simulation game genre, to work within this setting.

1. Introduction

Tables are a pervasive component in many real-world games. Players sit around a table playing board games; even though most require turn-taking, the 'inactive' player remains engaged and often has a role to play (e.g., the 'banker' in Monopoly; the chess player who continually studies the board). In competitive game tables, such as air hockey and foosball, players take sides and play directly against each other – both are highly aware of what the other is doing (or about to do), which affects their individual play strategies. Construction games such as Lego® invite children to collaborate while building structures and objects (here, the floor may serve as a 'table'). The dominant pattern is that tabletop games invite co-located interpersonal play, where players are engaged with both the game and each other. People are tightly coupled in how they monitor the game surface, and each other's actions [10]. There is much talk between players, ranging from exclamations to taunts to instructions and encouragement. Since people sit around a digital table, they can monitor both the artefacts on the digital display as well as the gestures of others.

Oddly, most home-based computer games do not support this kind of play. Consider the dominant game products: desktop computer games, and console games played on a television. Desktop computers are largely constructed as a single user system: the size of the screen, the standard single mouse and keyboard, and how people orient computers on a desk impedes how others can join in. Consequently, desktop computer games are typically oriented for a single person playing either alone, or with remotely located players. If other co-located players are present, they normally have to take turns using the game, or work 'over the shoulder' where one person controls the game while others offer advice. Either way, the placement and relatively small size of the monitor usually means that co-located players have to jockey for space [7]. Console games are better at inviting co-located collaboration. Televisions are larger and are usually set up in an area that invites social interaction, meaning that a group of people can easily see the surface. Interaction is not limited to a single input device; indeed four controllers are the standard for most commercial consoles. However, co-located interaction is limited. On some games, people take turns at playing game rounds. Other games allow players to interact simultaneously, but they do so by splitting the screen,

[1]Mitsubishi Electric Research Laboratories [shen, forlines]@merl.com and
[2]University of Calgary, Alberta, Canada [tsee, saul]@cpsc.ucalgary.ca

providing each player with one's own custom view onto the play. People sit facing the screen rather than each other. Thus the dominant pattern is that co-located people tend to be immersed in their individual view into the game at the expense of the social experience.

We believe that a digital table can offer a better social setting for gaming when compared to desktop and console gaming. Of course, this is not a new idea. Some vendors of custom video arcade games (e.g., as installed in video arcades, bars, and other public places) use a tabletop format, typically with controls placed either side by side or opposite one another. Other manufacturers create special purpose digital games that can be placed atop a flat surface.

The pervasive gaming community has shown a growing interest in bringing physical devices and objects into the gaming environment. For example, Magerkurth [12] tracked tangible pieces placed atop a digital tabletop. Akin to physical devices in arcades, the physical manipulation of game pieces supports rich visceral and gestural affordances (e.g., holding a gun).

Yet to our knowledge, no one has yet analyzed the relevant behavioural foundations behind tabletop gaming and how that can influence game design. Our goal in this paper is to take on this challenge, First, we summarize the behavioural foundations of how people work together over shared visual surfaces. As we will see, good collaboration relies on at least: (a) people sharing a common view, (b) direct input methods that are aware of multiple people, (c) people's ability to monitor how others directly access objects on the surface, and (d) how people communicate to each other and interact atop the surface via gestures and verbal utterances. From these points, we argue that the *digital tabletop* is a conducive form factor for co-located game play as it lets people easily position themselves in a variety of collaborative postures (side by side, kitty-corner, round table, etc.) while giving all equal and simultaneous opportunity to reach into and interact over the surface**.** We also argue that *multimodal gesture and speech input* benefits collaborative tabletop interaction. Second, we apply this knowledge to the design of a multimodal, multiplayer gaming environment that allows people to interact directly atop a digital table via speech and gestures, where we transform single player computer games to work within this setting via our Gesture Speech Infrastructure [18].

2. Behavioural Foundations

The rich body of research on how people interact over horizontal and vertical surfaces agrees that spatial information placed atop a table typically serves as conversational prop to the group. In turn, this creates a common ground that informs and coordinates their joint actions [2]. Rich collaborative interactions over this information often occur as a direct result of *workspace awareness:* the up-to-the-moment understanding one person has of another person's interaction with the shared workspace [10]. This includes awareness of people, how they interact with the workspace, and the events happening within the workspace over time. As summarized below, key behavioural factors that contribute to how collaborators maintain workspace awareness by monitoring others' gestures, speech and gaze. [10].

2.1 Gestures

Gestures as intentional communication. In observational studies of collaborative design involving a tabletop drawing surface, Tang noticed that over one third of all activities consisted of intentional gestures [17]. These intentional gestures serve many communication roles [15], including: pointing to objects and areas of interest within the workspace, drawing of paths and shapes to emphasise content, giving directions, indicating sizes or areas, and acting out operations.

Rich gestures and hand postures. Observations of people working over maps showed that people used different hand postures as well as both hands coupled with speech in very rich ways [4]. These animated gestures and postures are easily understood as they are often consequences of how one manipulates or refers to the surface and its objects, e.g., grasping, pushing, and pointing postures.

Gestures as consequential communication. Consequential communication happens as one watches the bodies of other's moving around the work surface [16][15]. Many gestures are consequential *vs.* intentional communication. For example, as one person moves her hand in a grasping posture towards an object, others can infer where her hand is heading and what she plans to do. Gestures are also produced as part of many mechanical actions, e.g., grasping, moving, or picking up an object: this also serves to emphasize actions atop the workspace. If accompanied by speech, it also serves to reinforce one's understanding of what that person is doing.

Gestures as simultaneous activity. Given good proximity to the work surface, participants often gesture simultaneously over tables. For example, Tang observed that approximately 50-70% of people's activities around the tabletop involved simultaneous access to the space by more than one person, and that many of these activities were accompanied by a gesture of one type or another**.**

2.2 Speech and alouds.

Talk is fundamental to interpersonal communication. It serves many roles: to inform, to debate, to taunt, to command, to give feedback [2]. Speech also provides awareness through alouds.

Alouds are high level spoken utterances made by the performer of an action meant for the benefit of the group but not directed to any one individual in the group [11]. This 'verbal shadowing' becomes the running commentary that people commonly produce alongside their actions. When working over a table, alouds can help others decide when and where to direct their attention, e.g., by glancing up and looking to see what that person is doing in more detail [10]. For example, a person may say something like "I am moving this car" for a variety of reasons:

- to make others aware of actions that may otherwise be missed,
- to forewarn others about the action they are about to take,
- to serve as an implicit request for assistance,
- to allow others to coordinate their actions with one's own,
- to reveal the course of reasoning,
- to contribute to a history of the decision making process.

2.3 Combination: Gestures and Speech

Deixis: speech refined by gestures. Deictic references are speech terms ('this', 'that', etc.) whose meanings are disambiguated by spatial gestures (e.g., pointing to a location). A typical deictic utterance is "Put that…" (points to item) "there…" (points to location) [1]. Deixis often makes communication more efficient since complex locations and object descriptions can be replaced in speech by a simple gesture. For example, contrast the ease of understanding a person pointing to this sentence while saying 'this sentence here' to the utterance 'the 5th sentence in the paragraph starting with the word deixis located in the middle of page 3'. Furthermore, when speech and gestures are used as multimodal input to a computer, Bolt states [1] and Oviatt confirms [13] that such input provides individuals with a briefer, syntactically simpler and more fluent means of input than speech alone.

Complementary modes. Speech and gestures are strikingly distinct in the information each transmits. For example, studies show that speech is less useful for describing locations and objects that are perceptually accessible to the user, with other modes such as pointing and gesturing being far more appropriate [3,5,13]. Similarly, speech is more useful than gestures for specifying abstract or discrete actions (e.g., Fly to Boston).

Simplicity, efficiency, and errors. Empirical studies of speech/gestures *vs.* speech-only interaction by individuals performing map-based tasks showed that parallel speech/gestural input yields a higher likelihood of correct interpretation than recognition based on a single input mode [14]. This includes more efficient use of speech (23% fewer spoken words), 35% less disfluencies (content self corrections, false starts, verbatim repetitions, spoken pauses, etc.), 36% fewer task performance errors, and 10% faster task performance [14].

Natural interaction. During observations of people using highly visual surfaces such as maps, people were seen to interact with the map very heavily through both speech and gestures. The symbiosis between speech and gestures are verified in the strong user preferences stated by people performing map-based tasks: 95% preferred multimodal interaction *vs.* 5% preferred pen only. No one preferred a speech only interface [13].

2.4 Gaze awareness

People monitor the gaze of a collaborator [11,10]. It lets one know where others are looking and where they are directing their attention. It helps monitor what others are doing. It serves as visual evidence to confirm that others are looking in the right place or are attending one's own acts. It even serves as a deictic reference by having it function as an implicit pointing act [2]. Gaze awareness happens easily and naturally in a co-located tabletop setting, as people are seated in a way where they can see each other's eyes and determine where they are looking on the tabletop.

2.5 Implications

The above points, while oriented toward any co-located interaction, clearly motivates digital multiplayer tabletop gaming using gesture and speech input. Intermixed speech and gestures comprise part of the glue that makes tabletop collaboration effective. Multimodal input is a good way to support individual play over visual game artefacts. Taken together, gestures and speech coupled with gaze awareness support a rich choreography of simultaneous collaborative acts over games. Players' intentional and consequential gestures, gaze movements and verbal alouds indicate intentions, reasoning, and actions. People monitor these acts to help coordinate actions and to regulate their access to the game and its artefacts. Simultaneous activities promote interaction ranging from loosely coupled semi-independent tabletop activities to a tightly coordinated dance of dependant activities. It also explains the weaknesses of existing games. For example, the seating position of console game players and the detachment of one's input from the display means that gestures are not really part of the play, consequential communication is hidden, and gaze awareness is difficult to exploit. Because of split screens, speech acts (deixis, alouds) are decoupled from the artefacts of interest.

In the next section, we apply these behavioural foundations to 'redesign' two existing single player games. As we will see, we create a wrapper around these games that affords multimodal speech and gesture input, and multiplayer capabilities.

3. Warcraft III and The Sims

To illustrate our behavioural foundations in practice, we implemented multiplayer multimodal wrappers atop of the two commercial single player games illustrated in Figure 1: Warcraft III (a command and control strategy game) and The Sims (a simulation game). We chose to use existing games for three reasons. First, they provide a richness and depth of game play that could not be realistically achieved in a research prototype. Second, our focus is on designing rich multimodal interactions; this is where we wanted to concentrate our efforts rather than on a fully functional

Figure 1. Two People Interacting with (left) Warcraft III, (right) The Sims

game system. Finally, we could explore the effects of multimodal input on different game genres simply by wrapping different commercial products. The two games we chose are described below.

Warcraft III, by Blizzard Inc., is a real time strategy game that portrays a command and control scenario over a geospatial landscape. The game visuals include a detailed view of the landscape that can be panned, and a small inset overview of the entire scene. Similar to other strategy games, a person can create *units* comprising semi-autonomous characters, and then direct characters and units to perform a variety of actions, e.g., move, build, attack. Warcraft play is all about a player developing strategies to manage, control and reposition different units over a geospatial area.

The Sims, by Electronic Arts Inc., is a real time domestic simulation game. It implements a virtual home environment where simulated characters (the Sims) live. The game visuals include a landscape presented as an isometric projection of the property and the people who live in it. Players can either control character actions (e.g., shower, play games, sleep) or modify the layout of their virtual homes (e.g., create a table). Game play is about creating a domestic environment nurturing particular lifestyles.

Both games are intended for single user play. By wrapping them in a multimodal, multiuser digital tabletop environment, we repurpose them as games for collaborative play. This is described next.

4. Multiplayer Multimodal Interactions over the Digital Table

For the remainder of this paper, we use these two games as case studies of how the behavioural foundations of Section 2 motivated the design and illustrated the benefits of the rich gestures and multimodal speech input added through our multiplayer wrapper. Tse et. al. [18] provides technical aspects of how we created these multi-player wrappers, while Dietz et. al. [6] describes the DiamondTouch hardware we used to afford a multiplayer touch surface.

4.1 Meaningful Gestures

We added a number of rich hand gestures to player's interactions of both Warcraft III and The Sims. The important point is that a gesture is not only recognized as input, but is easily understood as a communicative act providing explicit and consequential information of one's actions to the other players. We emphasise that our choice of gestures are not arbitrary. Rather, we examined the rich multimodal interactions reported in ethnographic studies of brigadier generals in real world military command and control situations [4].

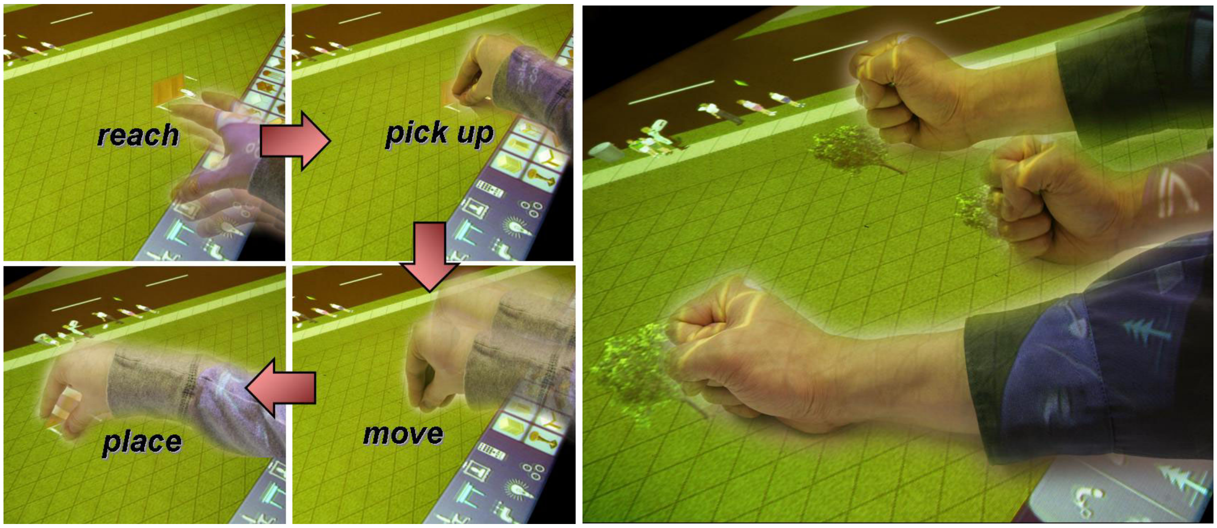


Figure 2. The Sims: five-finger grabbing gesture (left), and fist stamping gesture (right)

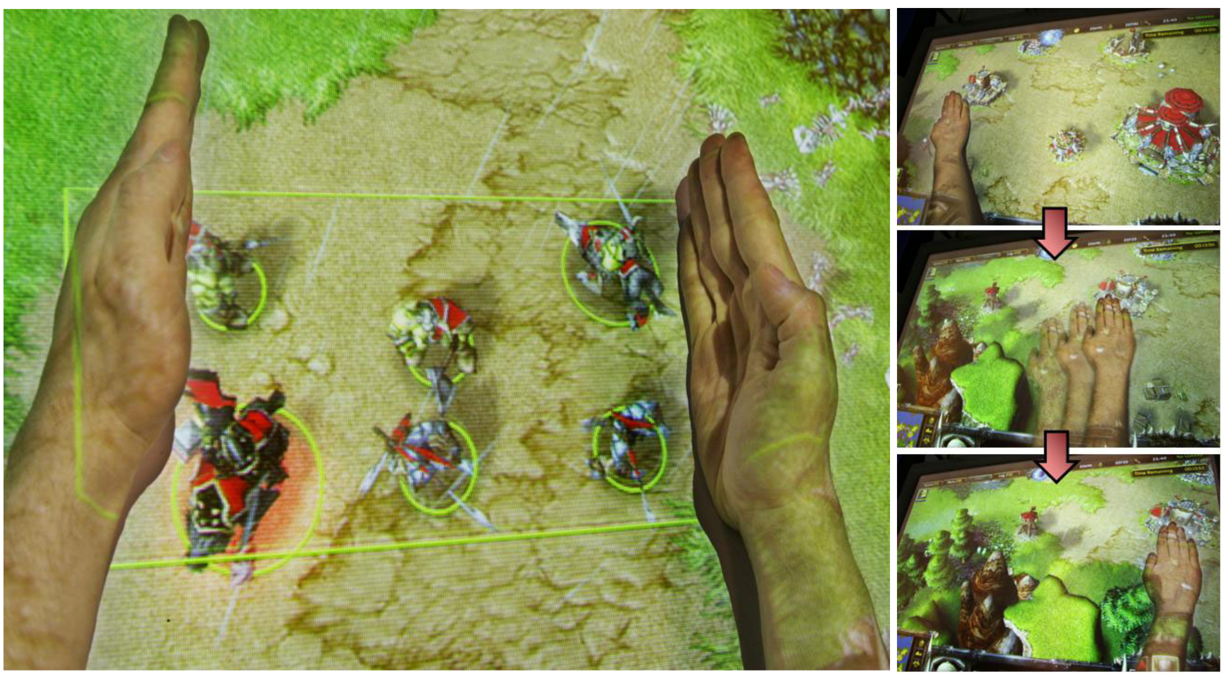


Figure 3. Warcraft III, 2-hand region selection gesture (left), and 1-hand panning gesture (right)

To illustrate, observations revealed that multiple controllers would often use two hands to bracket a region of interest. We replicated this gesture in our tabletop wrapper. Figure 3 (left) and Figure 1 (left) show a Warcraft III player selecting six friendly units within a particular region of the screen using a two-handed selection gesture, while Figure 3 (right) shows a one handed panning gesture similar to how one moves a paper map on a table. Similarly, a sampling of other gestures includes:

- a 5-finger grabbing gesture to reach, pick up, move and place items on a surface (Figure 2, left).
- a fist gesture mimicing the use of a physical stamp to paste object instances on the terrain (Figures 1+2, right).
- pointing for item selection (Figure 1 left, Figure 4) .

Table 1. The Speech and Gesture Interface to Warcraft III and the Sims

Speech Commands in Warcraft III		Speech Commands in The Sims	
Unit <#>	Selects a numbered unit, e.g., one, two	**Rotate**	Rotates the canvas clockwise 90 degrees
Attack / attack here [point]	Selected units attack a pointed to location	**Zoom <In / Out>**	Zooms the canvas to one of three discrete levels
Build <object> here [point]	Build object at current location, e.g., farm, barracks	**<First / Second> Floor**	Moves the current view to a particular floor
Move / move here [point]	Move to the pointed to location	**Return to Neighbourhood**	Allows a saved home to be loaded
[area] Label as unit <#>	Adds a character to a unit group	**Create <object> here [points / fists] okay**	Creates object(s) at the current location, e.g., table, pool, chair
Stop	Stop the current action	**Delete [point]**	Removes an object at the current location
Next worker	Navigate to the next worker	**Walls <Up / Down>**	Shows / Hides walls from current view

4.2. Meaningful Speech

A common approach to wrapping speech atop single user systems is to do a 1:1 mapping of speech onto system-provided command primitives (e.g., saying 'X', the default keyboard shortcut to attack). This is inadequate for a multiplayer setting. If speech is too low level, the other players would have to consciously reconstruct the intention of the player. As with gestures, speech serves as a communicative act (a meaningful 'aloud') that must be informative. Thus a player's speech commands must be constructed so that (a) a player can rapidly issue commands to the game table, and (b) its meaning is easily understood by other players within the context of the visual landscape and the player's gestures. In other words, speech is intended not only for the control of the system, but also for the benefits of one's collaborators.

To illustrate, our Warcraft III speech vocabulary was constructed using easily understood phrases: nouns such as 'unit one', verbs such as 'move', action phrases such as 'build farm' (Table 1). Internally, these were remapped onto the game's lower level commands. As described in the next section, these speech phrases are usually combined with gestures describing locations and selections to complete the action sequence. While these speech phrases are easily learnt, we added a 2nd display to the side of the table that listed all available speech utterances; this also provided visual feedback of how the system understood the auditory commands by highlighting the best match.

4.3 Combining Gesture and Speech together

The speech and gesture commands of Warcraft and The Sims are often intertwined. For example in Warcraft III, a person may tell a unit to attack, where the object to attack can be specified before, during or even after the speech utterance. As mentioned in Section 2, speech and gestures can interact to provide a rich and expressive language for interaction and collaboration, e.g., through deixis. Figure 1 gives several examples, where deictic speech acts are accompanied by one and two-finger gestures and by fist stamping; all gestures indicate locations not provided by the speech act. Further combinations are illustrated in Table 1. For example, a person may select a unit, and

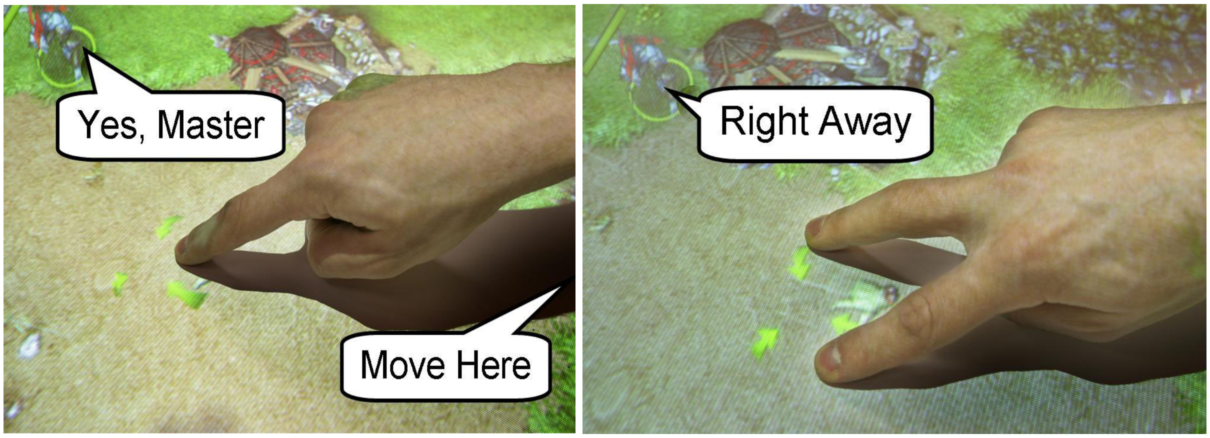


Figure 4. Warcraft III: 1-finger multimodal gesture (left), and 2-finger multimodal gesture (right)

then say 'Build Barracks' while pointing to the location where it should be built. This intermixing not only makes input simple and efficient, but makes the action sequence easier for others to understand.

These multimodal commands greatly simplify the player's task of understanding the meaning of an overloaded hand posture. A user can easily distinguish different meanings for a single finger using utterances such as 'unit two, move here' and 'next worker, build a farm here' (Figure 4, left).

We should mention that constraints and offerings of the actual commercial single player game significantly influences the appropriate gestures and speech acts that can be added to it via our wrapper. For example, continuous zooming is ideally done by gestural interaction (e.g., a narrowing of a two-handed bounding box). However, since The Sims provides only three discrete levels of zoom it was appropriate to provide a meaningful aloud for zooming. Table 1 shows how we mapped Warcraft III and The Sims onto speech and gestures, while Figure 1 illustrates two people interacting with it on a table.

4.3. Feedback and feedthrough

For all players, game feedback re-enforces what the game understands. While feedback is usually intended for the player who did the action, it becomes feedthrough when others see and understand it. Feedback and feedthrough is done by the visuals (e.g., the arrows surrounding the pointing finger in Figure 4, the bounding box in Figure 3 left, the panning surface in Figure 3 right). As well, each game provides its own auditory feedback to spoken commands: saying 'Unit One Move Here' in Warcraft III results in an in-game character responding with phrases such as 'Yes, Master' or 'Right Away' if the phrase is understood (Figure 4). Similarly, saying 'Create a tree' in The Sims results in a click sound.

4.4. Awareness and Gaze

Because most of these acts work over a spatial location, awareness becomes rich and highly meaningful. By overhearing alouds, by observing players' moving their hands onto the table (consequential communication), by observing players' hand postures and resulting feedback (feedthrough), participants can easily determine the modes, actions and consequences of other people's actions. Gestures and speech are meaningful as they are designed to mimic what is seen and understood in physical environments; this meaning simplifies communication [2]. As a player visually tracks what the other is doing, that other player is aware of where that person is looking and gains a consequential understanding of how that player understands one's own actions.

4.5 Multiplayer Interaction

Finally, our wrapper transforms a single player game into a multi-user one, where players can interact over the surface. Yet this comes at a cost, for single player games are not designed with this in mind. Single player games expect only a single stream of input coming from a single person. In a multiplayer setting, these applications cannot disambiguate what commands come from what person, nor can they make sense of overlapping commands and/or command fragments that arise from simultaneous user activities.

To regulate this, we borrow from ideas in shared window systems. To avoid confusion arising from simultaneous user input across workstations, a *turn taking* wrapper is interposed between the multiple workstation input streams and the single user application [8]. Akin to a switch, this wrapper regulates *user pre-emption* so that only one workstation's input stream is selected and sent to the underlying application. The wrapper could embody various turn taking protocols, e.g., explicit release (a person explicitly gives up the turn), pre-emptive (a new person can grab the turn), pause detection (explicit release when the system detects a pause in the current turn-holder's activity), queue or round-robin (people can 'line up' for their turns), central moderator (a chairperson assigns turns), and free floor (anyone can input at any time, but the group is expected to regulate their turns using social protocol) [9].

In the distributed setting of shared window systems, turn taking is implemented at quite gross levels (e.g., your turn, my turn). Our two case studies reveal far richer opportunities in tabletop multimodal games for social regulation by *micro turn-taking*. That is, speech and gestural tokens can be interleaved so that actions appear to be near-simultaneous. For example, Figure 1 (left) shows micro turn taking in Warcraft III. One person says 'label as unit one' with a two hand side selection, and the other person then immediately directs that unit to move to a new location. Informal observations of people playing together using the multimodal wrappers of Warcraft III and The Sims showed that natural social protocols mitigated most negative effects of micro turn taking over the digital table. Players commented about feeling more engaged and entertained after playing on the tabletop as compared to their experiences playing these games on a desktop computer.

5. Summary and Conclusion

While video gaming has become quite pervasive in our society, there is still a large gulf between the technologies and experiences of arcade gaming versus home console gaming. Console games and computers need to support a variety of applications and games, thus they use generic input devices (e.g., controllers, keyboard and mouse) that can be easily repurposed. Yet generic input devices fail to produce meaningful gestures and gaze awareness for people playing together for two reasons: First, everyone is looking at a common screen rather than each other, thus gaze awareness has the added cost of looking away from the screen. Second, generic input devices lock people's hands and arms in relatively similar hand postures and spatial locations, thus people fail to produce useful awareness information in a collaborative setting.

Conversely, arcade games often use dedicated tangible input devices (e.g., gun, racing wheel, motorcycle, etc) to provide the behavioural and visceral affordances of gestures on real world objects for a single specialized game. Yet specialized tangible input devices (e.g., power glove, steering wheel) are expensive: they only work with a small number of games, and several input devices must be purchased if multiple people are to play together. Even when meaningful gestures can be created with these tangible input devices, people are still looking at a screen rather than each other; the spatial cues of gestures are lost since they are performed in mid air rather than on the display surface.

This paper contributes multimodal co-located tabletop interaction as a new genre of home console gaming, an interactive platform where multiple people can play together using a digital surface with rich hand gestures normally only seen in arcade games with specialized input devices. Our behavioural foundations show that allowing people to monitor the digital surface, gesture and speech acts of collaborators, produces an engaging and visceral experience for all those involved. Our application of multimodal co-located input to command and control (Warcraft III) and home planning (The Sims) scenarios show that single user games can be easily repurposed for different game genres. Consequently, this work bridge the gulf between arcade gaming and home console gaming by providing new and engaging experiences on a multiplayer multimodal tabletop display. Unlike special purpose arcade game, a single digital table can become a pervasive element in a home setting, allowing co-located players to play different game genres atop of it using their own bodies as input devices.

Acknowledgements: We are grateful for the support from our sponsors: Alberta Ingenuity, ARDA, iCORE, NGA, and NSERC.

6. References

[1] BOLT, R.A., Put-that-there: Voice and gesture at the graphics interface. *Proc ACM Conf. Computer Graphics and Interactive Techniques*, Seattle, 1980, 262-270.

[2] CLARK, H. *Using language.* Cambridge Univ. Press, 1996.

[3] COHEN, P.R., Johnston, M., McGee, D., Oviatt, S., Pittman, J., Smith, I., Chen, L. and Clow, J., QuickSet: Multimodal interaction for distributed applications. *Proc. ACM Multimedia*, 1997, 31-40.

[4] COHEN, P.R., Coulston, R. and Krout, K., Multimodal interaction during multiparty dialogues: Initial results. *Proc IEEE Int'l Conf. Multimodal Interfaces*, 2002, 448-452.

[5] COHEN, P.R, Speech can't do everything: A case for multimodal systems. *Speech Technology Magazine*, 5(4), 2000.

[6] DIETZ, P.H.; Leigh, D.L., DiamondTouch: A Multi-User Touch Technology, ACM Symposium on User Interface Software and Technology (Proc ACM UIST), 2001, 219-226.

[7] GREENBERG, S. Designing Computers as Public Artifacts. *International Journal of Design Computing: Special Issue on Design Computing on the Net (DCNet'99)*, November 30 - December 3, University of Sydney. 1999.

[8] GREENBERG, S., Sharing views and interactions with single-user applications. *Proc ACM COIS,* 1990, 227-237

[9] GREENBERG, S. Personalizable groupware: Accommodating individual roles and group differences. *Proc ECSCW*, 1991*,*17-32,

[10] GUTWIN, C., and Greenberg, S. The importance of awareness for team cognition in distributed collaboration. In E. Salas, S. Fiore (Eds) *Team Cognition: Understanding the Factors that Drive Process and Performance,* APA Press, 2004, 177-201.

[11] HEATH, C.C. and Luff, P. Collaborative activity and technological design: Task coordination in London Underground control rooms. *Proc ECSCW*, 1991, 65-80

[12] MAGERKURTH, C., Memisoglu, M., Engelke, T. and Streitz, N., *Towards the next generation of tabletop gaming experiences*. Proc. Graphics Interface, 2004, 73-80.

[13] OVIATT, S. L. Ten myths of multimodal interaction, *Comm. ACM*, 42(11), 1999, 74-81.

[14] OVIATT, S. Multimodal interactive maps: Designing for human performance. *Human-Computer Interaction* 12, 1997.

[15] PINELLE, D., Gutwin, C. and Greenberg, S. Task analysis for groupware usability evaluation: Modeling shared-workspace tasks with the mechanics of collaboration. *ACM TOCHI*, 10(4), 2003, 281-311.

[16] SEGAL, L. Effects of checklist interface on non-verbal crew communications, NASA Ames Research Center, Contractor Report 177639. 1994

[17] TANG, J. Findings from observational studies of collaborative work. *Int. J. Man-Machine. Studies.* 34 (2), 1991.

[18] TSE, E., Shen, C., Greenberg, S. and Forlines, C. (2006) Enabling Interaction with Single User Applications through Speech and Gestures on a Multi-User Tabletop. Proceedings of AVI 2006. To appear.

Cell Spell-Casting: Designing a Locative and Gesture Recognition Multiplayer Smartphone Game for Tourists

Steffen P. Walz[1], Rafael "Tico" Ballagas[2], Jan Borchers[2], Joel Mendoza[2], Sven Kratz[2], Christoph Wartmann[1], Claudia Fuhr[1], Martin J. Tann[1], Dong Youn Shin[1], Bilal Hameed[2], Laszlo Bardos[2], and Ludger Hovestadt[1]

[1] ETH Zurich, Chair for Computer Aided Architectural Design, HIL E15.1, 8093 Zurich, Switzerland
{walz, wartmann, fuhr, tann, shin, hovestadt}@arch.ethz.ch}
[2] RWTH Aachen University, Media Computing Group, Lehrstuhl Informatik X, 52056 Aachen, Germany
{ballagas, borchers, mendoza, kratz, hameed, bardos}@cs.rwth-aachen.de}

Abstract. In this work-in-progress paper, we present REXplorer, a mobile, location and gesture recognition based spell-casting multiplayer game for tourists. Launching in late summer 2006, this serious game will be installed as a permanent pervasive entertainment service on site the medieval city core of Germany's best preserved historic city, Regensburg. In REXplorer, visitors roleplay volunteering scientific assistants who partake in a self-guided field trip to explore odd, magical incidents occurring all across the former capital of the German Empire. Whilst it is the player's goal to become the day's most successful assistant (and thus, the most notable mage) by gesturing proper location-based spells with a rental smartphone, as game design researchers, it is our goal to bring to light legend and history of Regensburg by the way of novel gameplay.

1 Introduction

Unlike practically all other German cities, Regensburg's urban heart was spared from WWII bombings. The mostly romanesque and gothic city core - see Figure 1 - is if not the best preserved medieval city core in Germany: More than 1'400 buildings within the city center are under historical preservation protection [1] [2].

Formally, the medieval cityscape suits well as a physical game board for a serious pervasive entertainment service concerned with historical sightseeing. Aspects to be considered include density of points of interest; walking distances and touristic workload per sight; sight accessibility; spatial interrelationships, that is: the architectural connectedness of buildings spread out across the city, e.g. churches; climate; and seasonal peaks. Dramaturgically, the history of the city offers a manifold of starting points for immersive and engaging narrative architecture, for example concerning premise, stories, and characters [3]; legends, myths, and fairy tales [4]; and historical trivia [5].

Fig. 1. Regensburg city core including the Old Stone Bridge and St. Peter's Cathedral.

REXplorer, the project we present in this work-in-progress paper, takes advantage of the city core's functional and dramaturgical setup in that we try to design "aus dem Wohnen und für das Denken" - *engl.* "from dwelling and for thinking" [6] - by translating facts and legends into pervasive gameplay for visiting tourists. The game thus can be classified as a "serious pervasive game" serving an end beyond Huizinga's demarcation of games' "magic circle" [7]. In this, REXplorer can be compared to other, yet smaller scale and prototypical serious pervasive game projects such as a location based collaborative learning game [8], or a live action role playing tourist game designed for the UNESCO world heritage protected city core of Split, Croatia [9].

2 Game Design Cornerstones

2.1 The Regensburg Experience

Launching in late summer 2006, REXplorer is a crucial part of the „Regensburg Experience" (REX), a high tech visitor centre and experience space where history shakes hands with the future, fusing Offline / Online and in house / urban space multimedia offerings. The Regensburg Experience aims at promoting Regensburg as Germany's most beautiful and historical city. The project will be implemented in three spaces, (i) in the renovated 1620 salt storehouse „Salzstadel"; (ii) in the virtual space of the WWW; (iii) in the urban space of the city taking on the form of REXplorer, cf. http://www.rex-regensburg.de. It is planned to intertwine these spaces scenographically where appropriate.

REXplorer is a joint project between RWTH Aachen University, Germany; the ETH Zurich, Switzerland; non-profit company Regensburg Experience GmbH; the city of Regensburg; and Regensburg sightseeing guides. Out of the 1.6 million national and international visitors to the city per year, REXplorer targets mainly young adult day trippers, local and regional school groups, as well as a portion of the increased number of expected tourists with Regensburg becoming a UNESCO world heritage in 2006. The number of expected REXplorer players totals to > 15'000 per year, who we believe will rent a „wand“ at the Salzstadel museum location. We design REXplorer on the assumption of a maximum of 30 simultaneous players, with an average gameplay session ranging from 1-2 hours.

2.2 Game Premise

The basic premise of REXplorer is that in our "light fantasy"-meets-science experiment setting, particular landmark buildings have locked magical - factual as well as fictional - spirits, secrets, and treasures inside of them, all of which can be unleashed and interacted with by the way of the proper spell gesture. REXplorer equips players with a rental „scientific apparatus" which turns out to be a magic wand. This wand is a gesture sensing and location tracking smartphone running custom software and data neccessary for the game. As if taking a positionable, Nintendo Revolution controller with built-in loudspeaker outdoors, players may not only interact with site specific game services including large public displays, but also "tickle" one another's wand to paralyze it for a while, or fulfill cooperative quests. REXplorer can be thought of as a situated, advanced, and handheld platform based „Waving Hands" [10], although we are not using the Waving Hands / Spellcast rules. For our game, we are not laying out an explicit magical setting, but we are being inspired by popular themes such as the „Harry Potter" series, Magic the Gathering® trading cards, and the GURPS fantasy campaigning manual [11]. In addition, we are taking into account (mobile) game design patterns [12], as well as research about techno-surveillance [13], and situated or computer mediated interaction in the public sphere [14] [15].

3 Core Interactions

3.1 Status Quo

At present, the game is in its early implementation phase, taking advantage of existing technologies and research, as well as prior design experiences.

2.2 Gesture Vocabulary

At its technological core, REXplorer builds on top of existing interaction techniques that have been developed by the Media Computing Group at RWTH Aachen University, Germany. The Sweep technique, for example, allows a Nokia Series 60 phonecam to be used like an optical mouse [16]. Using optical flow image processing, the phonecam samples successive images and then sequentially compares them to determine relative motion in the (x, y, theta) dimensions, thus allowing the camera to be used as a three degrees of freedom input device.

With Sweep as a starting point, we are currently developing SweepSpell, the basic gesture vocabulary including device feedback (audio, screen animation), as well as gameplay feedback (e.g. player hears disgruntled voice of building spirit after a spell cast incorrectly). The gesture vocabulary we are implementing follows both functional, technological, and city historical demands, allowing for four basic gestures, see Figure 2.

Functionally and technologically, these gestures are simple enough to be performable and processable. We are planning to allow players to, theoretically, sequence up to four gestures, so that the combination set results into an interaction permutation matrix. However, we are aware that we will need to limit interactions to a manageable and sufficient quantity.

Historically, our vocabulary refers to a secret argot used on an infant's stone grave in the cloister of St. Peter's Cathedral, dating back to 1583, cf. http://www.geschichte.uni-muenchen.de/ghw/geheimschriften/g9.shtml. It is one of the many secret languages that were invented in the city due to the plenty diplomats and legations that stayed in Regensburg during the "Immerwährender Reichstag", a prototype of the EU parliament (*engl.* "Perpetual Imperial Diet").

Fig. 2. Gestures to be performed with REXplorer's magic smartphone.

2.3 Geo-Positioning

The gameplay we are envisioning demands (a) to let players move around the city core seamlessly, (b) to be able to measure their locations, and (c) to measure proximate player-to-player interaction such as spell-casting tickling situations. Thus, we are presently researching and testing appropriate geo-positioning methods such as PlaceLab next to GPS Bluetooth receivers that work with the Nokia N70 phones we are deploying. In addition, we are currently probing operators for forwarding the geo-positions to our game server via their UMTS network.

From the player perspective, we translate retrieved location information into device appropriate clues. The closer two players are to one another, the more intense their wands pulsate, for example.

4 Game Design Issues

4.1 Design Challenges

REXplorer is a public-private endeavour, juggling with research interests, as well as with academic, entertainment, mobile social software [17], and tourist market demands. Beyond balancing stakeholder interests, there are a number of interplaying game design and technological challenges we are dealing with and have to solve for the final product. Examples include:

- **Transforming a Tourist experience into a Game Experience.** Tourists – even younger ones – bring expectations with them what a tourist experience should be like. Usually, these dispositions include (self-)guided sightseeing, or, in seldom cases, maybe even puppetmastered role playing. So, convincing potential players of the added value of participating in REXplorer will be part of the game design already, comparable to package design for off-the-shelf products.
- **Transforming a Game Experience into a Tourist Experience.** From a serious game design standpoint, it is important to leave a sustainable message with the players, to transfer city history across the magic circle. This can be instantiated by interacting with historical facts in a suspenseful fashion so players will want to solve a riddle themselves, rather than have shown to them how to solve it.
- **Spell-Casting Expectations.** The Harry Potter series and brand has made spell-casting a popular theme. We assume that there is a lot of potential for reaching a greater number of players by making it possible to actually spell-cast with a wand-like device wherever a player is. The tradeoff of choosing a magic / medieval scheme lays in player expectations: If the game does not cater to the prevalent entertainment record of players, it may fail to immerse and entertain.
- **Unfamiliarity of Place.** Typically, tourists are unfamiliar with the destination they are visiting. This makes location services, especially navigation and recommendation services, more appealing. However, players will need to trust the service, which can be at odds, or even counter, gameplay elements and actions such as unexpected, or unconsciously triggered events, which – from the perspective of the game design - are supposed to thrill players.
- **Privacy.** The utility of location services in unfamiliar settings may tilt the utility-privacy tradeoff that tourists are willing to give up more personal information in return for a better game. The potential privacy concerns of the players may also be eased by the temporary nature of the visit (and associated privacy invasion). Naturally, minimizing the necessity of privacy invasions should be vigorously pursued. On the other hand, engaging collaborative interaction for joint quests may force the designers to plan for privacy intrusion.
- **Personal Device Suitability.** Focusing on mobile phone technologies, many tourists may be reluctant or unable to use their own mobile phones because of roaming charges or network compatibility issues, or they may simply not have a mobile phone with them on the trip. Additionally, many people may be reluctant to download special third party software to their personal mobile phone, possibly because they don't know how, or because they are aware of potential malware. Thus, REXplorer will be offered along with a rental smartphone.
- **Rental Device / Controller Unfamiliarity.** Specifically in time constrained settings such as the one REXplorer represents, getting to know a new device along with unfamiliar controller functionalities is already quite a task for a player who is very likely not a hardcore gamer. Consequentially, we have to limit the overall in-game functionality to a functionality core, and not overwhelm unaccustomed play-

ers with a „featurama“. This also includes limiting the basic gesture vocabulary to a fixed, easy-to-learn set, as well as feedbacking to a core channel, namely, audio.

- **Player and Playmate Identification.** Many pervasive and mobile games require players to identify, locate, and communicate with other players. These activities can be assisted using „mobile social software“, e.g. indicators such as a proximity radar or a buddy list. The design challenge, however, is to keep design consistency with the overall scheme of the game - spell-casting in a predominantly medieval architectural setting - and not to break it.
- **Publicity Sanitation.** Gestures are a subset of human non-verbal communication. Categories of commonly readable gestural communication include facial expression, clothing cues, postures, and body movements. Because the public and sudden hand-arm movement we instantiate is not easily interpretable for what it symbolizes within the game, the smartphone „wand“ gestures will cause confusion for non-players. Specifically around the launch of REXplorer, spell-casting could be associated with non-contextual interactions, e.g. waving about a real weapon. We try to compensate this by associating wand interaction with typical and loud game-like sounds.
- **Is this part of the game?** Location-based services have the added benefit of assisting participants in understanding the games physical boundaries, and helping them locate elements and landmarks relevant to the game in the real world.
- **Is this part of the game, too?** Previous pervasive games have shown that uncertainty about whether a certain event or encounter is part of the game can add excitement to the experience. We will apply this design pattern for REXplorer.
- **Tutorial.** How do we mobilize a player once she has decided to participate in REXplorer? After renting their wand, players have to pass a “gesture license test”, which involves learning core mechanics and functionalities in a playful fashion and, potentially, with the help of Salzstadel museum staff.
- **Content Accuracy vs. Suspension of Disbelief.** Along with the spell-casting expectations we have mentioned earlier in this section, we also need to keep up historical accuracy (a requirement of the Regensburg Experience operating company) whilst immersing players in an exciting hybrid reality fantasy setting that is coherent with the game’s premise. For this purpose, we are researching the city core’s landmark buildings, filtering interwoven stories that altogether help the player to puzzle together the “everlasting magic” of the city.
- **Geo-Building Accuracy.** The city of Regensburg is currently implementing a web map service based on UMN MapServer, with Mapbender as a frontend. The city’s Department for Measurement and Cartography has provided us with their UMN landmark database containing over 1’400 entries, including addresses, short descriptions of the building history and usages, as well as their geopositions. These geopositions base on the metric Gauss Krüger (GK) geosystem, which has been used in Germany-speaking countries and Eastern Europe for decades. The Universal Transverse Mercator (UTM) system can be thought of as a version of GK. We transformed the entire database into GPS data, preparing for GPS functionality on the smartphones. In addition, we are carrying out extensive on-site inspections with different GPS Bluetooth receivers in order to verify or correct the geo-data.

- **Gameplay Scenario Design.** We are using storyboards for designing scenarios and board game models to explore and solve design problems and solutions.
- **Testing.** Two months prior to the commercial launch of REXplorer, we are planning a series of playability tests under real life conditions, meaning a maximum of 30 simultaneous players / session. In addition, we are presenting the game to our target group, e.g. school classes, collecting feedback to optimize the game.
- **Research.** Throughout the implementation and iteration phases of REXplorer, we are carrying out game design evaluation and playability research. Aspects include cell phone gesture recognition player testing; determination of player strategies in spatial situations; usabilty and balancing of pervasive games etc..

5 Conclusion: Design Success of a Rhetorical Landscape

Of course, we hope that our game will be successful in the opinions of the REXplorer players. However, we also understand REXplorer as an academic and serious pervasive game design experiment that should have the right to partially fail, so there is a reason for REXplorer patches. In order to measure whether we have been successful with our design decisions, we plan to examine and analyse not only our design, and progress, but also the gameplay sessions once REXplorer has been launched.

Beyond pervasive game design, serious pervasive games (SPGs) represent not only mighty empowerment vehicles, but also surveillance tools. On the one hand, SPGs posit players into exciting playgrounds never seen before – the computerised world itself becomes the game board. On the other hand (and in order to assure a seamless experience), SPGs need to bring upon the player a quasi surveillant IT infrastructure to ensure gameplay, goal fulfilment, and closure. We can think of this dilemma as the dialectics of SPGs. These dialectics point out a future of situated drafting, implementation, and operation where, on the one hand, the ongoing intrinsic motivation of a "player" to interact with a built environment becomes an important planning goal. On the other hand, a planner must consider that SPGs install a form of Benthamian monitoring [13] that can be misused to steer and control the reward-seeking player. It is no wonder, then, that serious games in general are widely used for military purposes.

With the omnipresence of pervasive computing based services that appeal to us and make us "behave", we assume that our conceptions of place, presence, and everyday gratification will alter drastically; we would like to kick off a discussion about the future of these „rhetorical landscapes" [9].

Acknowledgements

This research has been partially funded by the Swiss National Fund NCCR Mobile Information and Communication Systems (MICS), and sponsored by Nokia Research, Finland. We would like to thank Dr. Julien Biere and Brigitte Weidmann (REX GmbH); Matthias Freitag and Joachim Lenz (City of Regensburg); Dr. Roland Popp (Agentur Wissensräume); Josef Kirchberger (Regensburg Tourismus GmbH); as well

as Maria Maier, Bettina Trautwein, and Katrin Schöbel for their artistic input. The photo in Figure 1 copyright by Peter Ferstl, Archiv Regensburg Tourismus GmbH.

References

1. Fink, A.: Romanik in Regensburg: Architektur. In: Schmid, P. (ed.), Geschichte der Stadt Regensburg, Band 2. Verlag Friedrich Pustet, Regensburg (2000) 1079-1097
2. Hubel, A.: Gotik in Regensburg. Stadttopographie und städtebauliche Entwicklung vom 13. Jahrhundert bis zum frühen 16. Jahrhundert. In: Schmid, P. (ed.), Geschichte der Stadt Regensburg, Band 2. Verlag Friedrich Pustet, Regensburg (2000) 1106-1140
3. Freitag, M.: Kleine Regensburger Stadtgeschichte. Verlag Friedrich Pustet, Regensburg (2004)
4. Böck, E.: Regensburger Stadtsagen, Legenden und Mirakel. Verlag Friedrich Pustet, Regensburg (1982)
5. Bauer, K.: Regensburg. Kunst-, Kultur- und Alltagsgeschichte. 5th edn. Mittelbayerische Druck- & Verlags-Gesellschaft, Regensburg (1997).
6. Heidegger, M.: Bauen Wohnen Denken, in: M. Heidegger: Vorträge und Aufsätze. 10th edn. Klett Cotta, Stuttgart (2000) 214-236.
7. Huizinga, J.: Homo Ludens. Vom Ursprung der Kultur im Spiel. Rowohlt, Reinbek bei Hamburg (1987)
8. Walz, S.P., Schoch, O.: Pervasive Game Design as an Architectural Teaching and Research Method., in: Gibson, D, Aldrich, C., Prensky, M. (eds.): Games and Simulations in Online Learning. IDEA Group Publishing, Hershey, PA (2006) [in print]
9. Walz, S.P.: A Spatio-Ludic Rhetoric: Serious Pervasive Game Design for Sentient Architectures. In: Proceedings of game set and match II. International Conference 2006 on Computer Games, Advanced Geometries and Digital Technologies, TU Delft (2006) [in print]
10. Bartle, R.: Waving Hands. In: M. Lean (ed.) Duel Purpose. Originally published in: Bartle, R. (ed.), Sauce of the Nile. Available Online at http://www.gamecabinet.com/rules/WavingHands.html
11. Stoddard, W.H.: GURPS Fantasy. 3rd edn. Steve Jackson Games, Austin, TX (2004)
12. Björk, S., Holopainen, J.: Patterns in Game Design. Charles River, Cambridge, MA (2005)
13. Foucault, M.: Surveiller et punir. La naissance de la prison. Gallimard, Paris (1975)
14. Goffman, E.: Interaction Ritual. Essays on Face-to-Face Behavior. Anchor Books, Garden City, NY (1967)
15. McCullough, M.: Digital Ground. Architecture, Pervasive Computing, and Environmental Knowing. The MIT Press, Cambridge, MA (2004)
16. Ballagas, R., Rohs, M., Sheridan, J. G., Borchers, J.: Sweep and Point & Shoot: Phonecam-Based Interactions for Large Public Displays. In: Extended Abstracts of the CHI 2005 Conference on Human Factors in Computing Systems. ACM Press, New York (2005) 1200-1203
17. Ballagas, R., Walz, S.P., Borchers, J.: REXplorer: A Pervasive Spell-Casting Game for Tourists as Social Software. Position paper for the CHI 2006 Mobile Social Software Workshop. Available Online at http://chi2006mososo.telin.nl (2006)